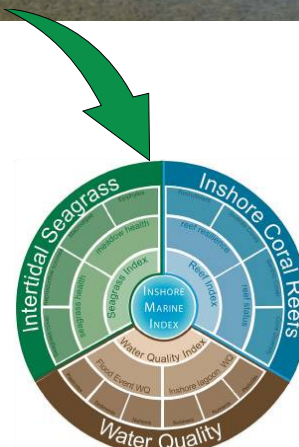
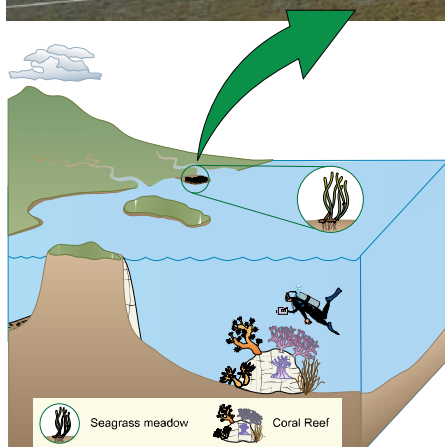


Great Barrier Reef Water Quality Protection Plan Marine Monitoring Program *Intertidal Seagrass*

FINAL REPORT

For the Sampling Period 1st September 2007 – 31st May 2008



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Project 1.1.3 Condition trend and risk in coastal habitats: Seagrass Indicators, distribution and thresholds of potential concern.



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Executive summary

- o The dominant species of seagrass present along the east coast of Queensland within the monitoring sites were *Halophila ovalis*, *Halodule uninervis* and *Zostera capricorni*. *Halophila ovalis* occurred ubiquitously and *Halodule uninervis* was found at twelve of the 15 locations monitored. Although *Zostera capricorni* was found at 9 locations from the north to the south, it was only collected from the southern locations as it was not representative of intertidal meadows in the north. Tissue nutrient and reproductive assessments were restricted to these dominant species.
- o Seagrass cover and abundance was higher over the last monitoring period compared to monitoring periods in previous years.
- o Seeds and reproductive structures were more common at coastal than offshore locations. The region with the greatest seed banks and reproductive effort was Burdekin Dry Tropics followed by the Wet Tropics and Mackay Whitsunday NRMs.
- o Tissue nutrient concentrations were extremely variable between years, across locations and within locations between years. Seagrass tissue C:N and C:P ratios indicate seagrass in estuary and coastal habitats were growing in low light and nutrient rich environments. However seagrass tissue C:N ratios at reef habitats indicate moderate light and nutrient poor environments.
- o Intertidal seagrass meadow distribution has changed little since monitoring was established. Some localised changes have occurred, but there is no overall trend. Seagrass meadow distribution over the 2007 / 2008 sampling period declined at some locations due primarily to natural physical disturbance (sediment movement).
- o Although epiphyte cover was lower in the late Monsoon 2008 compared to the late Dry 2007, it was not significant. Trends in epiphyte cover were similar to trends in seagrass abundance, but amplitudes differed between habitats.
- o Macro-algae abundance was generally low across the locations monitored, but variable in coastal/reef meadows and increased slightly in estuary meadows.
- o Most locations had a smaller N sediment nutrient pool relative to P. Adsorbed ammonium varied between years and regions. There appears to be a general decline in adsorbed P from 2005, suggesting no major influences of flooding were detected over the two intervening years. Estuarine habitats (predominately *Zostera capricorni* dominated) had relatively high N sediment nutrients.
- o We cannot generalize trends in seagrass tissue nutrients across the GBR as they are the result of their local nutrient environment. We do observe trends at the NRM scale. The Wet Tropics show seagrasses are nutrient replete. The Burdekin Dry Tropics show a separation between habitat type, coastal and reef. In the Mackay/Whitsunday region, coastal sites are replete or P limited suggesting saturating levels of nitrogen. The Fitzroy also show a dichotomy between habitat types. The Burnett Mary region are N limited.
- o Diuron was the only herbicide, of the thirteen analysed, found to be above detectable limits in the sediments of 10 of the 30 seagrass monitoring sites during the late Monsoon 2008. Diuron was detected in the sediments at all Townsville sites and coastal sites in the Mackay-Whitsundays, Fitzroy and Burnett-Mary. All concentrations were below levels reported to inhibit seagrass growth. The highest concentrations (0.32 and 0.27 µg/kg DW) were found in Sarina Inlet.

- o Within canopy temperatures over the past 12 months were slightly warmer at northern locations and cooler at southern locations than compared to the previous monitoring period. The only location to experience peaks in maximum temperatures above 40°C during the past 12 months was Yule Point.
- o Monitoring indicates intertidal seagrasses are influenced primarily by the availability of light and nutrients for primary production.
- o Seagrasses examined within the MMP over the last monitoring period were in a good to fair condition on a GBR wide scale. Declines were observed at two locations, however as these locations have relatively large seed banks and low epiphytes / macro-algae seagrass are expected to improve/increase.

Summary of condition and overall trend at each seagrass monitoring location, values are Oct07 – Apr08 (refer to Table 47) with the long term average in parentheses. Red = poor, Green = good, Yellow = fair, white = ambiguous or insufficient data, amber = sites of concern with respect to water quality. || = no change. 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 = $N:P < 30$, replete $N:P = 30$; P limited = $N:P > 30$.

NRM (Board)	Catchment	Location (habitat)	Seagrass Cover (%)	Seagrass Seeds (no. m ⁻²)	Reproductive effort (no. core ⁻¹)	Meadow (area)	Epiphytes (%)	Macro-Algae (%)	C:N _{plant} status	C:P _{plant} status	N:P _{plant} status	N:P _{sediment} trend (status)
Cape York	Endeavour	Archer Pt (reef)	15 – 13 (19) decline	323 - 255 (162) increase	increase	increase	29 - 11 (23) decline	7 - 2 (9) decline	moderate	poor	P limited	N↑P (N>P)
Wet Tropics (Terrain)	Barron Russell / Mulgrave Johnstone	Yule Pt (coast)	15 – 29 (15) increase	526 - 382 (429) stable	increase	increase	15 - 51 (17) increase	<1 (2) variable	low	rich	replete	N P↓ (N<P)
		Green Is (reef)	38 – 34 (42) increase	nil	stable (low)	stable	7 - 25 (24) increase	5 - 5 (4) stable	moderate	poor	replete	N↓P↓ (N<P)
		Lugger Bay (coast)	4 – 6 (4) recovering	0 - 17 (14) decline	decrease (low)	recovery	5 - 1 (3) variable	0 (<1) variable	low	rich	replete	N P↓ (N=P)
		Dunk Is (reef)	12 – 15 (12) NA	4 - 42 (9) NA	NA	NA	7 - 10 (10) NA	6 - 8 (7) NA	moderate	poor	replete	NA (N<P)
Burdekin (Burdekin Dry Tropics)	Burdekin	Townsville (coast)	24 – 14 (19) decline	4793 - 7388 (3227) increase	increase (high)	decline	7 - 23 (17) decline	6 - 1 (4) decline	low	rich	P limited	N↑P↓ (N>P)
		Magnetic Is (reef)	43 – 56 (35) increase	14 - 8 (34) decline	stable	stable	51 - 54 (42) stable	21 - 6 (8) stable	moderate	poor	N limited	N↓P↓ (N<P)
Mackay Whitsunday (Mackay Whitsunday)	Proserpine	Pioneer Bay (coast)	33 – 15 (20) increase	166 - 225 (279) increase	increase	increase	22 - 13 (15) decline	10 - 2 (13) stable	low	rich	P limited	N↑P↓ (N<P)
		Hamilton Is* (reef)	10 – 3 (9) NA	nil	NA	NA	31 - 25 (23) NA	1 - 3 (2) NA	low	poor	P limited	NA (N<P)
	Pioneer	Sarina Inlet (estuary)	13 – 11 (14) recovery	0 (66) variable	increase	variable	31 - 2 (16) variable	2 - <1 (1) variable	low	rich	replete	N↑P↓ (N<P)
Fitzroy (Fitzroy Basin Association)	Fitzroy	Shoalwater (coast)	36 – 32 (27) increase	nil	NA	stable	15 - 10 (12) decline	5 - <1 (6) decline	moderate	poor	N limited	N↓P↓ (N<P)
		Great Keppel (reef)	6 – 2 (3) NA	nil	NA	NA	32 - 53 (34) NA	14 - 5 (8) NA	low	rich	P limited	NA (N<P)
	Boyne	Gladstone (estuary)	25 – 18 (16) recovery	nil	increasing	recovery	33 - 30 (27) variable	9 - 28 (22) stable	low	rich	N limited	N↑P↓ (N<P)
Burnett Mary (Burnett Mary Regional Group)	Burnett	Rodds Bay (estuary)	41 – 7 (24) NA	0 - 8 (4) NA	decreasing	NA	9 - 1 (5) NA	1 - 3 (2) NA	moderate	poor	N limited	NA (N<P)
	Mary	Urangan (estuary)	0.2 – 0.8 (16) recovery	nil	increasing	recovery	2 - 1 (19) decline	<1 (1) variable	low	rich	N limited	N↓P↓ (N=P)

1. Introduction

A key component of Reef Water Quality Protection Plan is the implementation of a long-term water quality and ecosystem monitoring program in the Great Barrier Reef lagoon. The Great Barrier Reef Marine Park Authority (GBRMPA) has responsibility for implementation of this program. The Queensland Department of Primary Industries & Fisheries (DPI&F) 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. Detect long-term trends in seagrass abundance, community structure, distribution, reproductive health and nutrient status from representative intertidal seagrass meadows in relation to large river inputs (provided by other programmes) into the GBRWHA.
- b. Detect long-term trends in levels of ecologically significant nutrient pollutants from representative intertidal seagrass meadows in relation to large river inputs into the GBRWHA.
- c. To work closely with and involve community partners (Seagrass-Watch) to ensure broad acceptance and ownership of the MMP by the Queensland and Australian community.

Background

There are nearly 6,000 km² of seagrasses in waters shallower than 15 metres, relatively close to the coast, and in locations that can potentially be influenced by adjacent land use practices. 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.

One of the paramount requirements of the MMP, apart from being scientifically robust, is that its findings must have broad acceptance and ownership by the North Queensland and Australian community. It was identified very early in development of 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 community volunteer monitoring activities were enhanced through;

- Value adding by collecting other information by scientists in the field,
- Where community groups can not monitor DPI&F staff and fee for service trained personnel collect the data.

DPI&F has developed long-term collaboration/partnerships with individuals, community groups and government organizations participating in the Seagrass-Watch program to help monitor and collect samples for long-term condition and trend assessment of Queensland's seagrass resources. Volunteers collect quantitative data on seagrasses and their associated fauna by means of simple yet scientifically rigorous monitoring techniques. For detailed reports on each location/region, visit the long-term monitoring section of the website at www.seagrasswatch.org.

In late 2004 all existing Seagrass-Watch data was supplied to Glenn De'ath (AIMS) for independent review. De'ath (2005)¹ analysed the available Seagrass-Watch dataset to estimate expected performance of the monitoring program. He included data from 2000–2004 at 63 sites in 29 locations in 6 regions (Cooktown, Cairns, Townsville, Whitsundays, Hervey Bay, Great Sandy Strait). Results concluded that the Seagrass-Watch monitoring is providing valuable information about temporal trends and spatial differences, with changes in seagrass cover occurring at various spatial and temporal scales. The monitoring showed recovery in the Hervey Bay Region, from ~3% cover in 2000 increasing to ~17% cover in 2004. The report recommended that the value of the monitoring would be greatly enhanced by adding more widely spread regions to the surveys.

There are 15 species of seagrass in the GBRWHA. A high diversity of seagrass habitats is provided by extensive bays, estuaries, rivers and the 2600 km of 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 MSL. There is in excess of 5,000 km² of coastal seagrass meadows in eastern Queensland waters shallower than 15 metres and it is likely that approximately 40,000km² of the seafloor in the GBRWHA deeper than 15 metres has some seagrass (Coles *et al* 2003a). This represents about 36% of the total recorded area of seagrass in Australia.

Seagrasses in the GBRWHA can be split 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.

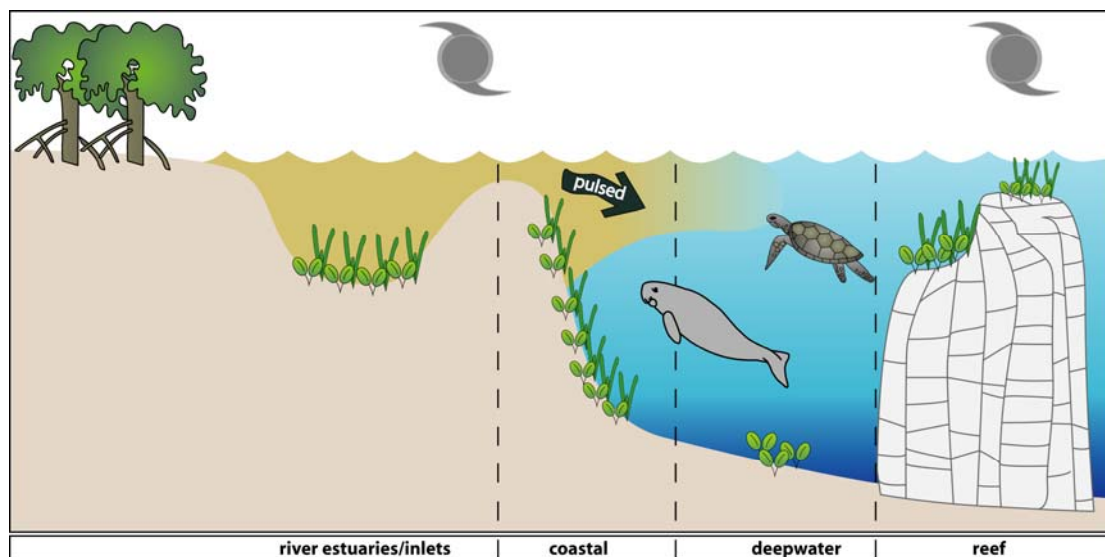


Figure 1. General conceptual model of seagrass habitats in north east Australia (from Carruthers *et al.* 2002)

¹ De'ath, G (2005) Water Quality Monitoring: From River to Reef (AIMS, Townsville) 108pp.

Methodology

[Note: detailed documentation of methods was provided to GBRMPA in a separate report in October 2005: *Water Quality and Ecosystem Monitoring Programs - Reef Water Quality Protection Plan: Methods and Quality Assurance/Quality Control Procedures.*]

Sites were monitored as scheduled (Table 1). This included nine coastal locations and six offshore intertidal reef locations. A description of all the data collected during the sampling period under the monitoring contract has been collated by NRM region site, parameter, and the number of samples collected per sampling period is listed in Table 2. The presence of the targeted seagrass species at monitoring sites is listed in Table 3.

Inter-tidal seagrass monitoring

Survey methodology followed Seagrass-Watch standard methodology (McKenzie *et al.*, 2004, 2005a, b; see also www.seagrasswatch.org). At each sampling location, sampling includes two sites nested in location and three 50m transects nested in each site. A site is defined as a 50m x 50m area within a relatively homogenous section of a representative seagrass community/meadow (McKenzie *et al* 2000). Community-based monitoring at the sites identified for the MMP long-term intertidal monitoring in late dry and late monsoon of each year is supervised on-site by a qualified and trained scientist. Monitoring conducted outside these months, is conducted by trained community volunteers. Sites are monitored for seagrass cover and species composition. Additional information is collected on canopy height, algae cover and epiphyte cover and macrofaunal abundance. An assessment of *Halodule uninervis* reproductive health is also conducted via seedbank monitoring. Monitoring of within canopy temperatures was also recorded at all established sites.

Edge mapping

Mapping the edge of the seagrass meadow within 100m of each monitoring site was conducted at all sites in the late Dry (October 2007) and late Monsoon (April 2008) monitoring periods. Training and equipment (GPS) were provided to personnel involved in the edge mapping.

Table 1. 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 <i>Coastal intertidal</i>	AP1	Archer Point	15°	36.5	145°	19.143	<i>H. uninervis</i> / <i>H. ovalis</i> with <i>Cymodocea</i> / <i>T. hemprichii</i>
				AP2	Archer Point	15°	36.525	145°	19.108	<i>H. uninervis</i> / <i>H. ovalis</i> with <i>C. rotundata</i>
Northern	Wet Tropics (Terrain)	Barron Russell/Mulgrave Johnstone	Green Island <i>Offshore intertidal</i>	GI1	Green Island	16°	45.789	145°	58.31	<i>C. rotundata</i> / <i>T. hemprichii</i> with <i>H. uninervis</i> / <i>H. ovalis</i>
				GI2	Green Island	16°	45.776	145°	58.501	<i>C. rotundata</i> / <i>T. hemprichii</i> with <i>H. uninervis</i> / <i>H. ovalis</i>
			Cairns <i>Coastal intertidal</i>	YP1	Yule Point	16°	34.159	145°	30.744	<i>H. uninervis</i> with <i>H. ovalis</i>
				YP2	Yule Point	16°	33.832	145°	30.555	<i>H. uninervis</i> with <i>H. ovalis</i>
		Tully	Mission Beach <i>Coastal intertidal</i>	LB1	Lugger Bay	17°	57.645	146°	5.61	<i>H. uninervis</i>
				LB2	Lugger Bay	17°	57.674	146°	5.612	<i>H. uninervis</i>
			Dunk Island <i>Offshore intertidal</i>	DI1	Dunk Island	17°	56.6496	146°	8.4654	<i>H. uninervis</i> with <i>T. hemprichii</i> / <i>C. rotundata</i>
				DI2	Dunk Island	17°	56.7396	146°	8.4624	<i>H. uninervis</i> with <i>T. hemprichii</i> / <i>C. rotundata</i>
Central	Burdekin (Burdekin Dry Tropics)	Burdekin	Magnetic island <i>Offshore intertidal</i>	MI1	Picnic Bay	19°	10.734	146°	50.468	<i>H. uninervis</i> with <i>H. ovalis</i> & <i>Zostera</i> / <i>T. hemprichii</i>
				MI2	Cockle Bay	19°	10.612	146°	49.737	<i>C. serrulata</i> / <i>H. uninervis</i> with <i>T. hemprichii</i> / <i>H. ovalis</i>
			Townsville <i>Coastal intertidal</i>	SB1	Shelley Beach	19°	11.046	146°	45.697	<i>H. uninervis</i> with <i>H. ovalis</i>
				BB1	Bushland Beach	19°	11.028	146°	40.951	<i>H. uninervis</i> with <i>H. ovalis</i>
	Mackay Whitsunday (Mackay Whitsunday)	Proserpine	Whitsundays <i>Coastal intertidal</i>	PI2	Pioneer Bay	20°	16.176	148°	41.586	<i>H. uninervis</i> / <i>Zostera</i> with <i>H. ovalis</i>
				PI3	Pioneer Bay	20°	16.248	148°	41.844	<i>H. uninervis</i> with <i>Zostera</i> / <i>H. ovalis</i>
			Whitsundays <i>Offshore intertidal</i>	HM1	Hamilton Island	20°	20.7396	148°	57.5658	<i>H. uninervis</i> with <i>H. ovalis</i>
				HM2	Hamilton Island	20°	20.802	148°	58.246	<i>Z. capricorni</i> with <i>H. ovalis</i> / <i>H. uninervis</i>
		Pioneer	Mackay <i>Coastal intertidal</i>	SI1	Sarina Inlet	21°	23.76	149°	18.2	<i>Z. capricorni</i> with <i>H. ovalis</i> (<i>H. uninervis</i>)
				SI2	Sarina Inlet	21°	23.712	149°	18.276	<i>Z. capricorni</i> with <i>H. ovalis</i> (<i>H. uninervis</i>)
Southern	Fitzroy (Fitzroy Basin Association)	Fitzroy	Shoalwater Bay <i>Coastal intertidal</i>	RC	Ross Creek	22°	22.953	150°	12.685	<i>Zostera capricorni</i> with <i>H. ovalis</i>
				WH	Wheelans Hut	22°	23.926	150°	16.366	<i>Zostera capricorni</i> with <i>H. ovalis</i>
			Keppel Islands <i>Offshore intertidal</i>	GK1	Great Keppel Is.	23°	11.7834	150°	56.3682	<i>H. uninervis</i> with <i>H. ovalis</i>
				GK2	Great Keppel Is.	23°	11.637	150°	56.3778	<i>H. uninervis</i> with <i>H. ovalis</i>
		Boyne	Gladstone Harbour <i>Coastal intertidal</i>	GH1	Gladstone Hbr	23°	46.005	151°	18.052	<i>Zostera capricorni</i> with <i>H. ovalis</i>
				GH2	Gladstone Hbr	23°	45.874	151°	18.224	<i>Zostera capricorni</i> with <i>H. ovalis</i>
	Burnett Mary (Burnett Mary Regional Group)	Burnett	Rodds Bay <i>Coastal intertidal</i>	RD1	Rodds Bay	24°	3.4812	151°	39.3288	<i>Zostera capricorni</i> with <i>H. ovalis</i>
				RD2	Rodds Bay	24°	4.866	151°	39.7584	<i>Zostera capricorni</i> with <i>H. ovalis</i>
		Mary	Hervey Bay <i>Coastal intertidal</i>	UG1	Urangan	25°	18.053	152°	54.409	<i>Zostera capricorni</i> with <i>H. ovalis</i>
				UG2	Urangan	25°	18.197	152°	54.364	<i>Zostera capricorni</i> with <i>H. ovalis</i>

Table 2. Number of samples collected at each monitoring site per parameter for each Season. Activities include: SG = seagrass cover & composition, SM=seed monitoring, SH=sediment herbicide, TN=tissue nutrients, SN=sediment nutrients, EM=edge mapping, RH=reproductive health, TL=temperature loggers deployed, LL=light loggers deployed. *=additional activity.

Sector	Region	Catchment	Monitoring location		Late Dry Season (2007)								Late Monsoon Season (2008)							
					SG	SM	TN	SN	EM	RH	TL	LL	SG	SM	SH	SN	EM	RH	TL	LL
Far Northern	Cape York	Endeavour	Cooktown	AP1	33	30	3	5	✓	15	✓		33	30	3		✓	15*	✓	
				AP2	33	30	3	5	✓	15	✓		33	30	3		✓	15*	✓	
Northern	Wet Tropics	Russell / Mulgrave Johnstone	Green Island	GI1	33	30	3	5	✓	15	✓	✓*	33	30	3	3*	✓	15*	✓	✓*
				GI2	33	30	3	5	✓	15	✓		33	30	3	3*	✓	15*	✓	
			Cairns	YP1	33	30	3	5	✓	15	✓		33	30	3	3*	✓	15*	✓	
				YP2	33	30	3	5	✓	15	✓	✓*	33	30	3	3*	✓	15*	✓	✓*
		Tully	Mission Beach	LB1	33	30	3	5	✓	15	✓		33	30	3	3*	✓	15*	✓	
				LB2	33	30	3	5	✓	15	✓		33	30	3	3*	✓	15*	✓	
			Dunk Island	DI1	33	30	3	5	✓	15	✓		33	30	3	3*	✓	15*	✓	
				DI2	33	30	3	5	✓	15	✓		33	30	3	3*	✓	15*	✓	
Central	Burdekin	Burdekin	Magnetic Island	MI1	33	30	3	5	✓	15	✓		33	30	3	3*	✓	15*	✓	
				MI2	33	30	3	5	✓	15	✓	✓	33	30	3	3*	✓	15*	✓	✓
			Townsville	SB1	33	30	3	5	✓	15	✓		33	30	3	3*	✓	15*	✓	
				BB1	33	30	3	5	✓	15	✓	✓	33	30	3	3*	✓	15*	✓	✓
	Mackay Whitsunday	Proserpine	Whitsundays	PI2	33	30	3	5	✓	15	✓	✓*	33	30	3	3*	✓	15*	✓	
				PI3	33	30	3	5	✓	15	✓		33	30	3	3*	✓	15*	✓	
			Hamilton Is.	HM1	33	30	3	5	✓	15	✓		33	30	3	3*	✓	15*	✓	
				HM2	33	30	3	5	✓	15	✓		33	30	3	3*	✓	15*	✓	
		Pioneer	Mackay	SI1	33	30	3	5	✓	15	✓		33	30	3	3*	✓	15*	✓	
				SI2	33	30	3	5	✓	15	✓		33	30	3	3*	✓	15*	✓	
Southern	Fitzroy	Fitzroy	Shoalwater Bay	RC	33	30	3	5	✓	15	✓		33	30	3		✓	15*	✓	
				WH	33	30	3	5	✓	15	✓		33	30	3		✓	15*	✓	
			Great Keppel Is.	GK1	33	30	3	5	✓	15	✓		33	30	3	3*	✓	15*	✓	
				GK2	33	30	3	5	✓	15	✓		33	30	3	3*	✓	15*	✓	
		Boyne	Gladstone	GH1*	33*	30*			✓*		✓*		33*	30*			✓		✓	
				GH2*	33*	30*			✓*		✓*		33*	30*			✓			
	Burnett Mary	Burnett	Rodds Bay	RD1	33	30	3	5	✓		✓		33	30	3		✓	15*	✓	
				RD2	33	30	3	5	✓		✓		33	30	3		✓	15*	✓	
		Mary	Hervey Bay	UG1	33	30	3	5	✓	15	✓		33	30	3		✓	15*	✓	
				UG2	33	30	3	5	✓	15	✓		33	30	3		✓	15*	✓	

Table 3. Presence (■) of *Halophila ovalis*, *Halodule uninervis* and *Zostera capricorni* in monitoring locations sampled in 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 Carruther et al. (2002).

Zostera capricorni = *Zostera muelleri* subsp. *capricorni*

* indicates presence adjacent, but not within, 50m x 50m site.

+ only found at Picnic Bay

GBR region	NRM Board	Catchment	Seagrass monitoring location	Habitat type	<i>H. ovalis</i>	<i>H. uninervis</i>	<i>Z. capricorni</i>
Far Northern	Cape York	Endeavour	Cooktown	Reef	■	■	■*
Northern	Terrain (Wet Tropics)	Daintree	NA				
		Russell / Mulgrave Johnstone	Green Island	Reef	■	■	
			Yule Point	Coast	■	■	■*
		Tully	Lugger Bay	Coast	■*	■	
			Dunk Island	Reef	■*	■	
Central	Burdekin Dry Tropics	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 (status)

Seagrass reproductive health was assessed from samples collected in the late Dry 2007 and late Monsoon 2008 at locations identified in Table 2. Samples were processed according to standard methodologies.

In the field, 15 haphazardly placed cores of seagrass were collected from an area adjacent, of similar cover and species composition, to each Seagrass-Watch monitoring site.

In the laboratory, reproductive structures (spathes, fruit, female flower or male flowers) of plants from each core were identified and counted for each samples and species. If *Halodule uninervis* seeds (brown green colour) were still attached to the rhizome, they were counted as fruits. Seed estimates are not recorded for *Halophila ovalis* due to time constraints (if time is available post this first pass of the samples, fruits will be dissected and seeds counted). For *Zostera capricorni*, the number of spathes were recorded, male and female flowers and seeds were counted during dissection if there was time after the initial pass of the samples. Apical meristems were not recorded- as they were too damaged by the collection process to be able

to be identified correctly. All flowers and spathes and fruits /fruiting bodies were kept and re-frozen in the site bags for revalidation if required (see QAQC).

Seagrass tissue nutrient

In late Dry season October 2007, tissue nutrient (*Halodule uninervis*, *Halophila ovalis* and *Zostera capricorni*) samples were collected from the monitoring sites where present, as indicated Table 3.

Three haphazardly placed 0.25m² quadrats were harvested from an area adjacent, of similar cover and species composition, to each Seagrass-Watch monitoring site. Leaves were separated from the below ground material in the laboratory and epiphytic algae removed by scraping. A re-evaluation of the laboratory techniques, including sub-sampling, expedited the processing time. Samples were oven dried at 60°C to a constant weight and dried samples of leaves will be homogenized by milling to fine powders.

Nitrogen and phosphorus were extracted using a standardized selenium Kjeldahl digest and the concentrations determined with an automatic analyser using standard techniques at a Queensland Health and Scientific Services, (QHSS - a NATA certified laboratory). %C was determined by atomic absorption, also at QHSS. C:N:P were calculated using atomic weights.

Sediment nutrient

To sample sediment nutrients, five replicate sediment cores (50mL) were collected from each monitoring site for measurement of adsorbed nutrients. Samples were placed on ice then refrigerated. Adsorbed exchangeable ammonium (NH₄⁺) was extracted using KCl. Previous analyses had shown that within site variability was negligible, therefore bulking of sediment cores before extraction was considered acceptable (after discussion with D. Haynes) representing quite a savings on analyses.

To extract adsorbed phosphate (PO₄³⁻), the Olsen/ Colwell/Bicarbonate method was used.

This technique is not affected by pH, and potentially strips all adsorbed PO₄³⁻ from the sediments. Although this has the potential to overestimate the PO₄³⁻ that is bioavailable to the seagrass, it was used to represent the total phosphorus pool and to compare with previous research studies and datasets.

Chemical analyses of all inorganic nutrients were determined using a Skalar segmented flow auto-analyser, using standard water quality techniques.

Replicate samples (3) of saturated sediment cores were collected at each site at the time of nutrient sampling. Cores were collected in 'cut-off' 50 mL syringes and rubber stoppered. The volume of each core was measured from the syringe gradations. The intact core was weighed (g), dried in an oven (80°C, 48 h) and then reweighed to determine weight loss.

Particle size density (p_s) and porosity (Φ) was calculated (Eq 1, Eq 2) by converting adsorbed nutrients units ($\mu\text{mol kg}^{-1}$) to equivalent units ($\mu\text{mol L}^{-1}$ sediment) to enable the molar ratios of the total sediment nutrient pool to be calculated.

Equation 1:

$$p_s = (\text{Dry sample wt} - \text{Syringe weight}) / (\text{Volume} - ((\text{Wet sample wt} - \text{Dry sample wt}) / dw))$$

where dw = specific gravity of water = 1.025

Equation 2:

$$\Phi = (H/1.025) / (H/1.025 + ((1-H) / p_s))$$

where H = proportion of water - (wet weight - dry weight) / wet weight

and p_s = particle size density

QA/QC procedures

Sampling Design

Site marking

Each selected intertidal seagrass site was permanently marked with plastic star pickets at the 0m and 50m points of transect 2 if possible. Labels identifying the sites and contact details for the program were attached to these pickets. Positions of 0m and 50m points for all three transects at a site were also noted using GPS (Table 1). This ensures that the same site was monitored each event.

Seagrass Cover and Species Composition

The collection of data by Seagrass-Watch volunteers necessitates a high level of training to ensure that the data is of a standard that can be used by management agencies. Technical issues concerning quality control of data are important especially when the collection of data is by people not previously educated in scientific methodologies. By using simple and easy methods, Seagrass Watch ensures completeness (the comparison between the amount of valid or useable data originally planned to collect, versus how much was collected). Standard seagrass cover calibration sheets are used to ensure precision (the degree of agreement among repeated measurements of the same characteristic at the same place and the same time) and consistency between observers and across sites at monitoring times. Ongoing standardisation of observers is achieved by on-site refreshers of standard percentage covers by all observers prior to monitoring and through ad hoc comparisons of data returned from duplicate surveys (e.g., either a site or a transect will be repeated by scientist – preferably the next day and unknown to volunteers). Any discrepancy in these duplicates is used to identify and subsequently mitigate bias. For the most part however uncertainties in percentage cover or species identification are mitigated in the field via direct communication (as at least one experienced observer are always present), or the collection of voucher specimens (to be checked under microscope and pressed in herbarium) and the use of a digital camera to record images (protocol requires at least 27% of quadrats are photographed) for later identification and discussion. Coordinators are advised of errors in data identified through the Seagrass-Watch QAQC.

Seagrass reproductive health

After processing, samples are retained for future verification if required.

Laboratory Analysis

Sediment samples are sent to the QHSS for analysis. Sample receipting, handling, analysis and data reporting at QHSS will be based on NATA certified methods. QHSS holds NATA accreditation (Corporate Accreditation Number 41) for constituents of the environment including soil, sediments, waters and wastewaters. (Note that details of QHSS accreditation can be found at the NATA website <http://www.nata.asn.au/>). The NATA accreditation held by QHSS includes a wide variety of QA/QC procedures covering the registration and identification of samples with specific codes and the regular calibration of all quantitative laboratory equipment required for the analysis. QHSS has developed appropriate analytical techniques including QA/QC procedures and detection of nutrients. These procedures include blanks, duplicates where practical, and internal use of standards for quality assurance.

Seagrass Tissue Nutrient

Samples (0.25-0.40gm), standards and quality control samples are taken through the whole digestion process using a Kjeldahl Digestion Mix (potassium sulfate/sulfuric acid/copper sulfate). The digestion is automated using block digesters programmed to give a final digestion temperature of 360°C for a period of 2 hours and is based on procedures (with quite a few modifications to allow analysis for freshwater, saline waters and sediments) described in Standard Methods 1998 – 4500-Norg D.

After digestion, analyses for Total Kjeldahl Nitrogen (TKN) and Total Kjeldahl Phosphorus (TKP) are performed simultaneously using a segmented flow instrument (BRAN+LUEBBE). For TKN, NH₃ is analysed based on Standard Methods 1998 (20th Edition) – 4500- NH₃ H (it should be noted sodium salicylate is used in lieu of phenol). For TKP the analysis is based on the ascorbic acid reduction of phosphomolybdate for FRP (Standard Methods 1998 (20th Edition) – 4500-P). N:P ratios are calculated using atomic weights. These processes are all carried out at the QHSS Quality Assured and NATA certified laboratory (Accreditation No: AN 41).

Sediment Nutrient

To enable comparison with published results on sediment and nutrient dynamics in coastal intertidal seagrass of north eastern tropical Australia (see Mellors 2003 and Mellors *et al* 2005) the cores are analysed for extractable inorganic ammonium, and phosphate in the following manner and methods. All cores are homogenized to provide a depth-integrated sample and then bulked to provide an averaged sampled for that site.

Adsorbed exchangeable ammonium is extracted using KCl (Rayment and Higginson, 1993). Phosphate will be extracted using the Colwell method (Colwell, 1963; Mengel and Kirkby, 1987; Rayment and Higginson, 1993), as this method is not affected by pH and is more appropriate for alkaline soils pH>7.8 (Baker and Eldershaw, 1993). This technique will provide information on the amount of adsorbed PO that was bio-available to the seagrass. The chemical determination for the extracted phosphate is based on the method of Murphy and Riley (in Rayment and Higginson, 1993).

Each batch of samples are run with a reagent blank and a sample fortified with a known concentration of the analytes to give a concentration in the sediment. An internal standard, is added to all samples, fortified sample, reagent blank and standards before quantification.

Certified reference standards are used for instrument calibration with a standard being run every 10 samples.

Data Management

DPI&F has systems in place to manage the way data is collected, organised, documented, evaluated and secured. The Seagrass-Watch program collects and collates all data in a standard format. DPI&F has implemented a quality assurance management system to ensure that data collected by volunteers is organised and stored and able to be used easily.

All data (datasheets & photographs) received are entered onto a relational database on a secure server in Cairns at the Northern Fisheries Centre. Receipt of all original data hardcopies is documented and filed within the DPI&F Registered Management System, a formally organised and secure system. Seagrass-Watch HQ (DPI&F) operates as custodian of data collected from other participants and provides an evaluation and analysis of the data for reporting purposes. Access to the IT system and databases is restricted to only authorised personnel. Provision of data to a third party is only on consent of the data owner/principal.

Seagrass-Watch HQ (DPI&F) performs a quality check on long-term monitoring data submitted as part of Seagrass-Watch QA/QC. Seagrass-Watch HQ provides validation of data and attempts to correct incidental/understandable errors where possible (e.g., blanks are entered as -1 or if monospecific meadow percentage composition =100%). Validation is provided by checking observations against photographic records to ensure consistency of observers and by identification of voucher specimens submitted.

In accordance with QA/QC protocols, Seagrass-Watch HQ advises observers via an official data error notification of any errors encountered/identified and provides an opportunity for correction/clarification (this may include additional training). Any data considered unsuitable (e.g., nil response to data notification within 30 days) is removed from the database.

Statistical analysis

At the Scientific Advisory Panel meeting in April 2007, the Panel agreed that a statistician should be employed to assist all proponents of the Marine Monitoring Program of the Reef Water Quality Protection Plan. Until the statistician is employed we intend to analyze the data as has been conducted previously (described briefly below).

Seagrass Cover and species composition

Quadrat measures will be pooled across each site for each sampling period. Running averages of cover will be assessed against latest year of sampling to determine changes in seagrass cover for each site.

Sediment physical characteristics

All sediment physical characteristic variables were analysed using a General Analysis of Variance with Location and Year as factors and Site nested within Location. Normality of the data will be checked using standardised residual plots. Where data shows non-normal tendencies, the variables will be transformed accordingly. GenStat[®] will be used to detect data outliers (i.e. observations having unusually large residual values that fell outside the range of the response data and the model design). Where there are outliers in the data, analysis will be re-run excluding outliers to determine if there is any influence on the ANOVA outcome.

Results of previous analyses indicated that variation within locations was negligible compared to the differences between locations. Hence, Sites can be considered as replicates. Results will be reported for locations and graphed as mean ($\bar{x}$) as calculated by the ANOVA $\pm$ 95% Confidence Interval (CI) based on the pooled variance also determined by the ANOVA.

Interpretation of results from the analyses within each NRM region were mindful of the small sampling size. Sample size at location was comprised further by bulking sediment samples at the site level. This action was agreed to in discussion with the funding body, to physically rather than statistically average the sediment cores (bulk sampling) for each location. This decision was based on the outcomes of the initial ANOVA that showed variation within Location was negligible. Whilst this was appropriate for analysing data on a GBR scale, it poses certain challenges at the NRM scale. In NRM regions where two or more locations are monitored the data was analysed using ANOVA with Location and Year as treatments and Year only for NRMs with only one site being monitored. Site is no longer nested within Location to give the residual enough degrees of freedom to be tested against the treatment terms.

Seagrass tissue nutrients

Residual maximum likelihood (REML analysis) showed that differences in tissue nutrients between species was highly significant ($p < 0.001$). However, two of the species (*Halodule uninervis* and *Zostera capricorni*) were almost confounded with location, therefore nutrient data was analysed separately for each species. Analysing species separately is further supported by the knowledge that all seagrasses do not have the same environmental requirement or responses to environmental conditions as proposed by the “Seagrass Functional Form Model” (Walker *et al.* 1999).

Seagrass variables were analysed using Analysis of Variance (ANOVA) with Location and Year as treatments and Sites nested within Location as the blocking structure at the GBR scale and as previously mentioned with no blocking at the NRM scale. Normality of the data was checked using standardised residual plots. Transforming the data had no effect on the residual plots as the plots were heavily influenced by outliers. Analyses were re-run leaving out the outliers to ascertain their influence on the analysis outcome. Outliers were not deleted for analysis but their influence on the analyses is reported. Because of the variable nature of this data results are reported for sites and graphed as mean ($\bar{x}$) $\pm$ CI(95%)

Reproductive effort

Reproductive effort was calculated as the number of reproductive structures per node (leaf cluster emerging from the rhizome) as each of the three species examined (*Halophila ovalis*, *Halodule uninervis* and *Zostera capricorni*) have different reproductive structures. For comparative purposes only the presence of a reproductive structure per node was counted rather than the relative number of flowers, fruits or seeds. The number of nodes counted reflects the number of shoots found in the core. Thus cores with larger numbers of nodes contained more shoots. The average number of reproductive structures per node reflects the per unit area occurrence of reproductive output and this is the reproductive effort (i.e. average number of flowers, seeds or fruits per core).

Reporting Approach

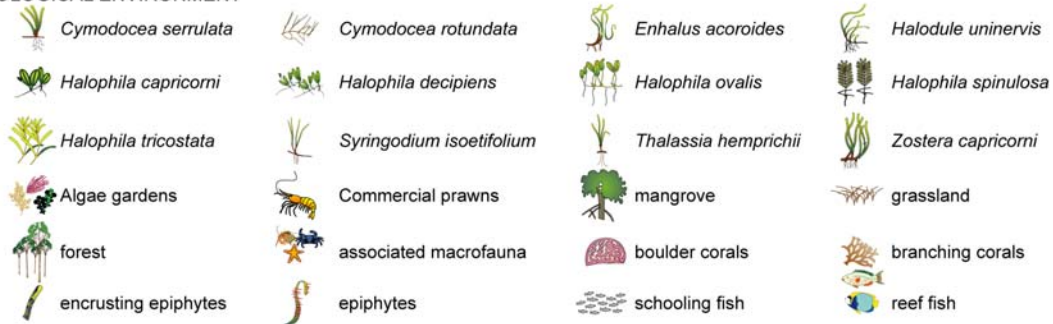
Results and discussion of monitoring is presented firstly by the Natural Resource Management Regions identified in the GBRWHA area and then in a GBRWHA general overview. These discrete regions have been used for stratifying issues of land and catchment based resource management and used to report downstream impacts on the reef environment such as from the affect of water quality. There are 56 Natural Resource Management regions identified in Australia, 15 are in Queensland and six are part of the coastal processes of the GBRWHA.

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 topo basemap (1:100 000 scale digital data).

Conceptual diagrams have been used to illustrate the general seagrass habitats type in each region (from Coles *et al.* 2007). Symbols/icons have been used in the conceptual diagrams to illustrate major controls, processes and threats/impacts (Figure 2).

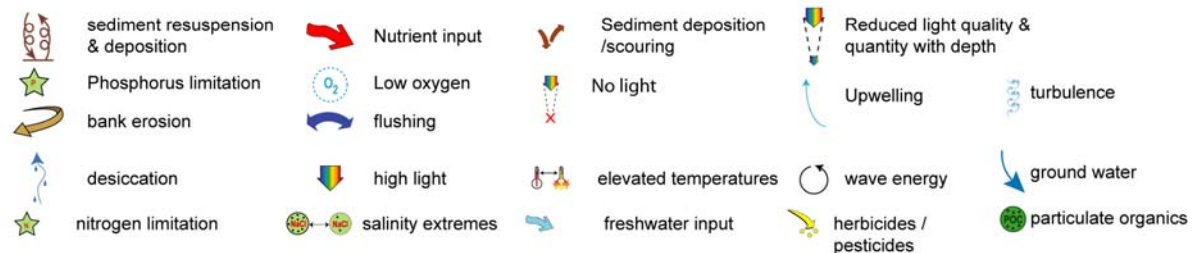
BIOLOGICAL ENVIRONMENT



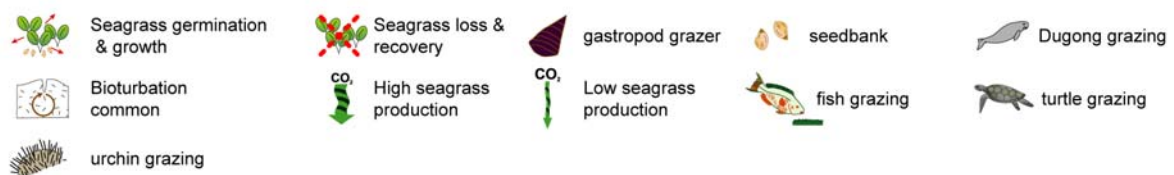
PHYSICAL ENVIRONMENT



PHYSICAL PROCESS



BIOLOGICAL PROCESS



ANTHROPOGENIC IMPACTS



Figure 2. Key to symbols used for conceptual diagrams.

2. Results



Cape York

Background

Cape York Peninsula is considered an area of exceptional conservation value and has cultural value of great significance to both Indigenous and non-Indigenous communities. (<http://www.nrm.gov.au/state/qld/cape-york/publications/report-card/index.html>). The majority of the land is relatively undeveloped and 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), MMP monitoring of intertidal seagrass meadows within this NRM is on a fringing reef platform. These habitats in the Cape York NRM 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 3). 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.

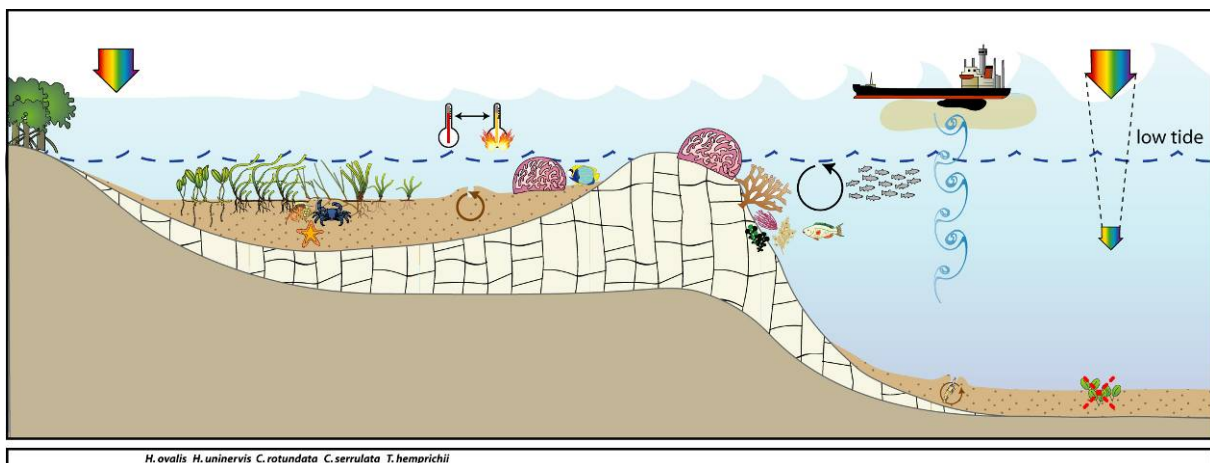


Figure 3. Conceptual diagram of reef-platform habitat in the Cape York region – major control is pulsed physical disturbance, salinity and temperature extremes: general habitat and seagrass meadow processes (See Figure 2 for icon explanation).

Seagrass cover and composition

The monitoring sites at Archer Point were located on a fringing reef platform in a protected section of bay adjacent to Archer Point, fringed by mangroves, approximately 15km south of Cooktown. The sites were dominated by *Halodule uninervis* and *Halophila ovalis* and seagrass cover long-term average was between 16% in winter (Dry) and 19% in late Dry season (Figure 4). Although sites were only 50m apart, AP2 had slightly more *Cymodocea* and *Thalassia* present. Species composition remained relatively stable over the past 12 months (Figure 6).

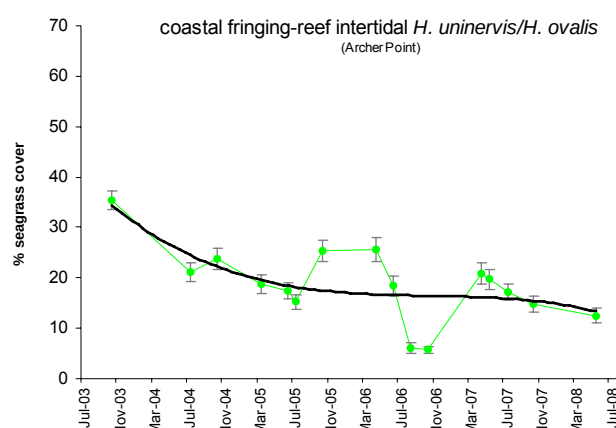


Figure 4. Seagrass abundance (% cover, $\pm$ Standard Error) at Archer Point, coastal intertidal fringing-reef habitat (sites pooled).

Seagrass cover significantly improved in 2007 compared to 2006, however it was lower in the late Monsoon 2008 than the previous year. Overall, the meadow appears to have generally declined in abundance since monitored was established in 2003 (Figure 4).

Since monitoring was established at AP1 in 2003, seagrass cover has generally followed a seasonal trend with higher abundance in late spring/early summer (Figure 5). However, no seasonal trend is apparent at AP2.

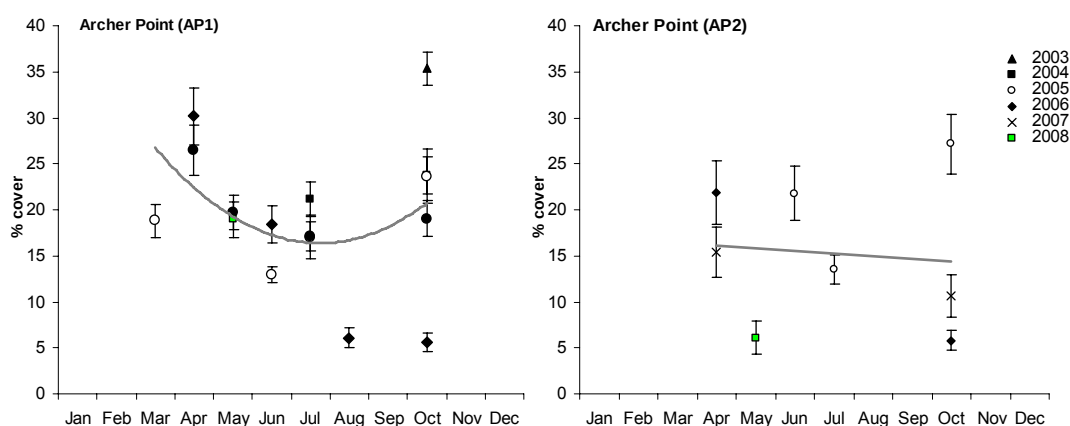


Figure 5. Mean percentage seagrass cover (all species pooled) ($\pm$ Standard Error) for inshore fringing-reef long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.

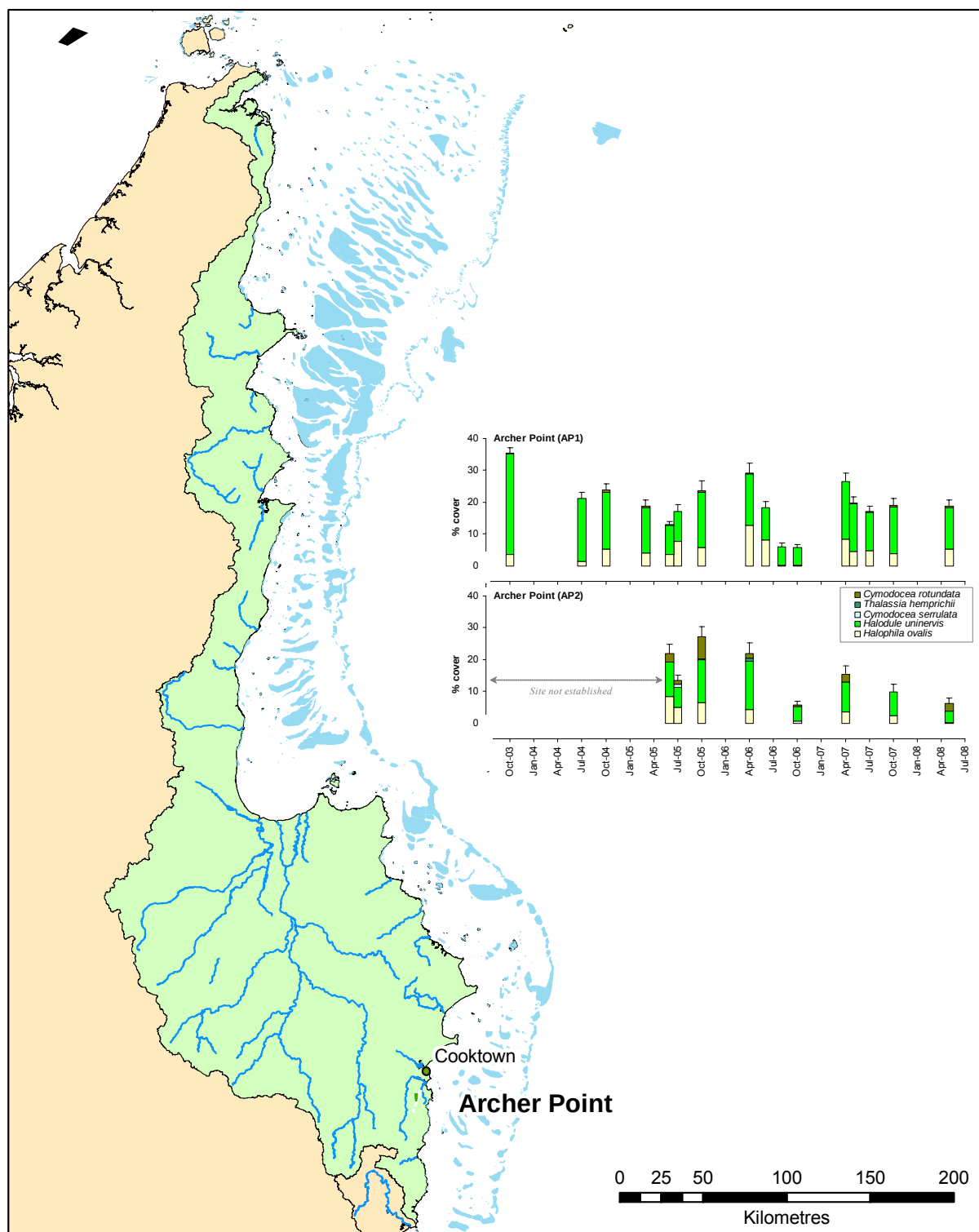


Figure 6. Mean percentage cover for each seagrass species at Archer Point monitoring sites (+Standard Error). NB: if no sampling conducted then x-axis is clear.

Seagrass reproductive health

Evidence of reproductive effort was found in all sampling periods (Figure 7). Overall reproductive health was significantly higher in 2007 than 2006 dry season sample.

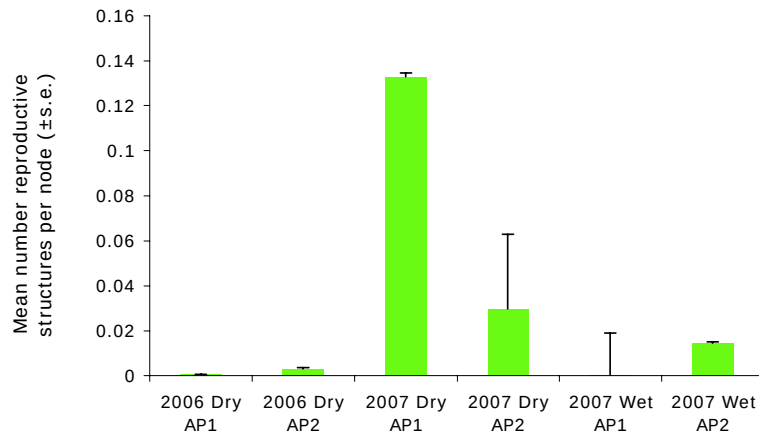


Figure 7. Mean number of reproductive structures per node across all seagrass species and all years sampled at Archer Point (+Standard Error).

Tissue nutrients

Halodule uninervis, *Halophila ovalis* and *Cymodocea rotundata* were present in harvested samples. The presence of *H. ovalis* and *C. rotundata* varied between years and sites. Consequent statistical analyses on these two species were limited due to the unbalanced nature of the data.

Halodule uninervis

Plant tissue percent C was not significantly different between years for *Halodule uninervis* despite the mean %C being lower in 2005 (29.6%) compared to 2006 and 2007 (40.2% and 39.0% respectively) (Figure 8a).

Plant tissue percent N ranged from 2.83%N (2006) to 1.6 %N (2005) (Figure 8b). Differences between levels in 2005 and 2006 were significant, while levels recorded for 2007 were not significantly different from either 2005 and 2006 (ANOVA d.f._(2,3) $p = 0.050$, Table 4).

A similar pattern was observed with %P at this location. Significant increases in %P between years were detected for *Halodule uninervis* (Figure 8c, ANOVA). Tissue %P was significantly different between 2005 and 2006 ($p = 0.031$) respectively. Tissue nutrients in 2007 were not significantly different from either 2005 or 2006.

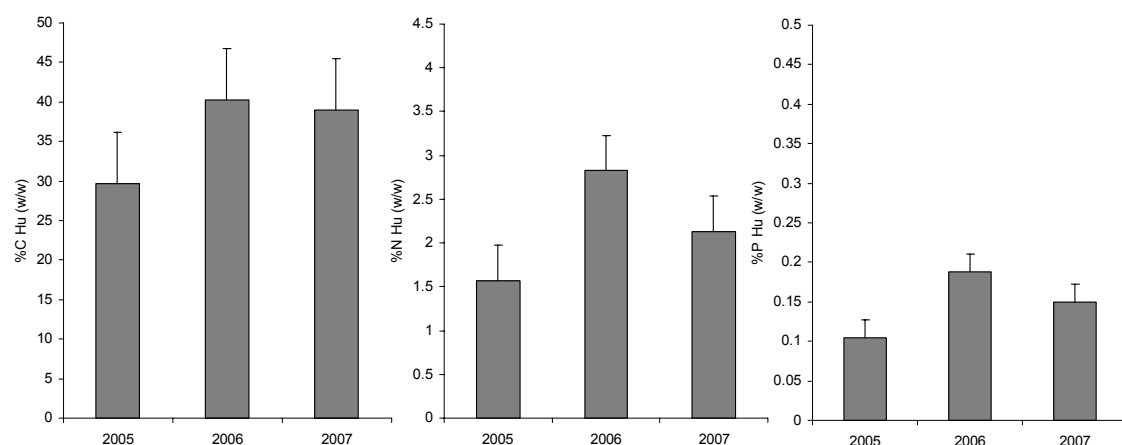


Figure 8. Plant tissue nutrients for *Halodule uninervis* at Archer Point – Cape York NRM for; a) %C, b) %N and c) %P

Table 4. Summary of Least Significant Differences (LSD) for %N, Archer Point, 2005-2007.

Year	LSD summary
2005	b
2006	a
2007	ab

Halophila ovalis

Statistical analysis of tissue nutrients for *Halophila ovalis* between years was not possible, as %C %N and %P were not determined in 2005 due to contamination during the grinding process. This was further compounded by insufficient plant material for Kjeldahl digestion in 2006. In 2007, there was sufficient plant material of this species to be represented graphically.

Halophila ovalis recorded plant tissue nutrients of 35%C, 2.25%N and 0.26%P (Figure 9). In comparison to the other species found at this location, *Halophila ovalis* recorded the lowest %C of any species in any year. With the exception of *Halodule uninervis* %N in 2006, *Halophila ovalis* %N in 2007 was the highest %N recorded for any species. Levels of %P for this species were the highest recorded for any species in any year. This evidence contributes to the notion that this species may represent a nutrient sponge for %N and %P.

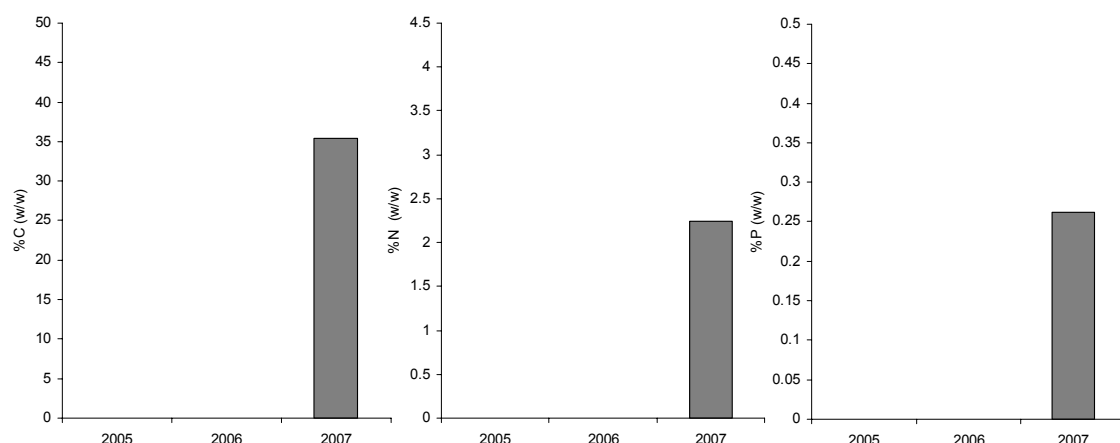


Figure 9. Plant tissue nutrients for *Halophila ovalis* at Archer Point – Cape York NRM for; a) %C, b) %N and c) %P

Cymodocea rotundata

Due to similar reasons as that stated for *Halophila ovalis* i.e. contamination and lack of plant material, no statistical analyses of plant tissue nutrients were undertaken for this species. Plant tissue nutrients are however represented graphically. Very little variation occurred between years in relation to plant tissue nutrients for this species (Figure 10). Per cent C and N were slightly higher in 2007 with %P being marginally lower (Figure 10).

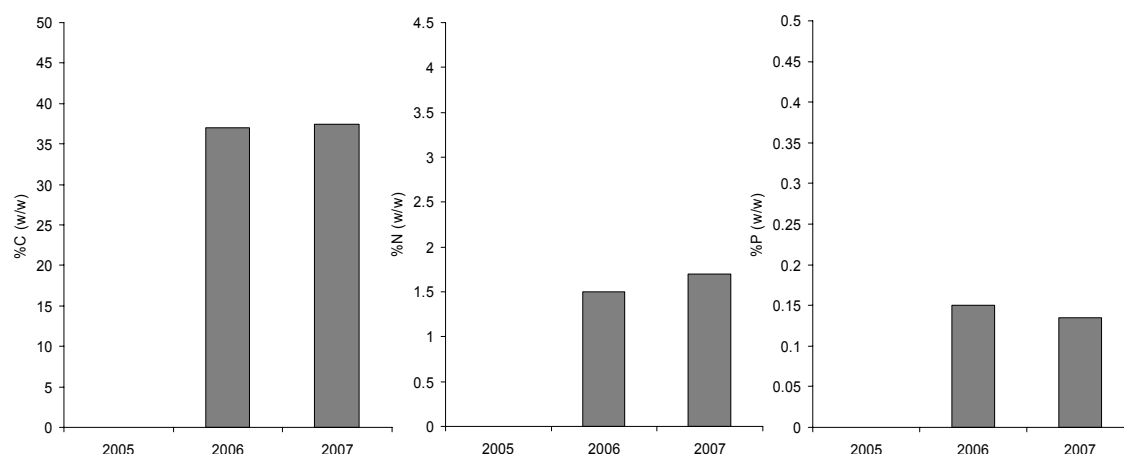


Figure 10. Plant tissue nutrients for *Cymodocea rotundata* at Archer Point – Cape York NRM for; a) %C, b) %N and c) %P

Seagrass Tissue Nutrients Ratios

There were no significant differences between years with regard to all tissue nutrient ratios for *Halodule uninervis* (Figure 11).

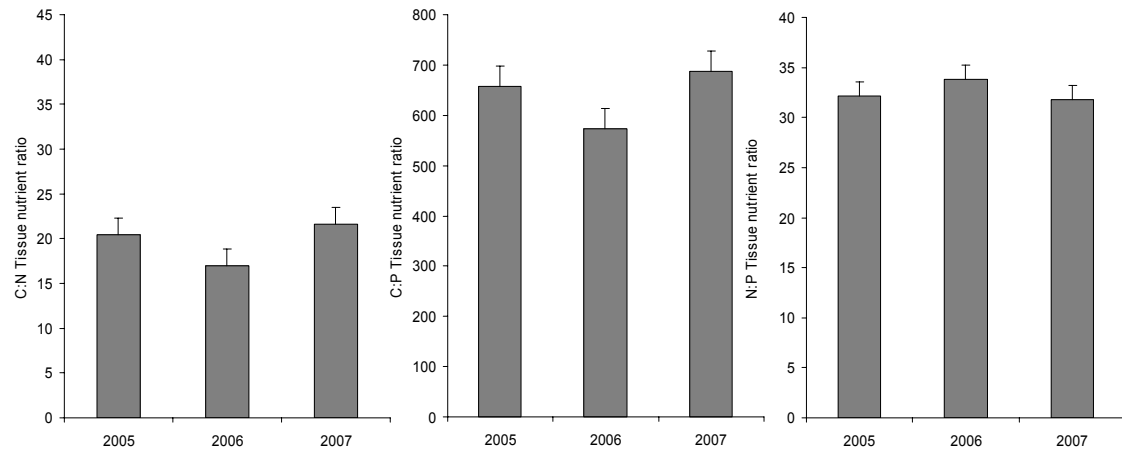


Figure 11. Plant Tissue Ratios (a) C:N, (b) C:P and (c) N:P for *Halodule uninervis* at Archer Point. (Mean and CI displayed).

Halophila ovalis

As mentioned previously due to contamination of samples during the grinding process no values for tissue nutrients were presented for 2005. Despite this, nutrient ratios were calculated for this species in 2005 as we assumed contamination to be equitable across the sample; ratios would be unaffected and presented graphically.

Plant tissue nutrient ratios differed little between 2005 and 2007 (Figure 12). C:N ratios for this increased from 16:1 to 19:1 (Figure 12a). C:P ratios increased from 326:1 to 355:1 (Figure 12b), while N:P ratios declined marginally from 20:1 to 19:1 (Figure 12c).

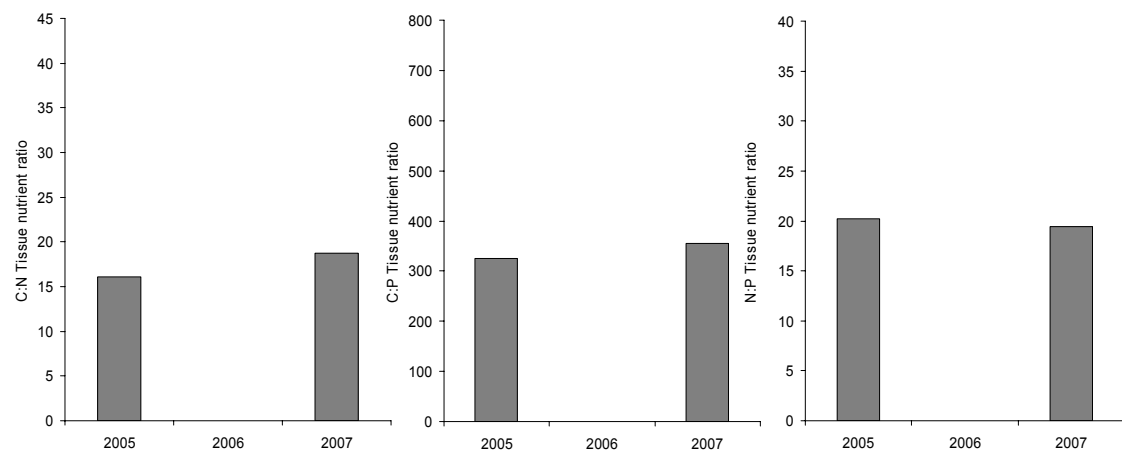


Figure 12. Plant Tissue Ratios (a) C:N, (b) C:P and (c) N:P for *Halophila ovalis* at Archer Point.

Cymodocea rotundata

This pattern is reflected in the C:N and C:P ratios for *Cymodocea rotundata* but not by N:P (Figure 13). N:P ratios for *Cymodocea rotundata* would suggest that from 2006 and 2007 this species was nutrient limited).

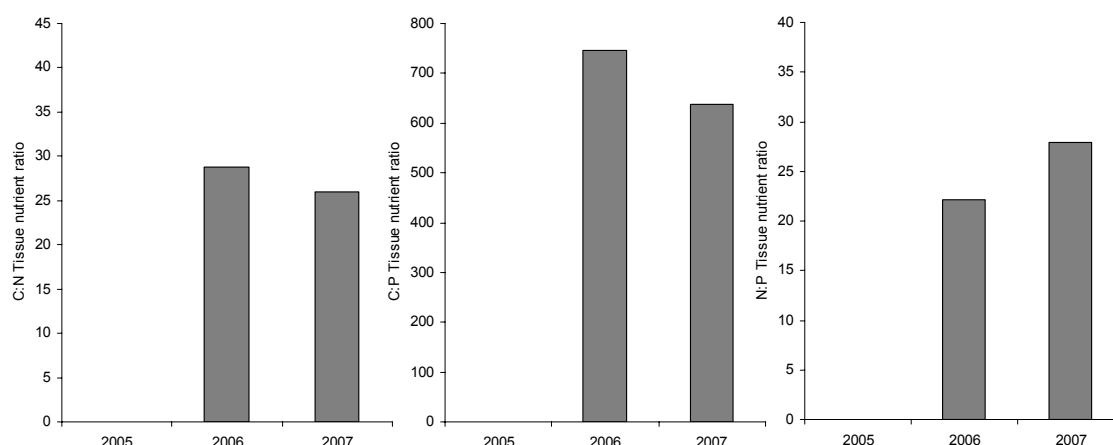


Figure 13. Plant Tissue Ratios (a) C:N, (b) C:P and (c) N:P for *Cymodocea rotundata* at Archer Point. .

The mean values of %N and %P for *Halodule uninervis* would suggest this species was nitrogen limited in 2005, nitrogen replete during 2006, 2007 and phosphate limited for all years based on levels quoted by Duarte (1990). Levels recorded for *Halophila ovalis* suggest nutrient repletion, while *Cymodocea rotundata* appears to be nutrient limited as both %N and %P are below the levels (1.8%N and 0.2%P) stated by Duarte (1990) which differentiate seagrasses that respond to increases in nutrients.

The ratios recorded for *Halodule uninervis* at this location suggest and that the light environment has improved slightly from low to moderate (a shift in C:N 2005, 2006 from <20:1 to 21.63 in 2007), with C:P ratios suggesting a nutrient poor environment. (C:P > 500). Plant N:P ratios suggest that the plants are nutrient replete (N:P ~ 30:1).

Ratios recorded for *Halophila ovalis* at this location suggest similar habitat characteristics as that for *Halodule uninervis* with the exception of N:P ratio. C:N ratios for this species indicates a slight improvement in the light environment, as the C:N ratio has increased in time. It is still below the threshold value of <20:1 (Johnson, *et al.* 2006). C:P ratios being greater than 500:1 indicated the habitat is nutrient poor. This is backed up the N:P ratio describing a nitrogen limited state for this species. This is contrast to the N:P ratio for *Halodule uninervis*.

The ratios derived for *Cymodocea rotundata* denote other set environmental conditions for this location. The C:N ratio for this species also indicates an improvement in the light environment. According to the *Cymodocea rotundata* C:N ratio the environment has improved from being moderate just above 20:1 to being quite adequate 27:1. The C:P ratio indicates this species is living in an extremely nutrient poor environment with ratios greatly over 500:1. N:P ratios, which had decreased over the years, indicate that this species is nitrogen limited.

Seagrass meadow edge mapping

Edge mapping was conducted within a 100m radius of both Archer Point monitoring sites in September/October and March/April of each year. Over the past 12 months, the meadow at AP1 and AP2 declines from the shoreward edges, decreasing the overall area of seagrass present within the mapping boundaries (Figure 14, Table 4).

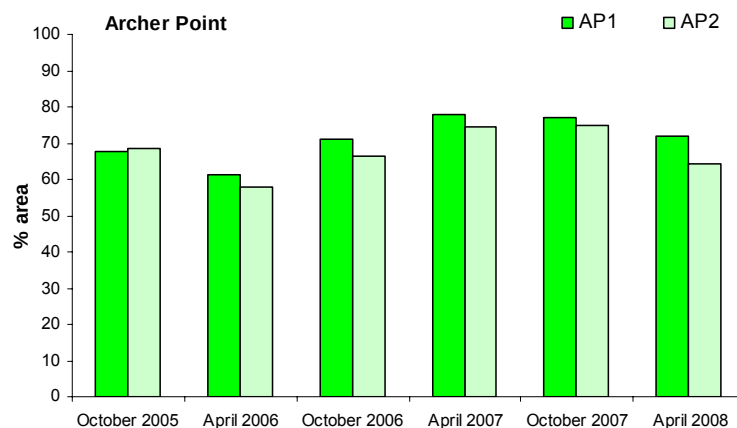


Figure 14. Percentage of area (100m radius of monitoring site) covered by seagrass at each monitoring site.

Table 5. Area (ha) of seagrass meadow being monitored within 100m radius of site. Value in parenthesis is % change from October 2005 baseline, and direction of change from previous mapping. Shading indicates decrease in meadow area since baseline.

Monitoring Site	October 2005	April 2006	October 2006	April 2007	October 2007	April 2008
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)
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)

Epiphytes and macro-algae

Epiphytes cover on seagrass leaf blades at Archer Point are generally variable (Figure 15) and not significantly different between seasons (ANOVA $p=0.48$, sites pooled). Overall, the abundance of epiphytes appears to have declines since monitoring began in 2003 (Figure 15).

Percentage cover of macro-algae is also variable, however there do not appear to be any long-term patterns in abundance (Figure 15).

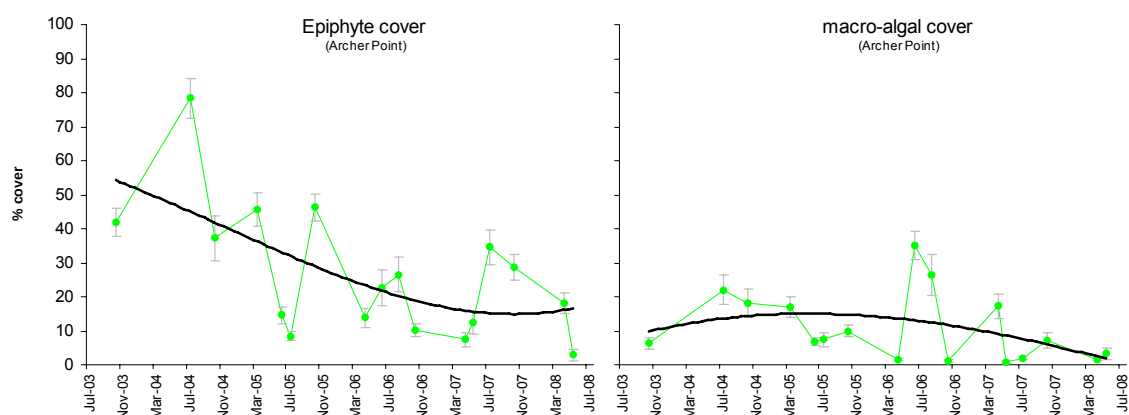


Figure 15. Mean abundance (% cover) ($\pm$ Standard Error) of epiphytes and macro-algae at Archer Point (sites pooled). NB: Polynomial trendline for all years pooled.

Sediment nutrients

Levels of NH_4^+ did not differ significantly between years even though increasing levels of NH_4^+ are evident. Average levels ranged between 158 - 264 $\mu\text{M L}_{\text{sed}}^{-1}$ (Figure 16a). In contrast levels of adsorbed PO_4^{3-} were significantly higher in 2006 than in either 2005 or 2007 (ANOVA d.f.(2,3) $p = 0.009$), (Table 6, Figure 16b).

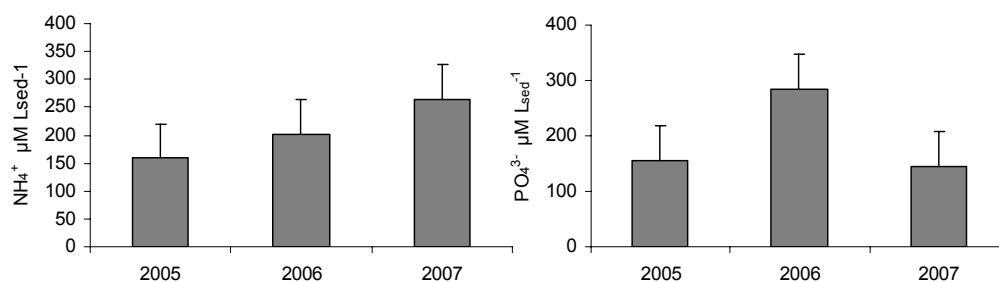


Figure 16. Sediment adsorbed (a) ammonium (b) phosphate concentrations at Archer Point in 2005, 2006 and 2007 (Mean and CI displayed).

Table 6. Summary of Least Significant Differences for phosphate levels from 2005-2007 for Archer Point.

Year	LSD summary
2005	b
2006	a
2007	b

Sediment N:P were significantly different between all years (ANOVA d.f.(2,3) $p = 0.002$) (Figure 17, Table 7). In 2005 and 2007, N:P ratios indicated a nutrient pool that is greater in adsorbed NH_4^+ , than PO_4^{3-} , with 2007 displaying a much greater NH_4^+ pool than in 2005 (Figure 17). N:P ratio in 2006 was converse with the ratio describing a pool much higher in PO_4^{3-} - than in NH_4^+ .

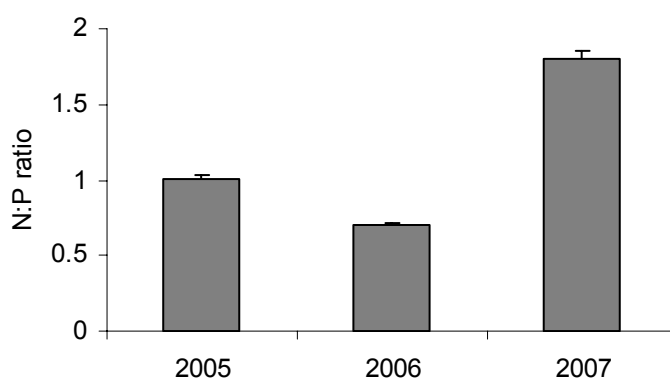


Figure 17. *Sediment adsorbed (sediment N:P at Archer Point in 2005, 2006 and 2007 (Mean and CI displayed).*

Table 7. *Summary of Least Significant Differences (LSD) for N:P, Archer Point, 2005-2007.*

Year	LSD summary
2005	b
2006	c
2007	a

Sediment herbicides

No detectable herbicides were found in the sediments of the seagrass meadows at either monitoring site (Table 8).

Table 8. *Concentration of herbicides ($\mu\text{g kg}^{-1}$) in sediments of Archer Point seagrass monitoring sites in post Monsoon 2008.*

Site	Flumeturon	Diuron	Simazine	Atrazine	Desethyl Atrz.	Desisopropyl Atrz.	Hexazinone	Tebuthiuron	Ametryn	Prometryn	Bromacil	Terbutryn	Metolachlor
AP1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
AP2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Within meadow canopy temperature

Temperature loggers were deployed at both sites during the monitoring period, however loggers deployed over the Aug-Nov 2007 period failed and no measures could be retrieved.

High temperatures were recorded from October 2007 to February 2008, however no temperatures exceeded 40°C (Figure 18), with the highest maximum recorded 36.5° in February at AP2 (Figure 19).

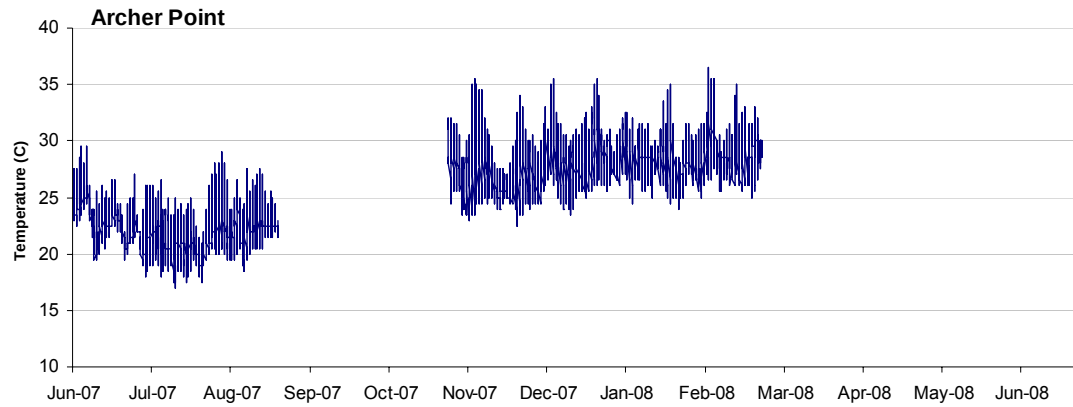


Figure 18. *Within seagrass canopy temperature (°C) at Archer Point intertidal meadow over the 2007/2008 monitoring period.*

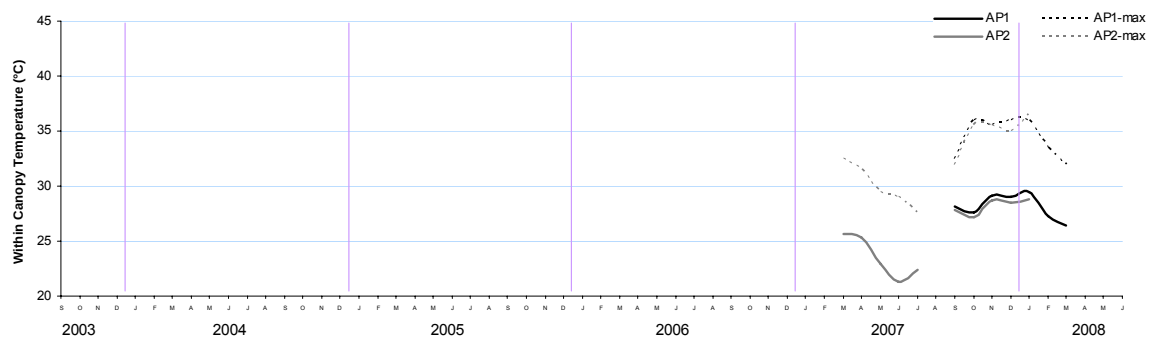


Figure 19. *Monthly mean and maximum within seagrass canopy temperatures (°C) at Archer Point intertidal meadow, Cape York region.*



Wet Tropics

The Terrain (Wet Tropics) NRM includes the wet tropics catchment region and covers 22,000 km² (NRM 2007e). Land use practices include primary production such as cane and banana farming, dairying, beef, cropping and tropical horticulture. Other uses within the region include fisheries, mining, tourism and World Heritage areas. 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). Of the seagrass habitats identified for Northeast Australia RWQPP monitoring occurs within two habitats: Coast and Reef.

Monitoring occurs at two coastal seagrass habitat locations: Yule Point, in the north and Lugga Bay to the south. The seagrass meadows at Yule Point and Lugga 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 20). The Barron, Tully and Hull Rivers are a major source of pulsed sediment and nutrient input to these monitored meadows.

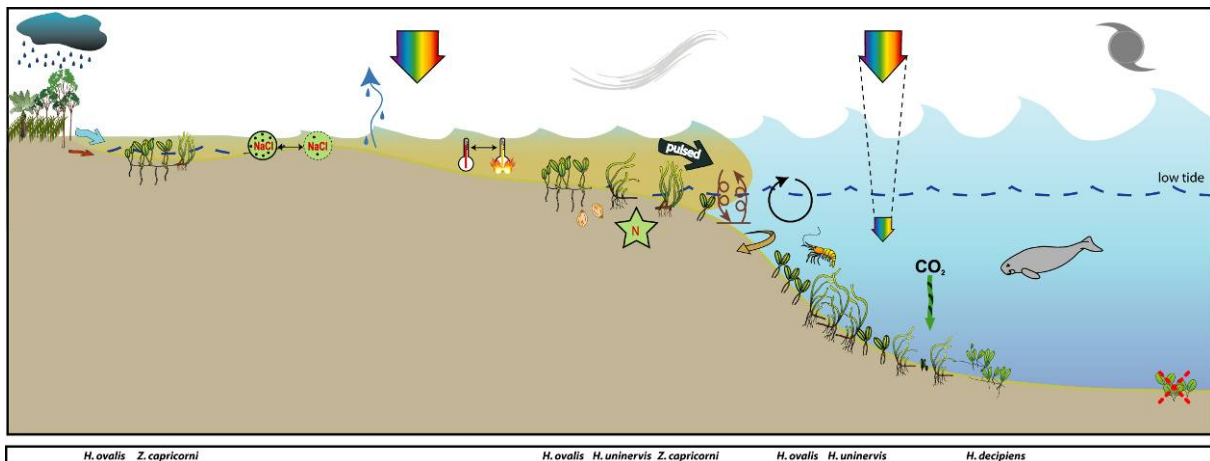


Figure 20. Conceptual diagram of coastal habitat (<15m) in the Far North Queensland region – major control is pulsed terrigenous runoff, salinity and temperature extremes: general habitat, seagrass meadow processes and threats/impacts (See Figure 2 for icon explanation).

Monitoring of reef habitats occurs at two locations: Green Island, and Dunk Island. The Dunk Island sites were only recently established (April 2007). 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 21). 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 sediments coral sand. 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 have been shown to be nitrogen limited (Udy *et al.* 1999).

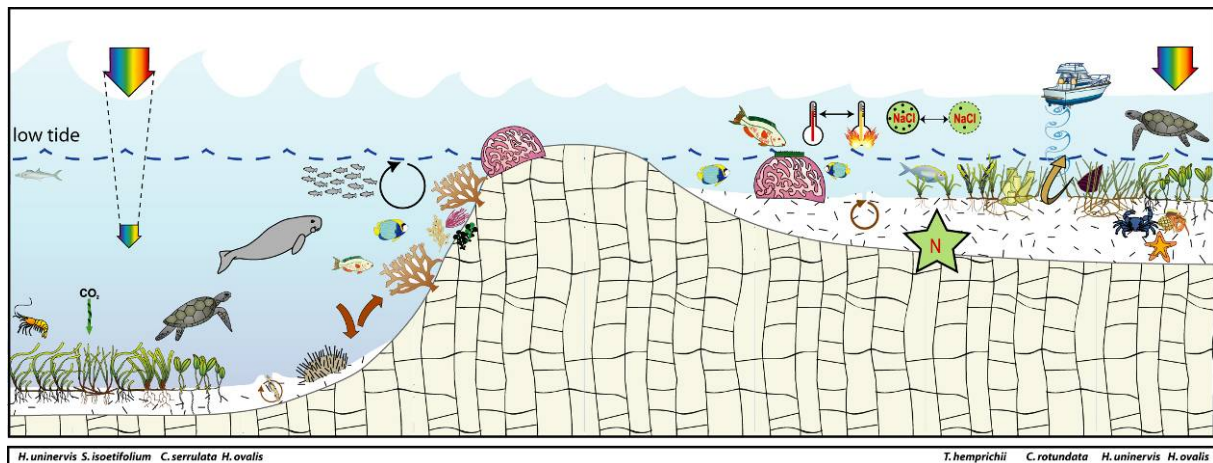


Figure 21. Conceptual diagram of reef habitat (<15m) in the Wet Tropics region – major control is nutrient limitation, temperature extremes, light and grazing: general habitat, seagrass meadow processes and threats/impacts (See Figure 2 for icon explanation).

Seagrass cover 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*. 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 from YP1 in 2002, and was absent during the period of the 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.

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 April 2008, the seagrass had recovered to 2005 abundances. No significant changes in species composition were observed at either of the locations (Figure 22).

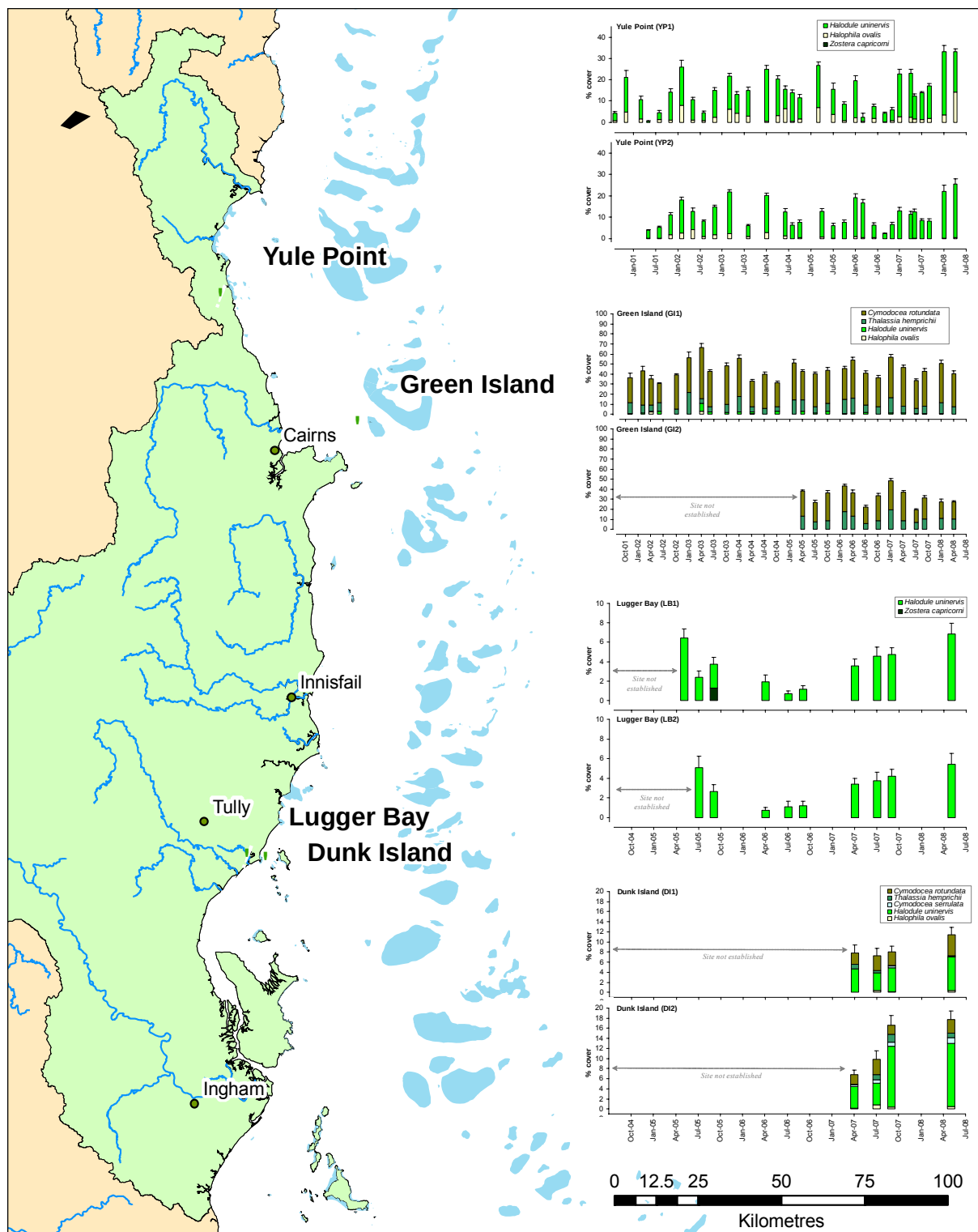


Figure 22. Mean percentage cover for each seagrass species at Townsville Seagrass-Watch long-term monitoring sites (+ Standard Error). NB: if no sampling conducted then x-axis is clear.

Seagrass cover from the start of monitoring at Yule Point in 2000, has changed little from year to year (Figure 23), however 2008 abundances were some of the highest recorded.

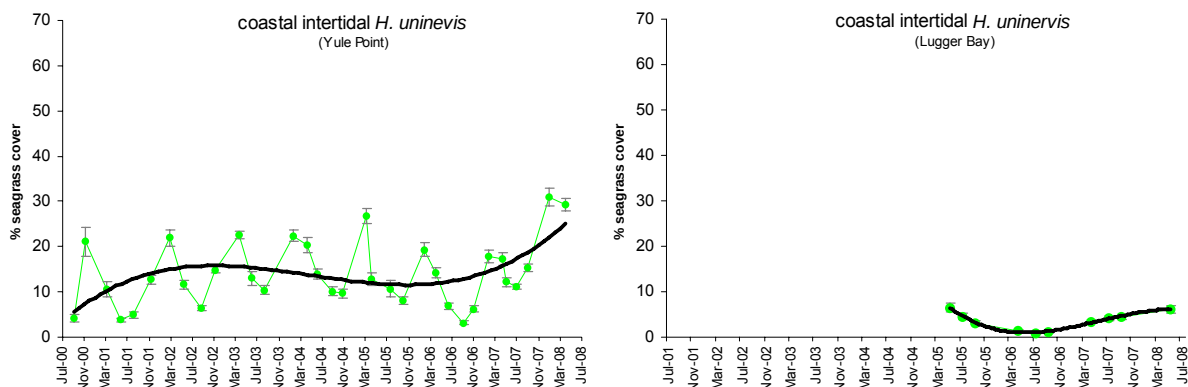


Figure 23. Changes in seagrass abundance (% cover) of coastal intertidal *Halodule uninervis* meadows monitored in the Wet Tropics region from 2000 to 2008.

Seagrass cover over the past 12 months at Yule Point appeared to follow a seasonal trend with higher abundance in the early months of the year (Figure 24).

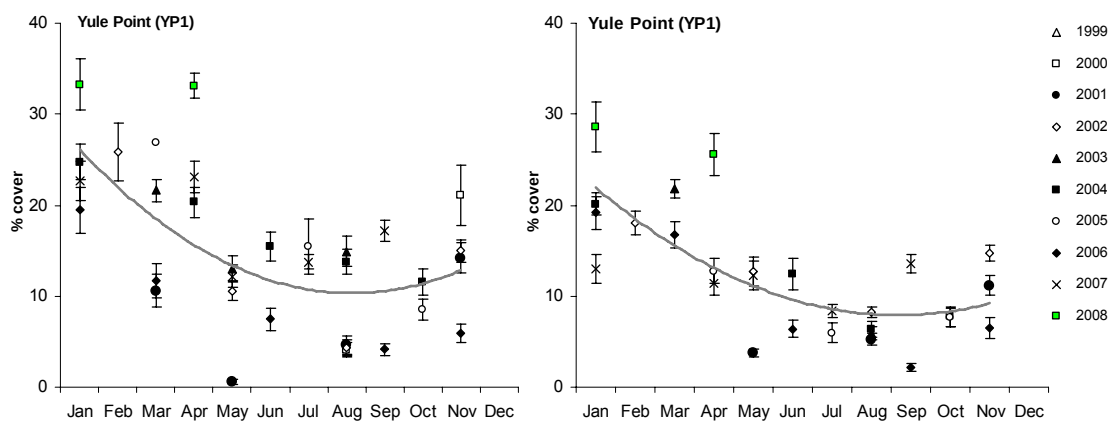


Figure 24. Mean percentage seagrass cover (all species pooled) ($\pm$ Standard Error) at Yule Point long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.

No clear seasonal trends in seagrass cover were apparent over the past 12 months at Lugger Bay, due to the paucity of data and possibly a consequence of the meadow recovering after significant losses in early 2006 (Figure 25).

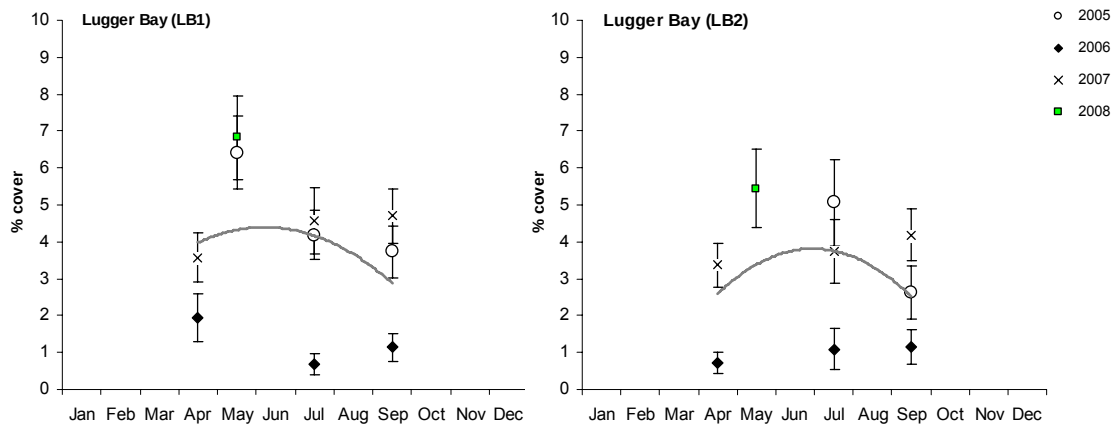


Figure 25. Mean percentage seagrass cover (all species pooled) ($\pm$ Standard Error) at Lugger Bay long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.



Above left: Dugong feedings trails at Yule Point. Above right: Dugong feedings trails at Lugger Bay



Seagrass monitoring site GI2 on the reef flat, Green Island.

Green Island and Dunk Island sites were on offshore reef-platforms. Dunk Island is a continental island offshore from Mission Beach and sites were only established in April 2007. Seagrass species at Dunk Island sites included *H. uninervis* and *C. rotundata* with *T. hemprichii*, *H. ovalis* and *C. serrulata* (Figure 22). Green Island is on a mid shelf reef, approximately 27 km north east of Cairns. The sites are located 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 summer and low cover in winter, and no significant changes in species composition were observed (Figure 22, Figure 26 and Figure 27).

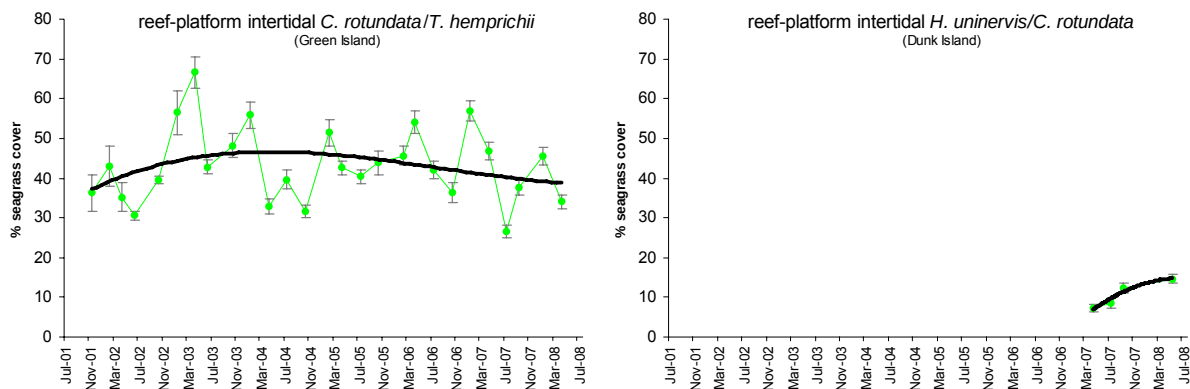


Figure 26. Mean percentage seagrass cover (all sites pooled) at Green Island long-term monitoring sites ($\pm$ Standard Error).

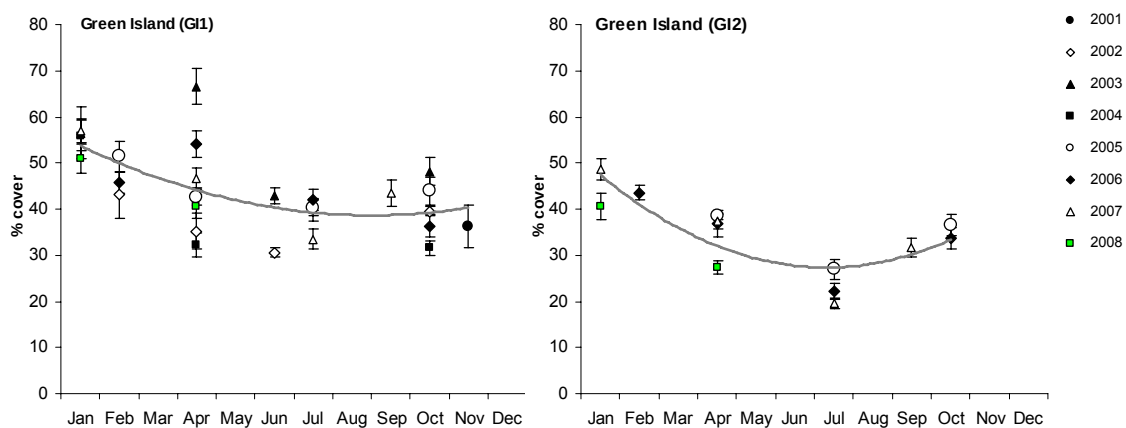


Figure 27. Mean percentage seagrass cover (all species pooled) ($\pm$ Standard Error) at Green Island long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.



Seagrass monitoring sites D11 (above left) and D12 (above right) at Dunk Island: meadows located on the shallow reef flat between Dunk Island and Kumboola Island.

Seagrass reproductive health

Reproductive effort was noted in all four locations (Figure 28). A considerably higher reproductive effort was noted at Yule Point compared to the other three locations. Luger Bay is recovering from a decline in 2006 (*cf.* Figure 22) and thus low reproductive effort is not unexpected.

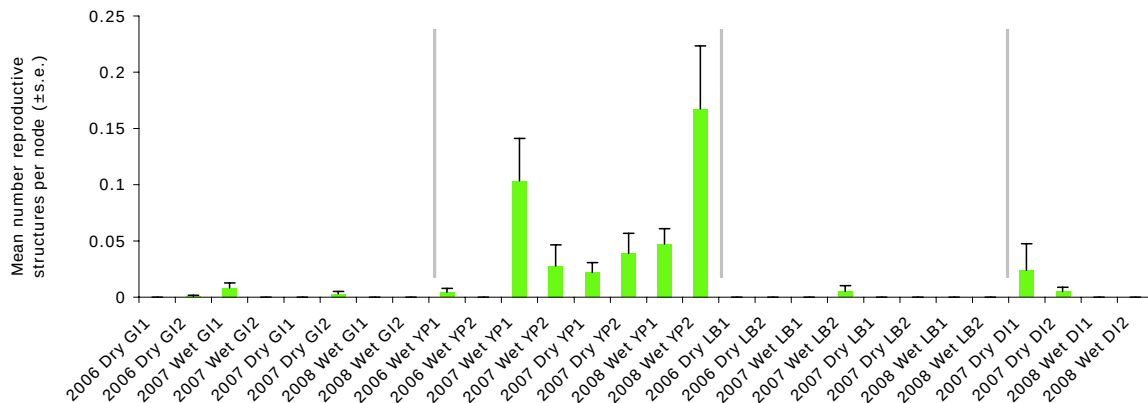


Figure 28. Mean number of reproductive structures (flowers, seeds, or fruits) per node across all seagrass species and all years sampled across sites in the Northern Region; Green Island, Yule point, Lugger Bay, and Dunk Island (+ Standard Error).

Tissue nutrients

Seagrasses are represented by *Halodule uninervis* and *Halophila ovalis* at all locations monitored in the Far North Queensland NRM region. Additionally *Cymodocea rotundata* and *Thalassia hemprichii* were collected from the reef habitat sites of Green Island and Dunk Island. *Cymodocea serrulata* was also collected from Green Island, during the 2005 monitoring period. Other than to mention its presence within samples during 2005, this species has not been included in this section of the report.

Halodule uninervis

Analyses of tissue nutrients for this species show significant interactions between Location and Year for %C (ANOVA d.f._(3, 4) $p = <0.001$), %N (ANOVA d.f._(3, 4) $p = <0.027$) and %P (ANOVA d.f._(3, 14) $p = <0.015$) (Figure 29). During 2005 %C differed significantly between all three locations included in the analysis and that all three locations recorded significantly higher %C during 2005 than was recorded at each respective location in 2006 and 2007 (Table 9). Differences between levels recorded at Green Island and Lugger Bay were non-significant, while at Yule Point significant differences were still detected between 2006 and 2007 (Table 9).

Halodule uninervis at Dunk Island registered a %C of 39% grouping it with the levels recorded for all locations during 2007 and that of Green Island for 2006 and 2007.

%N and %P displayed similar patterns within this NRM (Figure 29). Levels of %N and %P at Lugger Bay were significantly lower those recorded from sites monitored in the northern part of this NRM (Table 10, Table 11). In 2006 and 2007, Green Island recorded significantly lower %N and %P levels than the coastal locations. Levels of both %N and %P were consistent between years at Green Island whereas levels varied between years at the coastal locations.

Levels of %N and %P recorded at Dunk Island for *Halodule uninervis* in 2007 were similar to those recorded at Green Island for 2007. *Halodule uninervis* at reef habitats had lower levels of %P than the plants inhabiting coastal locations within this NRM. This may be accounted for in the differences of bioavailable P between reef habitats and coastal habitats.

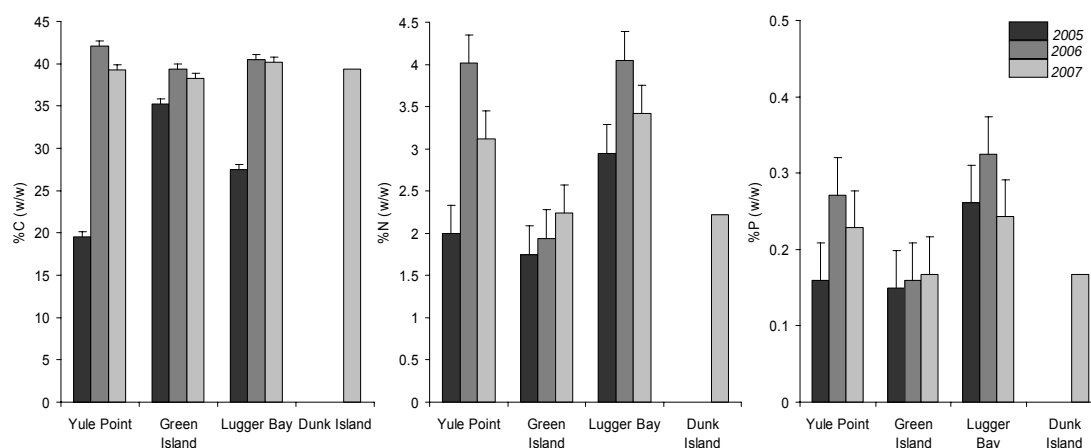


Figure 29. Plant tissue nutrients for *Halodule uninervis* within the Terrain NRM for; a) %C, b) %N and c) %P

Table 9. Summary of Least Significant Differences for *Halodule uninervis* %C from 2005-2007 for Yule Point, Green Island and Luggier Bay.

Location/Year	2005	2006	2007
Yule Point	g	a	cd
Green Island	e	bcd	d
Luggier Bay	f	b	bc

Table 10. Summary of Least Significant Differences for *Halodule uninervis* %N from 2005-2007 for Yule Point, Green Island and Luggier Bay.

Location/Year	2005	2006	2007
Yule Point	d	a	c
Green Island	d	d	d
Luggier Bay	c	ab	bc

Table 11. Summary of Least Significant Differences for *Halodule uninervis* %P from 2005-2007 for Yule Point, Green Island and Luggier Bay.

Location/Year	2005	2006	2007
Yule Point	d	b	c
Green Island	d	d	d
Luggier Bay	c	a	bc

Halophila ovalis

There is no data analysis on tissue nutrients for *Halophila ovalis*. This is because there were no records for %C, %N and %P due to the samples being contaminated during the grinding process with silica beads in 2005 for all locations. This species was also absent from samples collected during 2006 and 2007 from Luggar Bay. Tissue nutrient %C ranged from 37%C (Green Island 2006) to 31.5%C (Yule Point, 2007). *Halophila ovalis* at Dunk Island (2007) was intermediary in this range at 33%C.

%N levels were similar between years and locations with the exception of Dunk Island that recorded quite a low level at 1.65%N, around 1% lower than at the other locations (Figure 30b).

Halophila ovalis at reef habitat locations (Green and Dunk Islands) recorded lower %P than at coastal locations (Figure 30c). This is possibly a reflection of the bio-availability of phosphate at these locations (see sediment nutrient section above).

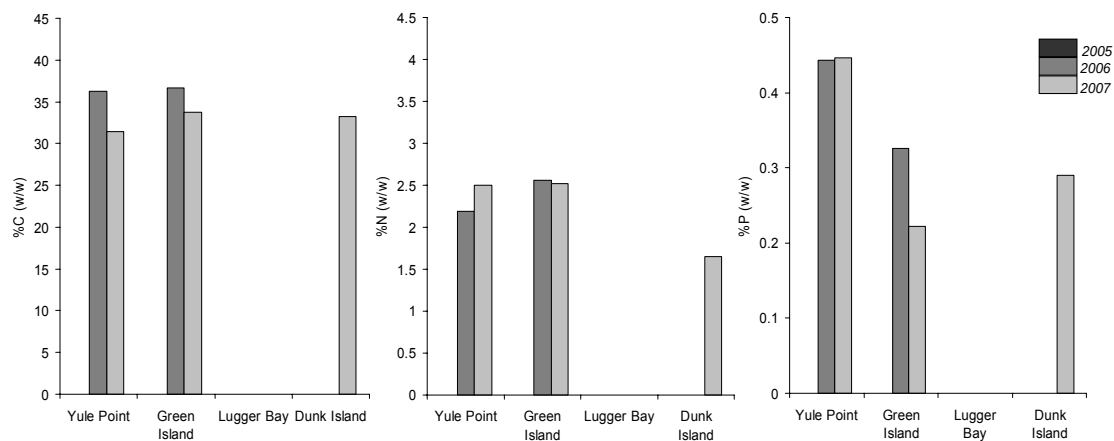


Figure 30. Plant tissue nutrients for *Halophila ovalis* within the Terrain NRM for; a) %C, b) %N and c) %P

Cymodocea rotundata

Cymodocea rotundata is only present at reef habitats. Tissue nutrients are higher at Green Island than they are at Dunk Island. There has been a continuous increase in all tissue nutrients across years at Green Island (Figure 31).

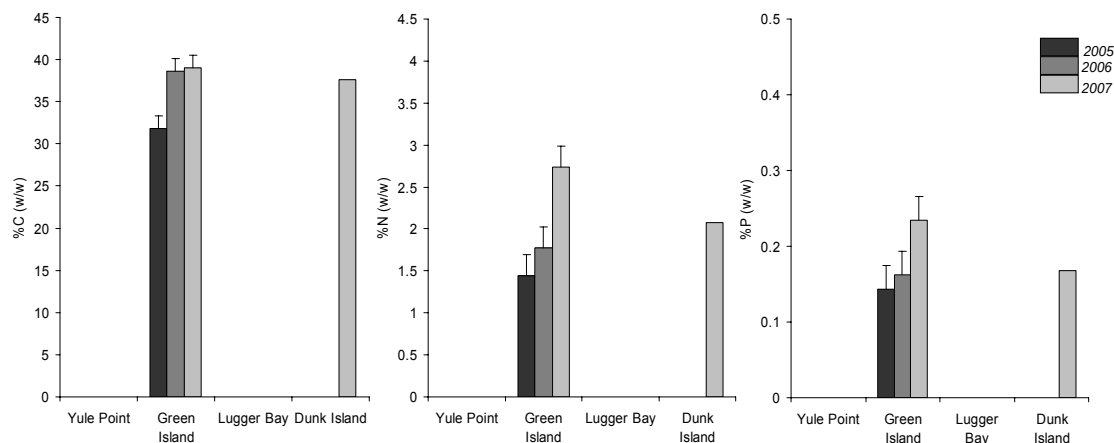


Figure 31. Plant tissue nutrients for *Cymodocea rotundata* within the Terrain NRM for; a) %C, b) %N and c) %P

Thalassia hemprichii

Like *Cymodocea rotundata*, *Thalassia hemprichii* was only found in reef habitats. Similar to *Cymodocea rotundata*, tissue nutrient contents have steadily increased since 2005. Tissue nutrient levels recorded at Dunk Island sites, are slightly higher than those recorded for Green Island in 2007 (Figure 32).

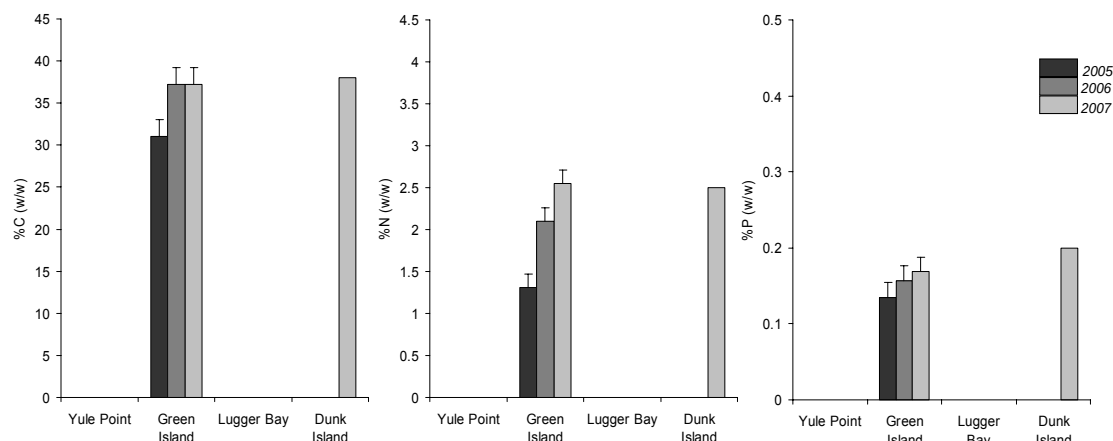


Figure 32. Plant tissue nutrients for *Thalassia hemprichii* within the Terrain NRM for; a) %C, b) %N and c) %P

Seagrass Tissue Nutrient Ratios

Halodule uninervis

C:P and C:P plant tissue ratios for *Halodule uninervis* showed significant Location effects (C:N ANOVA d.f. (2,3), $p = 0.035$; C:P, ANOVA d.f. (2,3) $p = 0.030$) (Figure 33a,b). Both C:P and C:N had significantly higher ratios at Green Island than the other two locations (Table 12, Table 13). C:N and C:P at Dunk Island were similar to those recorded at Green Island for 2007, Figure 33a,b).

N:P ratios ranged from 25:1 (Green Island, 2005) to 33:1 (Yule Point, 2005). No significant difference was detected for N:P ratios for this species either between locations or between years (Figure 33c). The N:P recorded for Dunk Island (30:1) is within this range and very similar to ratios recorded for the other locations during the 2007 monitoring period.

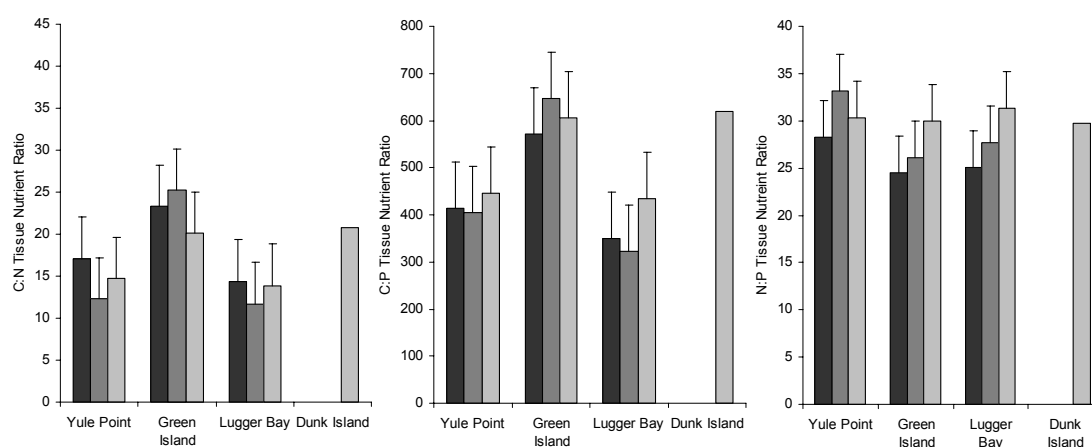


Figure 33. Plant tissue nutrients: a) C:N, b) C:P and c) N:P for *Halodule uninervis* for monitored sites within Terrain NRM.

Table 12. *Summary of Least Significant Differences (LSD) for tissue nutrient C:N of Halodule uninervis for locations monitored within the Terrain NRM between 2005 and 2007.*

Location	Grouping for LSD
Yule Point	b
Green Island	a
Lugger Bay	b

Table 13. *Summary of Least Significant Differences (LSD) for tissue nutrient C:P of Halodule uninervis for locations monitored within the Terrain NRM between 2005 and 2007.*

Location	Grouping for LSD
Yule Point	b
Green Island	a
Lugger Bay	b

Halophila ovalis

Despite no recording of tissue nutrients in 2005 (previous section) tissue nutrient ratios were calculated for this year. As explained earlier, due to the absence of this species from samples at Lugger Bay in 2006, 2007, only graphical representations are provided.

C:N ratios ranged from 25:1 (Yule Point, 2005) down to 14:1 (Yule Point, 2006). In general C:N ratios were below 20:1 with the exception Dunk Island in 2007. C:P ratios declined at Yule Point while C:P ratios increased over the years at Green Island. In general C:P ratios were below 500:1 with the exception of Green Island in 2007 (Figure 34b). Similar patterns are recorded for N:P (Figure 34c), with the majority of N:P ratio being below 20:1 except for Green Island in 2007.

The exceptionally higher ratios of C:P and N:P at Green Island in 2007 may be a reflection of the bioavailability of P being even lower during 2007 (compare with sediment nutrient section above)

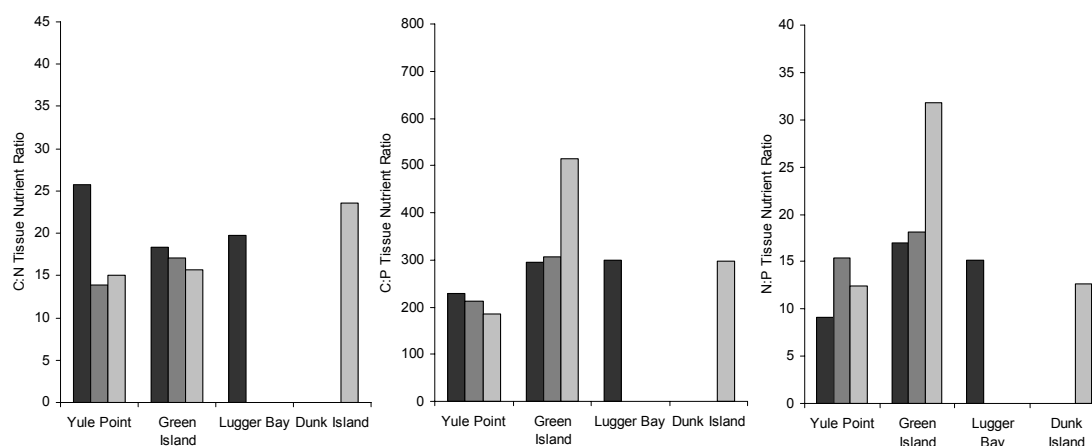


Figure 34. Plant tissue nutrients: a) C:N, b) C:P and c) N:P for *Halophila ovalis* for monitored sites within Terrain NRM.

Cymodocea rotundata

Both C:N and C:P of *Cymodocea rotundata* declined in 2007 at Green Island with a concomitant increase in N:P ratios (Figure 35). Plant tissue nutrient ratios for this species at Dunk Island were higher than those recorded at Green Island during the same monitoring period.

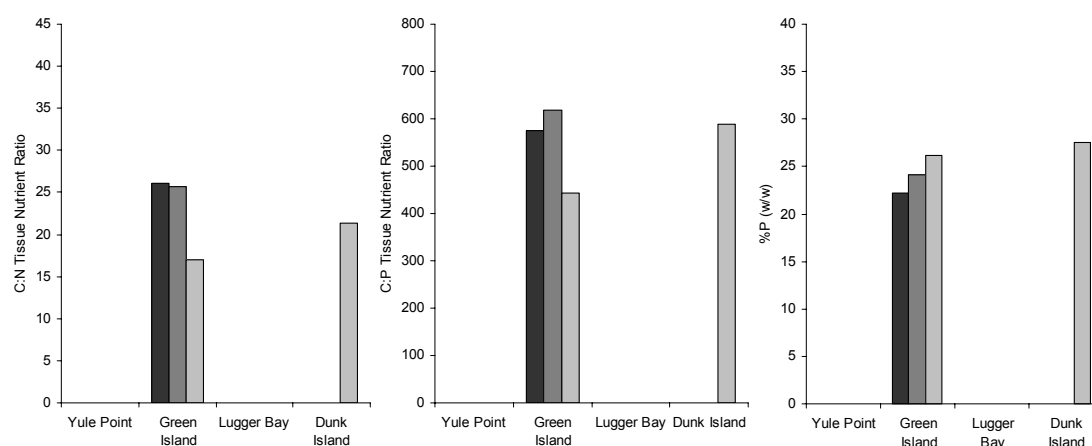


Figure 35. Plant tissue nutrients: a) C:N, b) C:P and c) N:P for *Cymodocea rotundata* for monitored sites within Terrain NRM.

Thalassia hemprichii

Similar patterns with respect to tissue nutrient ratios prevailed for this species. Levels at Dunk Island however were lower than those recorded at Green Island with the exception of C:P being lower at this location during the 2007 monitoring (Figure 36).

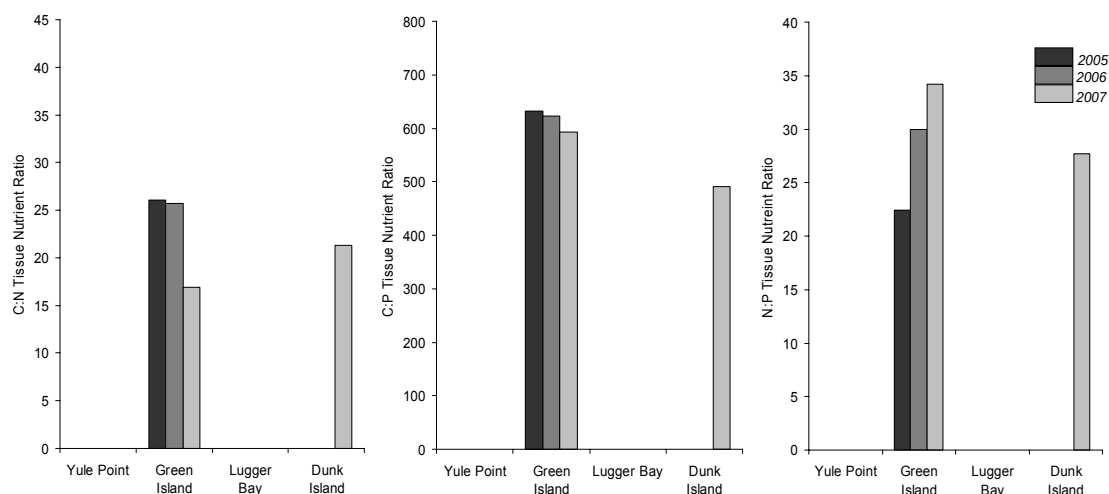


Figure 36. Plant tissue nutrients: a) C:N, b) C:P and c) N:P for *Thalassia hemprichii* for monitored sites within Terrain NRM.

Discussion seagrass tissue nutrients and nutrient ratios

Recordings of %N for *Halodule uninervis* indicate that this species was N limited during 2005 at Green Island but has since acquired a nutrient status representative of being N replete. All other locations recorded levels higher than 1.8%N. In contrast *Halodule uninervis* at reef habitat locations record levels of %P that indicate P limitation. The only indicator of nutrient limitation for *Halophila ovalis* was of N limitation at Dunk Island, 2007.

Cymodocea rotundata was N and P limited at Green Island during 2005 and 2006, by 2007 this species was recording levels above the threshold values of 1.8%N and 0.2% P respectively (Duarte 1990). *Cymodocea rotundata* at Dunk Island recorded levels indicative of P limitation. In contrast *Thalassia hemprichii*, Dunk Island was not P limited, but at Green Island has been P limited since monitoring commenced in 2005. %N levels are suggestive of N repletion with the exception of levels recorded in 2005.

Plant tissue ratios for *Halodule uninervis* demonstrate a nutrient division between reef habitats and coastal habitats. C:N and C:P levels recorded for this species at reef habitats are suggestive of conditions that are have moderate light quality and are nutrient poor in terms of P. However the ratios of C:N have declined each year indicating a possible decline in the light environment. N:P ratios at reef environments while lower than those recorded at coastal locations are still within the realms of nutrient repletion. Coastal locations presented ratios indicative of low light environments and nutrient rich environments. At these habitats there is also a trend of a reducing light environment.

Halophila ovalis C:N ratios also indicate a declining light environment at both Yule Point and Green Island, though at Dunk Island the species lives in a moderate light environment. C:P ratios indicate nutrient rich environments, with the exception of levels recorded at Green Island in 2007 being indicative of a nutrient poor state in relation to P. N:P ratios indicate with the exception of Green Island in 2007 that this species is N limited within this NRM. This vagary at Green Island during 2007 is overly influenced by the ratios recorded at one of the locations at Green Island. The C:P ratio at one of the Green Island sites was three times greater and the N:P was double that of the other site .

Cymodocea rotundata and *Thalassia hemprichii* only inhabit reef habitats within this NRM. Tissue nutrient ratios for these species indicated a declining light environment at Green Island, with a nutrient environment on the increase. N:P ratios have increased over the years

from N limitation to that of repletion. In 2007 *Thalassia hemprichii* recorded an N:P ratio indicative of P limitation.

Seagrass meadow edge mapping

Edge mapping was conducted within a 100m radius of all Seagrass-Watch monitoring sites in October/November and March/April of each year (Table 14). Both sites at Yule Point were negatively impacted by the occurrence of drainage channels in 2006. However by April 2007 the channels had moved out of YP1 and the seagrass recovered. The drainage channel still persist through part of YP2, however the meadow has continued to increase across other sections. Overall, the meadows at Yule Point have generally increased in size since 2005 (Figure 37). There were no detectable differences in the edge mapping data of the seagrass meadows at Green Island between 2007 and 2008 (Figure 37).

At Luggar Bay, the distribution of the seagrass meadow continued to recover from October 2006 (Table 14). The slight decrease in April 2008 may be a consequence of a seasonal low (Figure 38). The fringing reef meadow at Dunk Island expanded in the late Dry 2007 and decreased slightly in the late Monsoon 2008 (Table 14, Figure 38).

Table 14. *Area (ha) of seagrass meadow being monitored within 100m radius of site. Value in parenthesis is % change from October 2005 baseline, and direction of change from previous mapping. Shading indicates decrease in meadow area since baseline. NA=no data available as site not established.*

Monitoring Site	October 2005	April 2006	October 2006	April 2007	October 2007	April 2008
YP1	1.326	1.789 (34.9% increase shoreward)	1.768 (33.3% decrease overall)	2.452 (84.9% increase overall)	3.08 (132.3% increase overall)	2.861 (115.8% decrease overall)
YP2	3.596	4.120 (14.6% increase shoreward)	3.697 (2.8% decrease seaward)	3.735 (3.9% increase shoreward)	4.422 (23% increase overall)	4.724 (31.9% increase overall)
GI1	5.257	5.319 (1.2% increase shoreward)	5.266 (0.2% decrease seaward)	5.266 (0.2% no change)	5.266 (0.2% no change)	5.32 (1.2% increase shoreward)
GI2	4.632	4.647 (0.3% negligible)	4.674 (0.9% negligible)	4.605 (-0.6% negligible)	4.674 (0.9% negligible)	4.66 (0.6% negligible)
LB1	1.675	1.085 (-35.2% decrease landward)	0.453 (-73% decrease overall)	0.953 (-43.1% increase overall)	1.183 (-29.4% increase overall)	1.046 (-37.6% decrease seaward)
LB2	1.801	1.448 (-19.6% decrease landward)	0.561 (-68.8% decrease overall)	1.167 (-35.2% increase overall)	1.6 (-11.2% increase shoreward)	1.442 (-19.984.9% decrease seaward)
DI1	NA	NA	NA	3.278	3.479 (6.1% increase overall)	3.36 (2.5% decrease shoreward)
DI2	NA	NA	NA	3.972	4.19 (5.5% increase overall)	4.425 (11.4% increase overall)

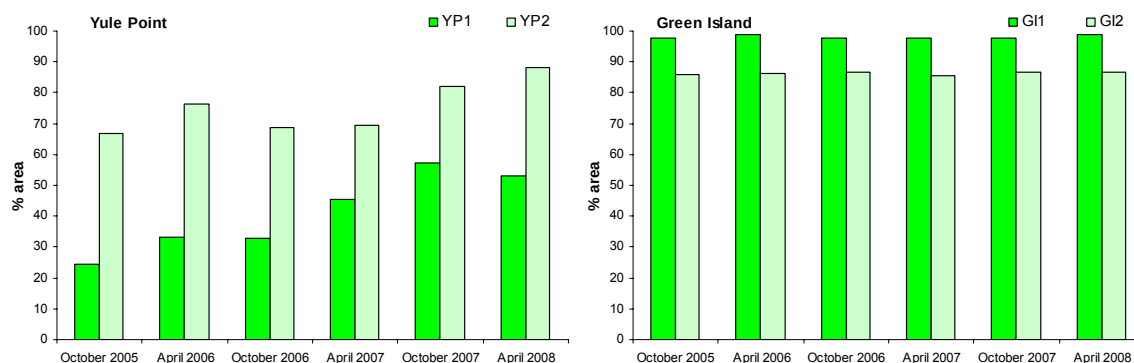


Figure 37. Percentage of area (100m radius of monitoring site) covered by seagrass at each coastal and offshore monitoring site at Cairns locations.

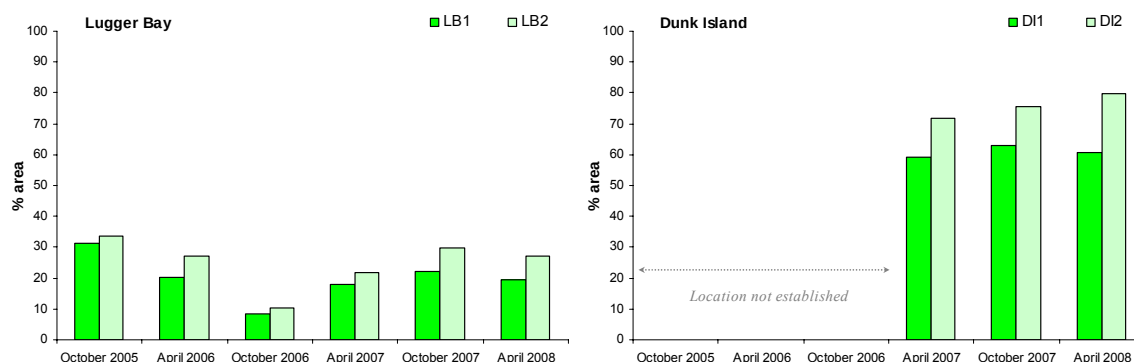


Figure 38. Percentage of area (100m radius of monitoring site) covered by seagrass at each coastal and offshore monitoring site at Mission Beach locations.

Epiphytes and macro-algae

Epiphytes cover on seagrass leaf blades at coastal sites was highly variable (Figure 39) and appears correlated with seagrass abundance. Epiphyte cover has increased at Yule Point over the past 12 months however appears to have remained low at Lugger Bay (Figure 39). Percentage cover of macro-algae at coastal sites is also variable, however at Yule Point abundance has declined over the last three years (Figure 39).

Epiphyte cover at reef sites is highly variable and there does not appear to be any apparent trend (Figure 40). Macro-algae at both reef locations were predominately composed of *Halimeda* spp. and abundance is relatively stable, with mean covers less than 10% (Figure 40).

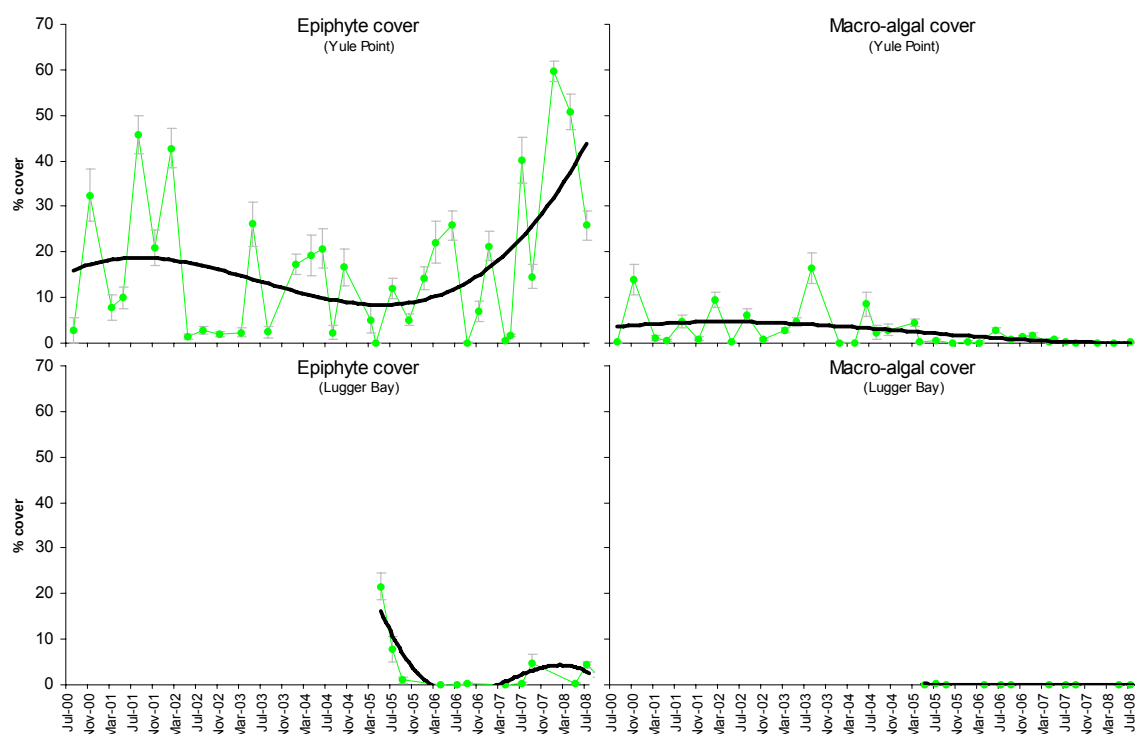


Figure 39. Mean abundance (% cover) ($\pm$ Standard Error) of epiphytes and macro-algae at coastal intertidal seagrass monitoring locations (sites pooled) in the Wet Tropics region. NB: Polynomial trendline for all years pooled.

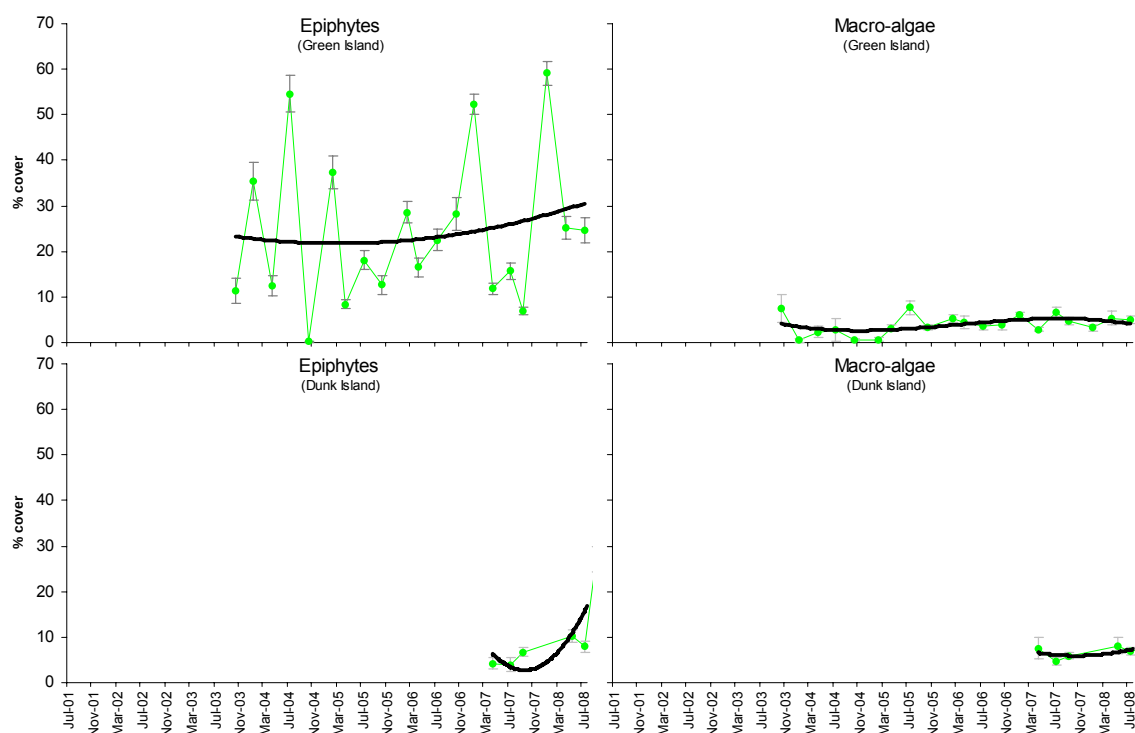


Figure 40. Mean abundance (% cover) ($\pm$ Standard Error) of epiphytes and macro-algae at reef intertidal seagrass monitoring locations (sites pooled) in the Wet Tropics region. NB: Polynomial trendline for all years pooled.

Sediment nutrients

Dunk Island was monitored for the first time in 2007. Data from this site is only represented graphically. The other sites have been monitored since 2005. Mean levels of NH_4^+ ranged from $367 \mu\text{mol L}_{\text{sed}}^{-1}$ (Green Island 2005) to $117 \mu\text{mol L}_{\text{sed}}^{-1}$ (Yule Point 2005) (Figure 41). Sediment ammonium for Dunk Island was within this range at $244 \mu\text{mol L}_{\text{sed}}^{-1}$, but was the highest level recorded for 2007.

Significant differences were detected between locations and years for the sites included in the ANOVA (d.f._(4,6) $p = 0.034$). Levels of sediment ammonium at Green island were significantly higher in 2005 than they were at Yule Point and at Green Island and Lugger Bay during 2006 and at all locations in 2007 (Table 15).

Levels of adsorbed PO_4^{3-} ranged from $2081 \mu\text{mol L}_{\text{sed}}^{-1}$ (Green Island, 2005) to $163 \mu\text{mol L}_{\text{sed}}^{-1}$ (Lugger Bay, 2007). At Dunk Island a level of $396 \mu\text{mol L}_{\text{sed}}^{-1}$ was recorded (Figure 41b). Significant differences were detected between Locations and Years (ANOVA d.f._(4,6) $p < 0.001$). Levels at Green Island were significantly different from each other, each year and from Yule Point and Lugger Bay in 2006 and 2007, Table 16). Overall sediment nutrient levels were less in 2007 that recorded from previous years.

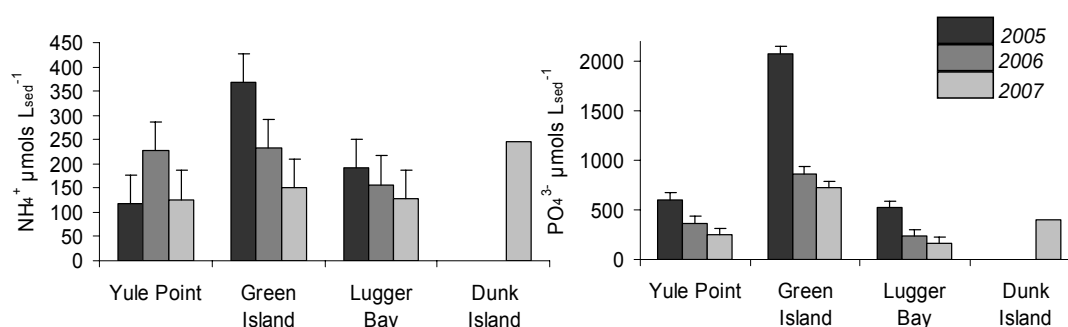


Figure 41. Adsorbed a) ammonium b) phosphate and c) Sediment N:P for locations within the Wet Tropics NRM - Terrain.

Table 15. Summary of Least Significant Differences for Ammonia levels from 2005-2007 for Yule Point, Green Island and Lugger Bay (the relationship between letters and nutrient levels is inverse i.e. ascending letters represent decreasing levels of nutrients).

Location/Year	2005	2006	2007
Yule Point	c	ab	bc
Green Island	a	bc	bc
Lugger Bay	abc	bc	bc

Table 16. *Summary of Least Significant Differences for Phosphate levels from 2005-2007 for Yule Point, Green Island and Luggar Bay.*

Location/Year	2005	2006	2007
Yule Point	bc	de	de
Green Island	a	b	c
Luggar Bay	cd	e	e

From 2005 sediment N:P ratios ranged from 0.8 (Luggar Bay,2007 (N>P)) to 0.2 (Green Island, 2005 (N<P)) (Figure 42). Significant differences between location and year were detected for sediment N:P (ANOVA d.f. (4,6) $p < 0.001$). Whilst locations recorded similar levels to each other within a particular year, levels within locations varied between years (Table 17).

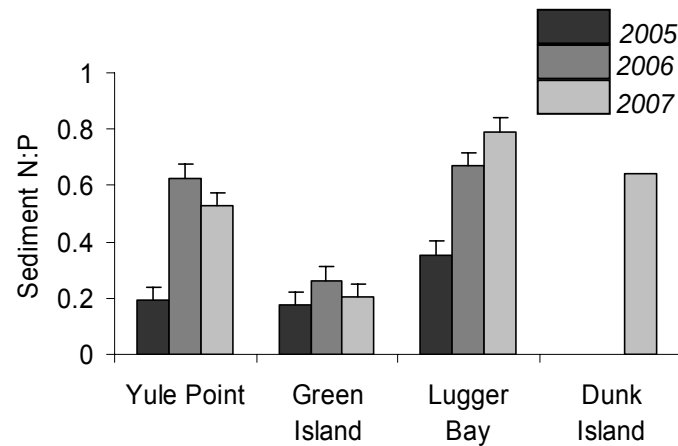


Figure 42. *Adsorbed Sediment N:P for locations within the far North Queensland NRM - Terrain.*

Table 17. *Summary of Least Significant Differences for sediment N:P from 2005-2007 for Yule Point, Green Island and Luggar Bay.*

Location/Year	2005	2006	2007
Yule Point	ejj	acf	bdgh
Green Island	fhj	ceg	cefg
Luggar Bay	fgi	cde	ab

Overall, the sediment nutrient levels were lower in 2007 than that recorded from previous years. Nitrogen levels at Dunk Island were much higher than those recorded for the other sites in 2007. Green Island continued to record the highest levels of phosphate for all the sites monitored in the Terrain NRM.

Across all GBR sites, levels of sediment ammonium (with the exception of Green Island 2005) were comparatively low. Levels of phosphate were spread along the continuum of ranges recorded for all GBR sites. Levels recorded in 2005 were above the median phosphate level of $420 \mu\text{mol L}_{\text{sed}}^{-1}$, whilst all other recorded levels were below. Luggar Bay recorded

values of N:P around and higher than the median value as did Dunk Island indicating sediment pools relatively higher in nitrogen than phosphate than the other sites monitored within this NRM. Yule Point and Green Island recorded N:P ratios lower than the median N:P value for the GBR, indicating that they had relatively larger phosphate pools than the Yule Point and Dunk Island sites.

Sediment herbicides

No detectable herbicides were found in the sediments of the seagrass meadows at any of the monitoring sites in Post-Wet 2008.

Table 18. Concentration of herbicides ($\mu\text{g kg}^{-1}$) in meadow sediments in post Wet 2008.

Site	Flumeturon	Diuron	Simazine	Atrazine	Desethyl Atraz.	Desisopropyl Atraz.	Hexazinone	Tebuthiuron	Ametryn	Prometryn	Bromacil	Terbutryn	Metolachlor
YP1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
YP2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
GI1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
GI2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
LB1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
LB2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DI1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DI2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Within meadow canopy temperature

Temperature loggers were deployed at all locations monitored in the region (Figure 43). Intermittent logger failure was experienced at Lugger Bay and Dunk Island.

Extreme temperatures (41.5°C) were recorded at YP1 on the 5th February 2008 (Figure 43). Over the last 12 months maximum mean temperatures were recorded in February (30.2°C at YP) and October 2007 during the low spring tides.

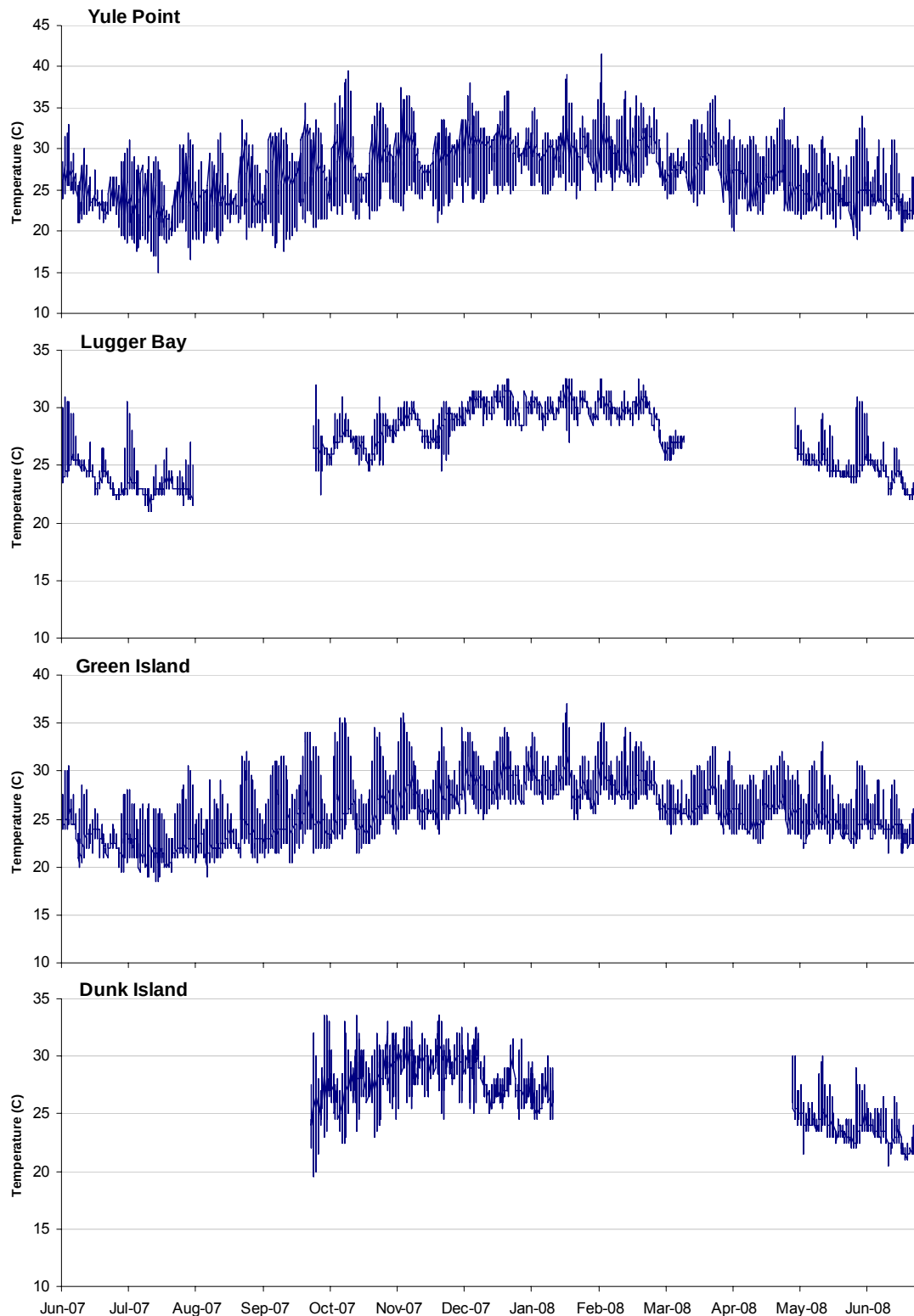


Figure 43. *Within seagrass canopy temperature (°C) at coastal (Yule Point and Luggar Bay) and offshore (Green Island and Dunk Island) intertidal meadows within the Far North Queensland region over the 2007/2008 monitoring period.*

Mean temperatures were generally within the 22 – 31°C range, with highest mean temperatures in the late Dry and Monsoon seasons. Temperatures at the coastal and reef-platform locations generally follow a similar pattern (Figure 44).

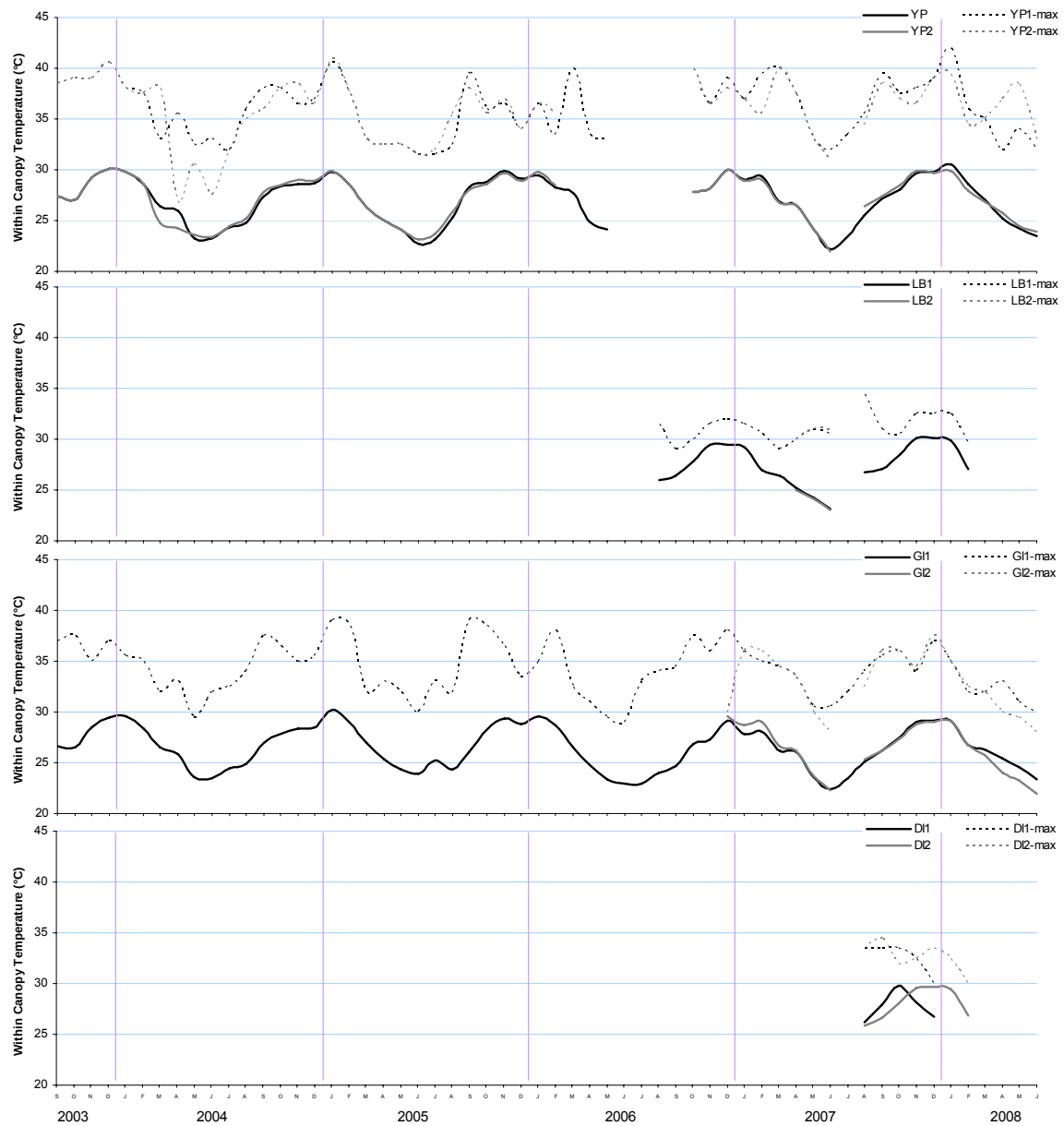


Figure 44. Monthly mean and maximum within seagrass canopy temperatures (°C) at coastal (Yule Point and Lugga Bay) and fringing-reef (Green Island and Dunk Island) intertidal meadows within the Far North Queensland region.



Burdekin Dry Tropics

Background

The Burdekin Dry Tropics 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 (NRM 2007a). 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 (Schleitinga 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 Dry Tropics region, and Reef Plan 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. The meadows are frequented by dugongs and turtles as witnessed by feeding trials and scars. These meadows are also visited regularly by recreational fishers. 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 coastal zone that is likely to be a major short term driver (Figure 45). 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.

Seagrass cover and composition

Both Bushland Beach and Shelley Beach were dominated by *Halodule uninervis* with varying amounts of *Halophila ovalis*. There were no detected changes in species composition (Figure 47). Seagrass cover appears to have increased at Bushland Beach during the late Dry 2007, however cover at Shelley Beach continued to decline (Figure 48).

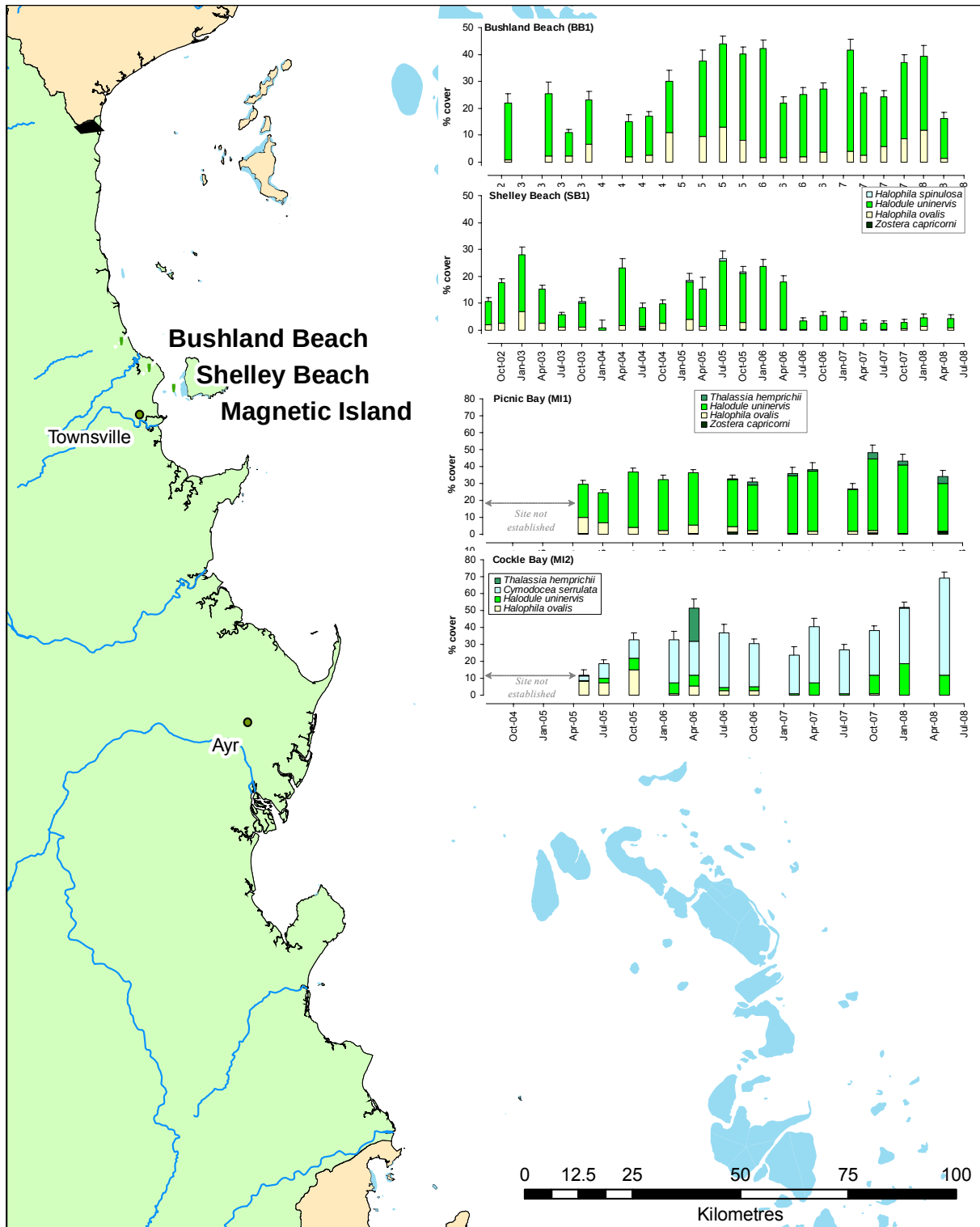


Figure 47. Mean percentage cover for each seagrass species at sites in the Burdekin region (+ Standard Error). NB: if no sampling conducted then x-axis is clear.

Seagrass cover has fluctuated both within and between years at Bushland Beach (Figure 48). Shelley Beach (SB1) appeared to follow a similar trend, until 2006, when the cover decreased and has not shown significant recovery (Figure 48).

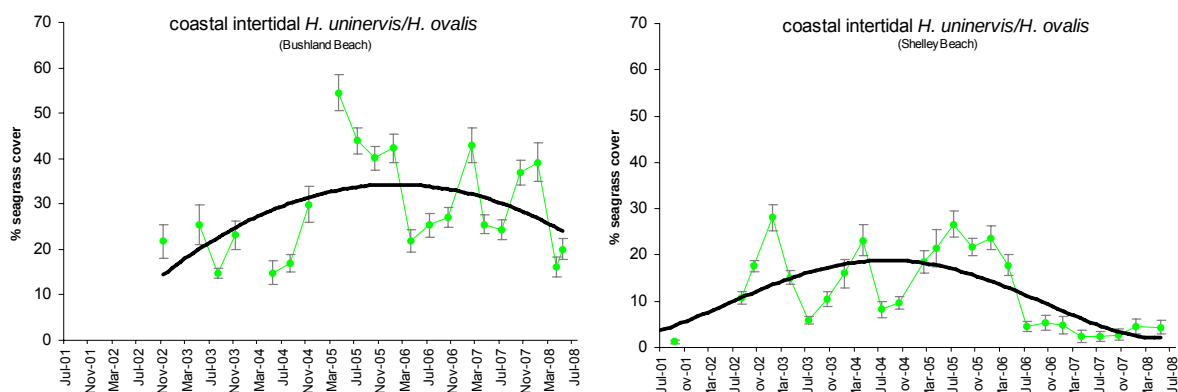


Figure 48. Change in seagrass abundance (percentage cover) at coastal intertidal meadows in the Burdekin Dry Tropics region.



Seagrass-Watch participants monitoring Bushland Beach (left) and Shelley Beach (right).

Since monitoring was established, both Bushland Beach and Shelley Beach have shown a seasonal pattern in seagrass cover, high in summer and low in winter (Figure 49).

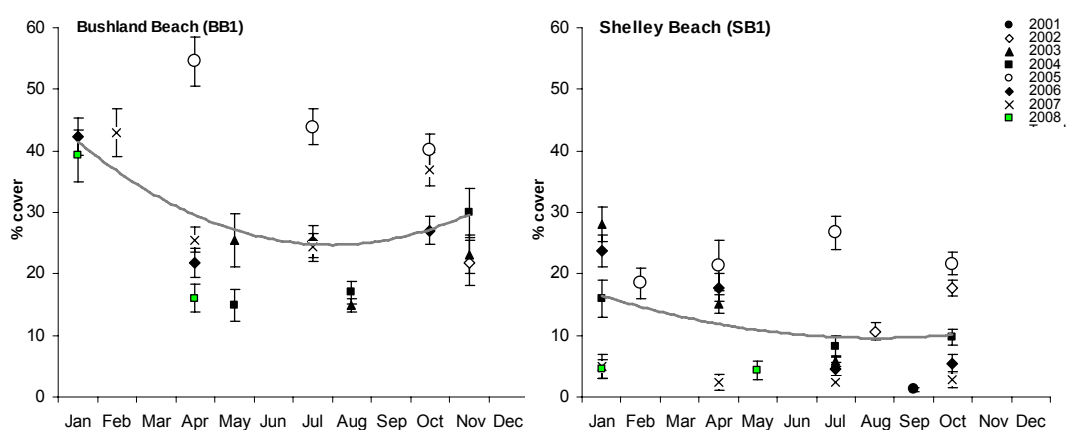


Figure 49. Mean percentage seagrass cover (all species pooled) ($\pm$ Standard Error) at Townsville coastal long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.

Offshore reef habitats are monitored on the fringing reef flats of Magnetic Island. Picnic Bay was dominated by *Halodule uninervis* with *Halophila ovalis* and the adjacent Cockle Bay was

dominated by *Halophila ovalis* with *Cymodocea serrulata*/ *Thalassia hemprichii*/ *Halodule uninervis* (Figure 47). Seagrass cover at both sites appears to have increased since monitoring was established in 2005 (Figure 50). Seagrass abundance at both locations appears to follow a seasonal pattern, which is clearer at Cockle Bay (Figure 51).

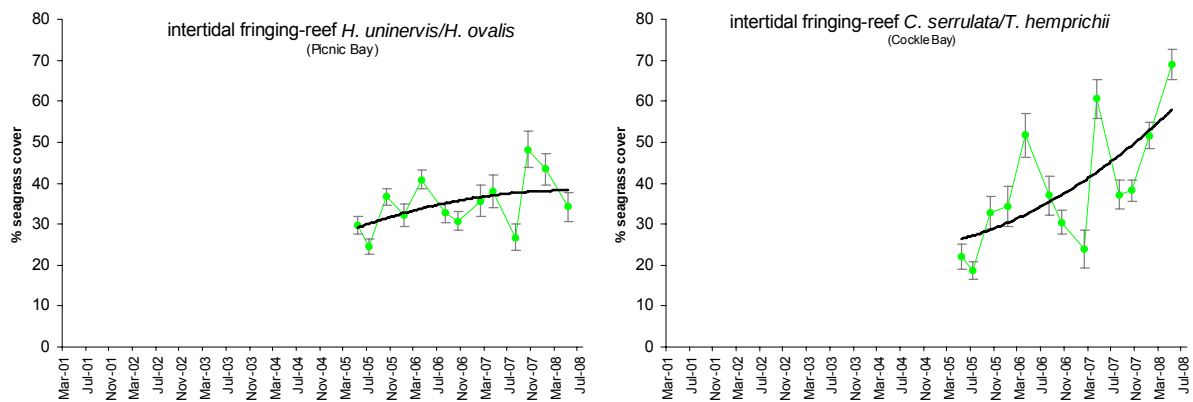


Figure 50. Change in seagrass abundance (percentage cover) at intertidal meadows on fringing reef platforms in the Burdekin Dry Tropics region.



Seagrass-Watch participants monitoring Picnic Bay (MI1, above left) and Cockle Bay (MI2, above right) on Magnetic Island.

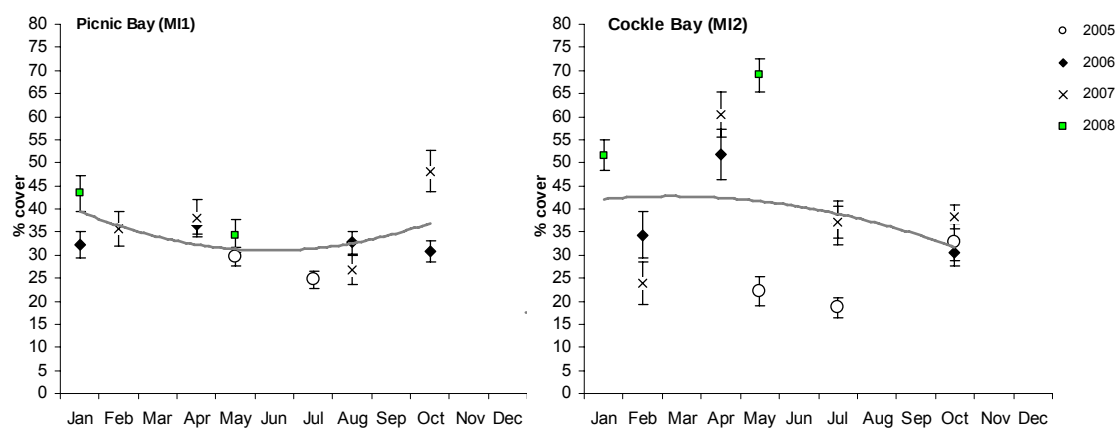


Figure 51. Mean percentage seagrass cover (all species pooled) ($\pm$ Standard Error) at Magnetic Island long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.

Seagrass reproductive health

Strong evidence of reproductive output is seen in all sites of the Burdekin dry tropics region (Figure 52). Reproductive health in the Burdekin dry tropics region is among the highest of all regions. This may be due to the high disturbance experienced in this region and the fact that seagrasses have adapted to this in their reproductive output, i.e. more reproductive structure per node.

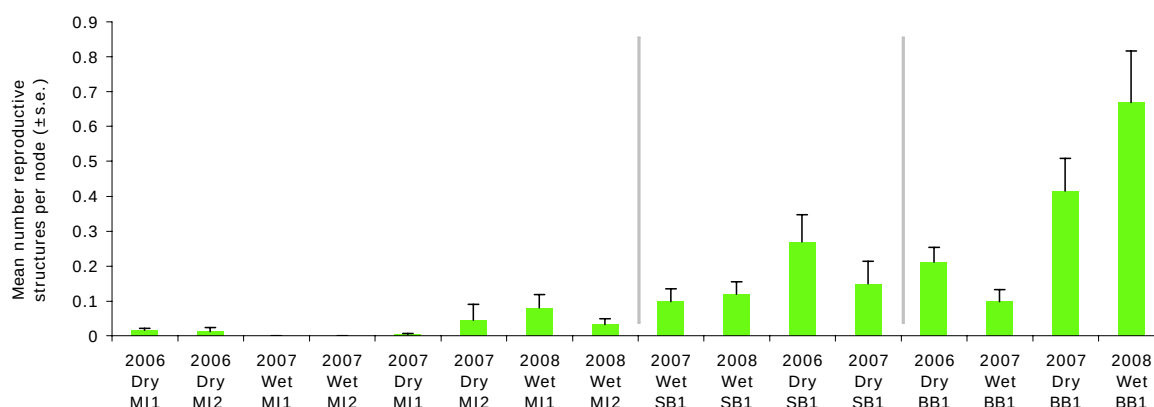


Figure 52. Mean number of reproductive structures (flowers, seeds, or fruits) per node across all seagrass species and all years sampled across sites in the Burdekin Dry Tropics Region; Magnetic Island-Picnic Bay and Cockle Bay, Shelley Beach, and Bushland Beach (+ Standard Error).

Tissue nutrients

Halophila ovalis and *Halodule uninervis* were the predominant species within the harvested samples. *Thalassia hemprichii* and *Cymodocea serrulata* were also present in minor amounts in samples collected from the reef habitats at Magnetic Island. These species were not represented consistently across years; consequently no statistical analyses were undertaken.

Halodule uninervis

Halodule uninervis %C differed significantly between years (ANOVA d.f._(2,4) $p = 0.046$) (Figure 53a). The years 2007 and 2006 recorded levels of %C significantly higher than that recorded during 2005 (Figure 53a, Table 19). No significant differences were detected for levels of %N or %P for this species.

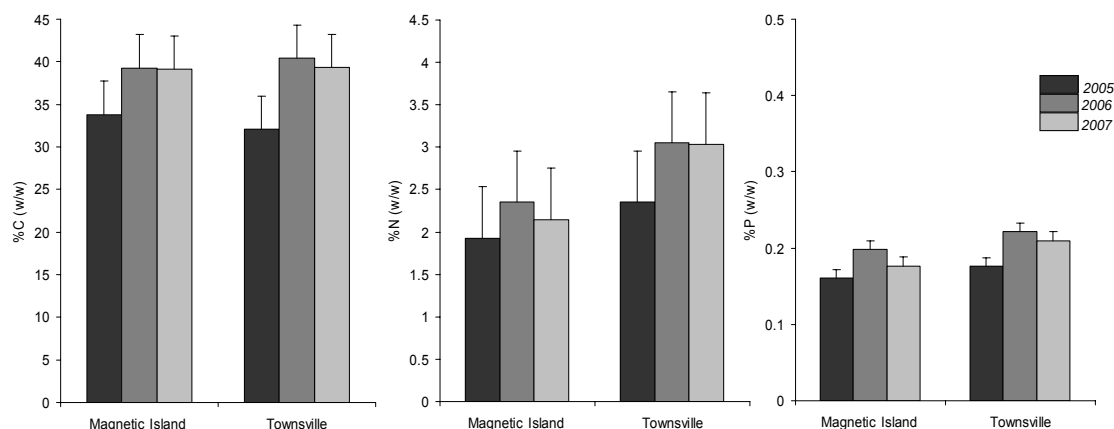


Figure 53. Plant tissue nutrients for *Halodule uninervis* within the Burdekin Dry Tropics NRM for; a) %C, b) %N and c) %P

Table 19. Summary of Least Significant Differences between years for %C of *Halodule uninervis* within the Burdekin Dry Tropics NRM .

Location	Grouping for LSD
2005	b
2006	a
2007	a

Halophila ovalis

No records were available for the Townsville sites in 2005 due to the contamination of samples during the grinding process. This was further compounded by the lack of sufficient biomass at one of the Townsville sites during 2006. Interpretations of the following analyses must be circumspect due to the unbalanced design of the ANOVA and the ensuing limited number of degrees of freedom.

No significant differences were detected for any of the plant tissue nutrients. Levels of %N and %P appeared higher at Townsville sites (Figure 54b,c). Levels of %P for this species were extraordinarily high (Figure 54c). In general all plant tissue nutrients were higher in 2006 (Figure 54).

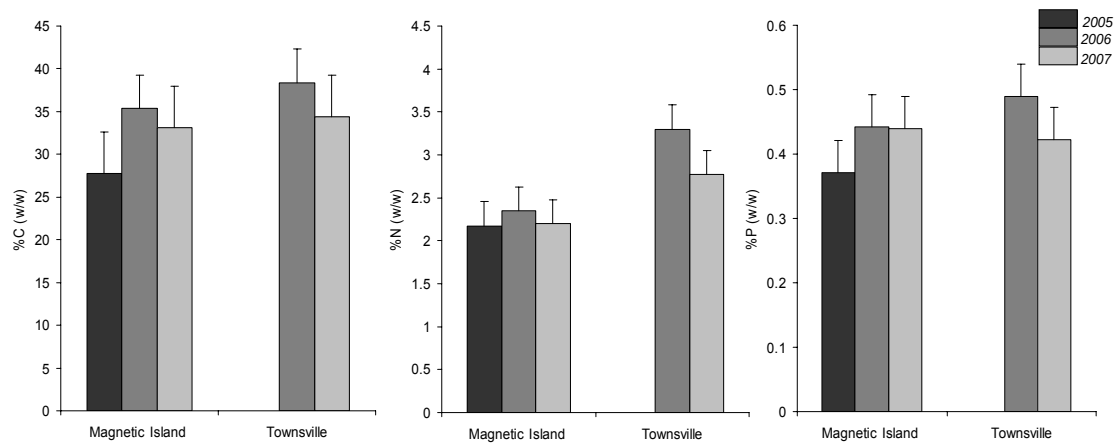


Figure 54. Plant tissue nutrients for *Halophila ovalis* within the Burdekin Dry Tropics NRM for; a) %C, b) %N and c) %P.

Cymodocea serrulata* and *Thalassia hemprichii

These species were only harvested from Magnetic Island and were not represented in every year of harvesting. *Cymodocea serrulata* tended to have lower plant tissue nutrients than *Thalassia hemprichii* (Figure 55 cf. Figure 56). For the data that is available for these species, %N and %P levels indicate N and P limitation, though %N of *Thalassia hemprichii* had reached the threshold level of 1.8%N as determined by Duarte (1990).

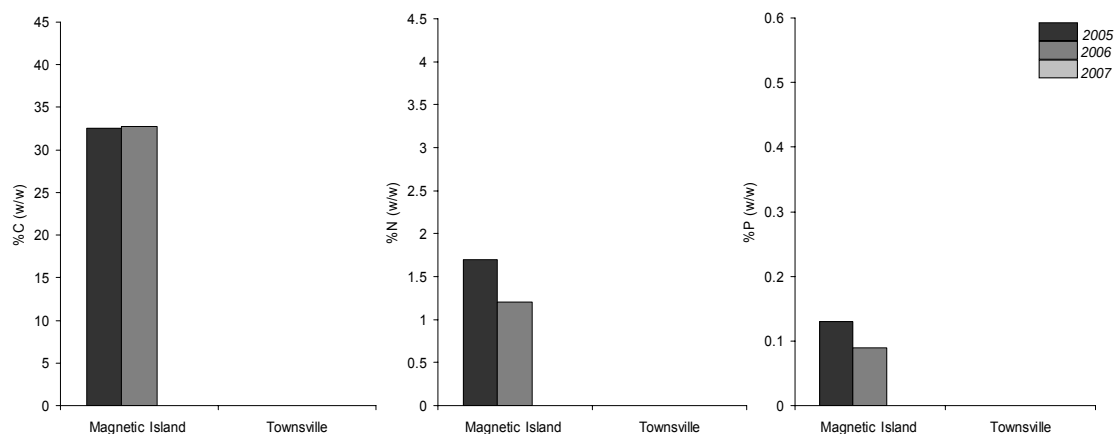


Figure 55. Plant tissue nutrients for *Cymodocea serrulata* within the Burdekin Dry Tropics NRM for; a) %C, b) %N and c) %P.

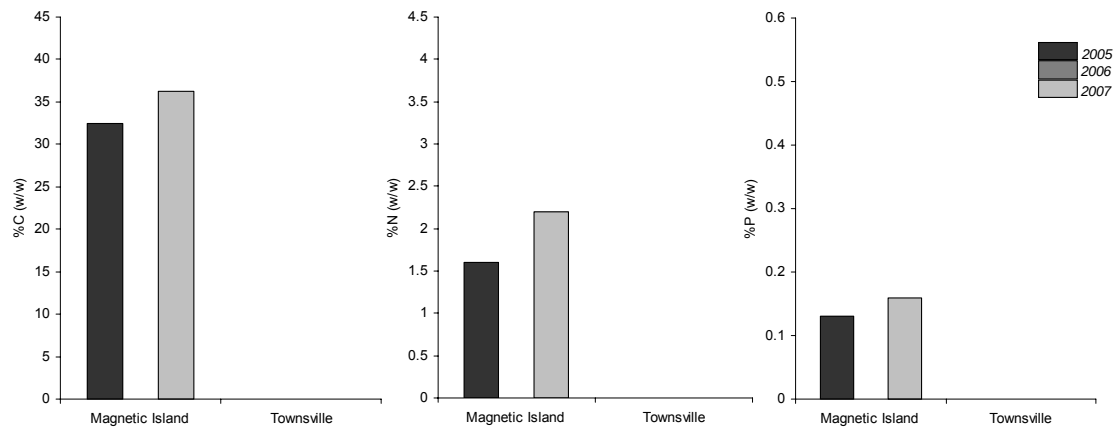


Figure 56. Plant tissue nutrients for *Thalassia hemprichii* within the Burdekin Dry Tropics NRM for; a) %C, b) %N and c) %P

At Magnetic Island, *Halodule uninervis* recorded levels indicative of P limitation. All other recordings of %N and %P suggested nutrient repletion for this species. Plant tissue nutrients for *Halophila ovalis* suggest that these plants are nutrient replete. Levels of %P for this species were extremely high. Reef inhabiting seagrasses *Cymodocea serrulata* and *Thalassia hemprichii* had levels of %N and %P below the threshold values determined by Duarte (1990) that separate plants from those that respond to nutrient inputs and those that don't.

Tissue nutrient ratios

Halodule uninervis

No significant differences were detected between year or location for C:N for *Halodule uninervis*, despite Magnetic Island recording on average higher ratios than Townsville sites (Figure 57a). The lack of significance can probably be attributed to the variable data recorded from the individual sites at Magnetic Island.

C:P ratios were significantly different between locations within this NRM (ANOVA d.f._(1,2) $p = 0.041$). Magnetic Island sites recorded higher ratios than the coastal sites at Townsville (Figure 57b).

Differences in N:P ratios were non significant between years and locations, despite Townsville sites recording, on average, higher ratios than the sites on Magnetic Island (Figure 57c).

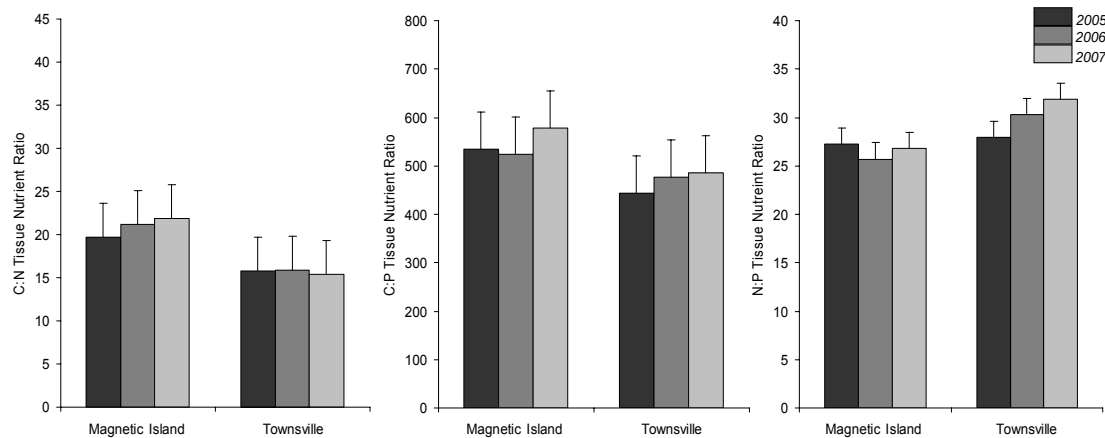


Figure 57. Plant tissue nutrients: a) C:N, b) C:P and c) N:P for *Halodule uninervis* for monitored sites within Burdekin Dry Tropics NRM.

Halophila ovalis

Despite no recording of tissue nutrients for Townsville sites in 2005 (previous section) tissue nutrient ratios were still able to be calculated and analyzed. No significant differences were detected for this species within the Burdekin Dry Tropics NRM (Figure 58).

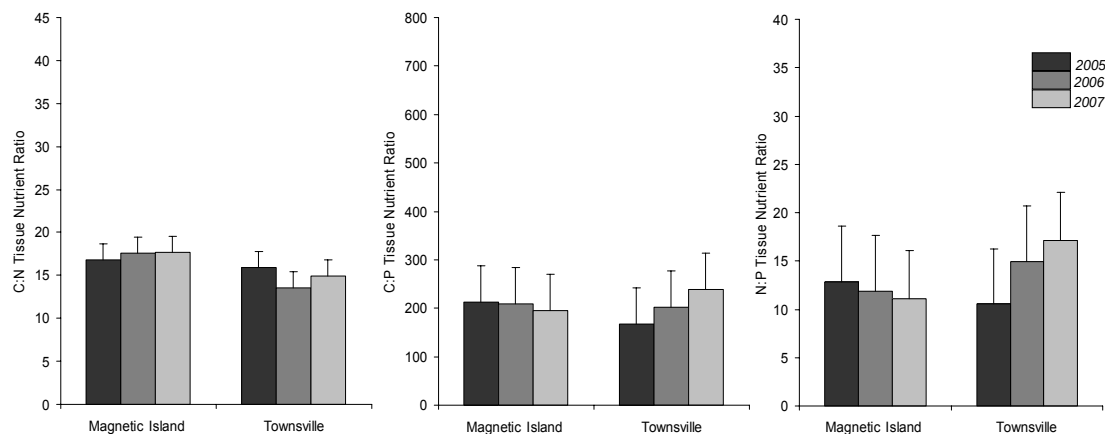


Figure 58. Plant tissue nutrients: a) C:N, b) C:P and c) N:P for *Halophila ovalis* for monitored sites within Burdekin Dry Tropics NRM.

Cymodocea serrulata and *Thalassia hemprichii*

Cymodocea serrulata recorded higher nutrient ratios than *Thalassia hemprichii* did (Figure 59, Figure 60). Differences between years were more obvious for *Cymodocea serrulata* than *Thalassia hemprichii*. The increase in C:N and C:P ratios for *C. serrulata* suggest that the reef habitats of Magnetic Island are showing some decline in water quality (Figure 59). This observation is not supported by the ratios recorded for *Thalassia hemprichii* (Figure 60).

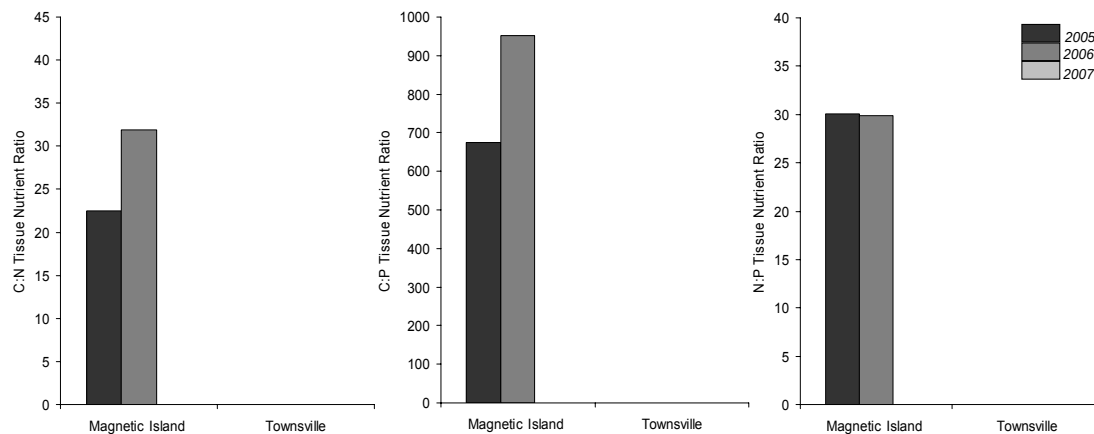


Figure 59. Plant tissue nutrients: a) C:N, b) C:P and c) N:P for *Cymodocea serrulata* for monitored sites within the Burdekin Dry Tropics NRM.

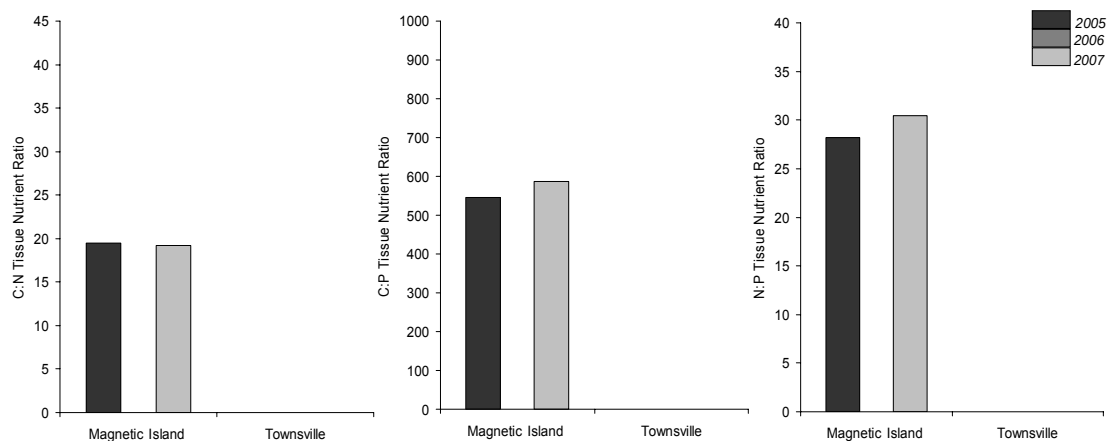


Figure 60. Plant tissue nutrients: a) C:N, b) C:P and c) N:P for *Thalassia hemprichii* for monitored sites within Burdekin Dry Tropics NRM.

Despite the lack of significant differences for C:N for *Halodule uninervis* a clear distinction between habitats types was evident. Levels recorded were clearly divided between habitats with a moderate light environment (reef C:N ratios > 20:1) and coastal habitats with low light environments (C:N < 20:1). C:P ratios were significantly different between locations/habitat types. Reef habitats recorded levels of C:P ratios > 500 indicating a nutrient poor environment as opposed to coastal habitats with ratios < 500 indicating a nutrient rich environment. This is backed up the levels of N:P ratios that show reef sites displaying ratios below 30:1 indicating nitrogen limitation, while sites in coastal habitats had ratios around 30:1 suggestive of nutrient repletion.

C:N and C:P ratios for *Halophila ovalis* indicate that both of the habitats monitored around Townsville are low light, nutrient rich environments. N:P ratios for this species show that it is N limited.

A dichotomy exists between the species found solely within the reef habitat, in relation to C:N ratios. C:N for *Cymodocea serrulata* would suggest that these plants are living in a moderate light environment (i.e C:N > 20) while C:N ratios for *Thalassia* are indicative of a low light environment. Both species had C:P ratios suggestive of nutrient rich environments and N:P ratios of nutrient repletion.

Epiphytes and Macro-algae

Epiphytes cover on seagrass leaf blades at coastal sites was highly variable (Figure 61) and appears correlated with seagrass abundance. Epiphyte cover has remained relatively lower over the past 12 months compared to previous years (Figure 61). Percentage cover of macro-algae at coastal sites is also variable, but has similarly remained low over the past couple of years (Figure 61).

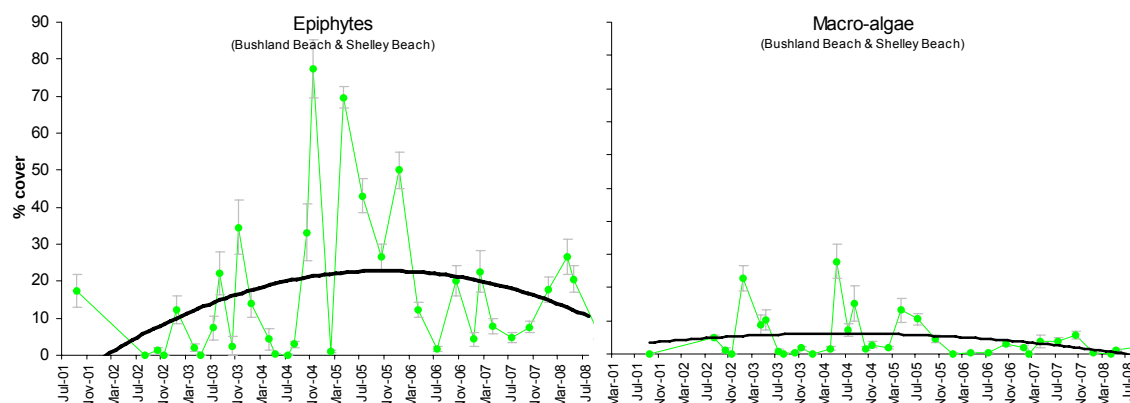


Figure 61. Mean abundance (% cover) ($\pm$ Standard Error) of epiphytes and macro-algae at coastal intertidal seagrass monitoring locations (sites pooled). NB: Polynomial trendline for all years pooled.

Epiphyte cover at reef sites differs greatly between sites (Figure 62). At Picnic Bay (MI1), epiphyte cover is generally <40%, compared to Cockle Bay where it is >50% on average (Figure 62). Similarly macro-algae is low at Picnic Bay, but higher and more variable at Cockle Bay (Figure 62). Macro-algae at Cockle Bay was predominately composed of *Halimeda* spp., however in 2008, the composition of *Hydroclathrus* spp. was increasing.

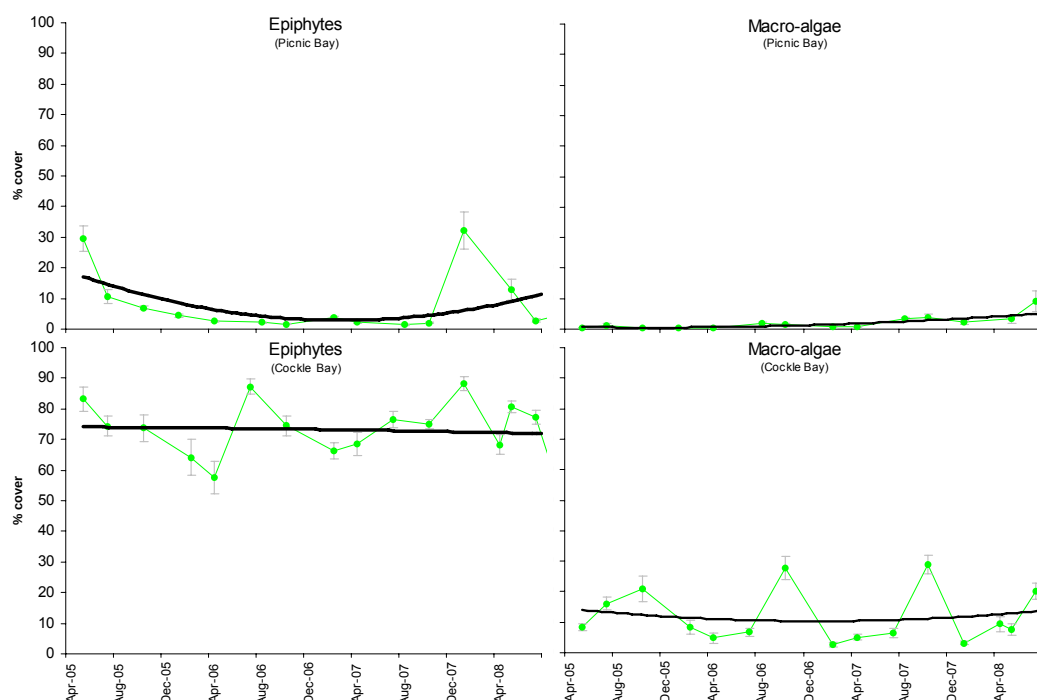


Figure 62. . Mean abundance (% cover) ($\pm$ Standard Error) of epiphytes and macro-algae at intertidal reef seagrass monitoring locations. NB: Polynomial trendline for all years pooled.

Seagrass meadow edge mapping

Edge mapping was conducted within a 100m radius of all Seagrass-Watch monitoring sites in September/October and March/April of each year (Table 6). Some meadows changed species or edges within the mapping area, but were outside the 50m x 50m monitoring sites. For example, at Cockle Bay (MI2, Magnetic Island) the seagrass within the monitoring site remained similar; however the edges of the meadows and the presence of sparse inshore *Halophila ovalis* differed slightly in October 2007 and April 2008 compared to previous years. Alternatively, there was a slight decrease in distribution of the Bushland Beach (BB1) meadow, the result of small gaps (possibly blowouts) forming in the seaward portion of the meadow in late Monsoon 2008.

The most dramatic changes over the past 12-24 months occurred in the meadow at Shelley Beach (SB1) (Figure 63). In October 2006 the Shelley Beach meadow was significantly fragmented due to “blowouts”. This resulted in relatively few of the sampling quadrats falling within the meadow. In April 2007 the meadow had recovered and the site was once again within a continuous meadow which continued to expand in the late Dry 2007. However in the late Monsoon 2008 the meadow fragmented due to “blowouts” once again. This may be indicating a long-term season trend.

Table 20. Area (ha) of seagrass meadow being monitored within 100m radius of site. Value in parenthesis is % change from October 2005 baseline, and direction of change from previous mapping. Shading indicates decrease in meadow area since baseline.

Monitoring Site	October 2005	April 2006	October 2006	April 2007	October 2007	April 2008
MI1	2.933	3.398 (15.9%, increase shoreward)	1.723 (-41.2% decrease seaward)	2.587 (-11.8%, increase shoreward)	3.119 (6.3%, increase shoreward)	2.69 (-8.3%, decrease seaward)
MI2	4.104	4.342 (5.8, increase shoreward)	4.112 (0.2, negligible)	4.141 (0.9%, increase shoreward)	4.144 (1.0%, increase shoreward)	4.191 (2.1%, increase shoreward)
BB1	5.312	5.312 (no change)	5.312 (no change)	5.113 (-3.7, decrease seaward)	5.221 (-1.7, increase shoreward)	5.08 (-4.4, decrease seaward)
SB1	4.303	3.485 (-19.1 decrease seaward)	2.861 (-33.5 decrease seaward)	3.939 (-8.5 increase shoreward)	4.529 (-5.2 increase shoreward)	2.095 (-51.3 decrease overall)

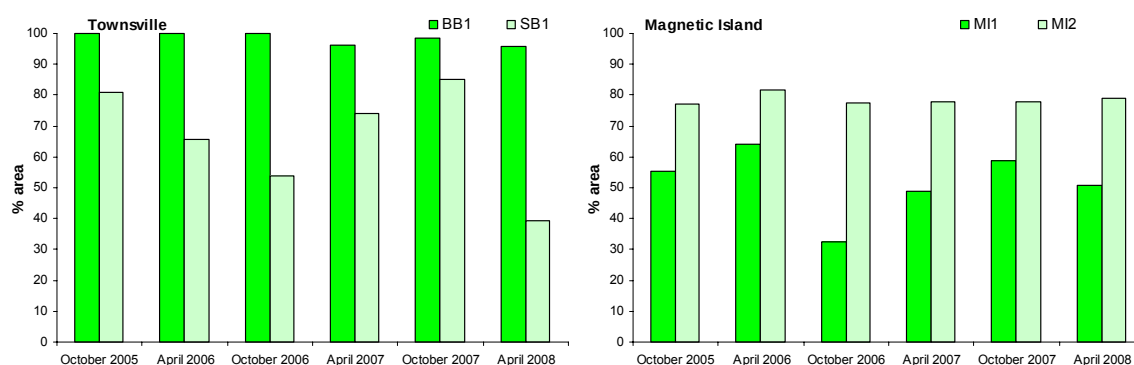


Figure 63. Percentage of area (within 100m radius of monitoring site) covered by seagrass at each coastal and offshore monitoring site at Townsville and Magnetic Island locations.

Sediment nutrients

Mean levels of ammonium recorded for this region ranged from 528 $\mu\text{mol L}_{\text{sed}}^{-1}$ (Magnetic Island 2005) to 196 $\mu\text{mol L}_{\text{sed}}^{-1}$ (Magnetic Island 2006). Adsorbed ammonium levels did not differ statistically between years or locations (Figure 64).

Levels of adsorbed phosphate differed significantly between years (ANOVA d.f. (2, 4) $p < 0.001$) and between locations (ANOVA d.f. (1, 2) $p = 0.009$). Levels of adsorbed phosphate were consistently higher at Magnetic Island than at Townsville with a significant decrease within the region between the year 2005 and the rest of the monitoring periods: 2006 and 2007 (Figure 64b).

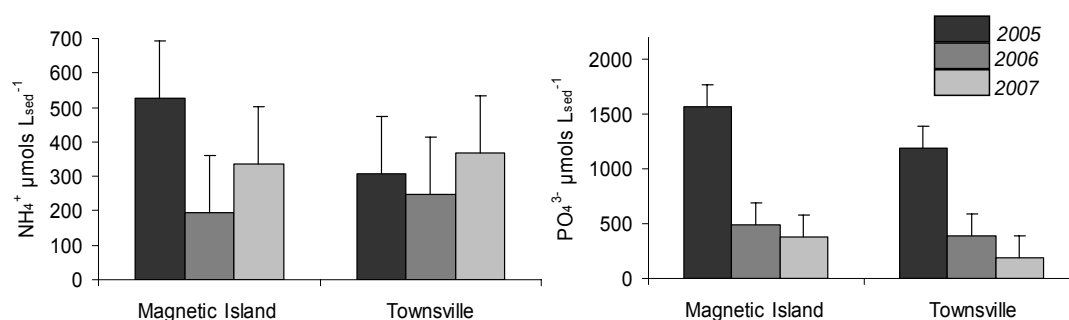


Figure 64. Sediment nutrients levels for a) ammonium, b) phosphate for the monitored sites within the Burdekin Dry Tropics NRM:2005 - 2007.

Table 21. Summary of Least Significant Differences for adsorbed phosphate between locations for sites monitored within the Burdekin Dry Tropics NRM.

Location	Grouping for LSD
Magnetic Island	a
Townsville	b

Table 22. Summary of Least Significant Differences for adsorbed phosphate for Years that the Burdekin Dry Tropics NRM has been monitored.

Location	Grouping for LSD
2005	a
2006	b
2007	b

This decrease in levels of adsorbed PO_4^{3-} is reflected in the increase in N:P ratios for the region. N:P ratios were significantly different across Locations (ANOVA d.f. (1,2) $p = 0.016$) and Years (ANOVA d.f. (2,4) $p = 0.006$) respectively (Figure 64, Table 23,

Table 24).

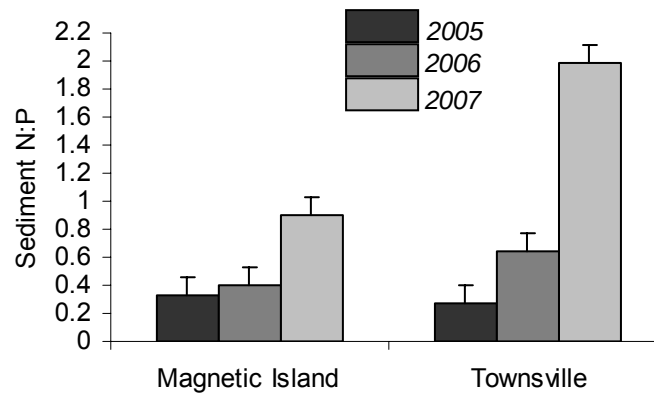


Figure 65. *Sediment nutrients levels for N:P for the monitored sites within the Burdekin Dry Tropics NRM:2005 - 2007.*

Table 23. *Summary of Least Significant Differences for N:P between locations for sites monitored within the Burdekin Dry Tropics NRM.*

Location	Grouping for LSD
Magnetic Island	b
Townsville	a

Table 24. *Summary of Least Significant Differences for adsorbed phosphate for Years within the Burdekin Dry Tropics NRM .*

Location	Grouping for LSD
2005	b
2006	b
2007	a

The sediment ammonium for the Burdekin Dry tropics showed no significant changes over the course of monitoring. Sediment ammonium levels in general were higher than the median value for the GBR since 2005.

In contrast a clear distinction between reef and coastal habitats was obvious for this region. Magnetic Island recorded much higher adsorbed P than Townsville sites. This was coupled with a decline in adsorbed phosphate since monitoring commenced. Adsorbed phosphate levels in 2007 were below the median value. In previous years with the exception of Townsville sites in 2006, recordings of phosphate were at levels higher than the median.

These observances have been mirrored inversely for N:P. Townsville recorded larger ratios than Magnetic Island with an increasing trend of N:P towards 2007.

Sediment herbicides

Diuron was the only herbicide detected in the sediments and was present at all coastal and reef monitoring sites in Post-Wet 2008 (Table 25).

Table 25. Concentration of herbicides ($\mu\text{g kg}^{-1}$) in meadow sediments in post Wet 2008.
 ND=not detectable, $<0.05 \mu\text{g kg}^{-1}$

Site	Flumeturon	Diuron	Simazine	Atrazine	Desethyl Atrz.	Desisopropyl Atrz.	Hexazinone	Tebuthiuron	Ametryn	Prometryn	Bromacil	Terbutryn	Metolachlor
MI1	ND	0.07	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI2	ND	0.08	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BB1	ND	0.11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SB1	ND	0.13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Within meadow canopy temperature

Within canopy temperature was monitored at coastal and reef-platform locations (Figure 66), and generally follow a similar pattern. No extreme temperatures ($>40^{\circ}\text{C}$) 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 of the Dry season at (Figure 66).

Mean temperatures were mostly within the $20 - 30^{\circ}\text{C}$ range, with highest mean temperatures in the January to February period (Figure 67).

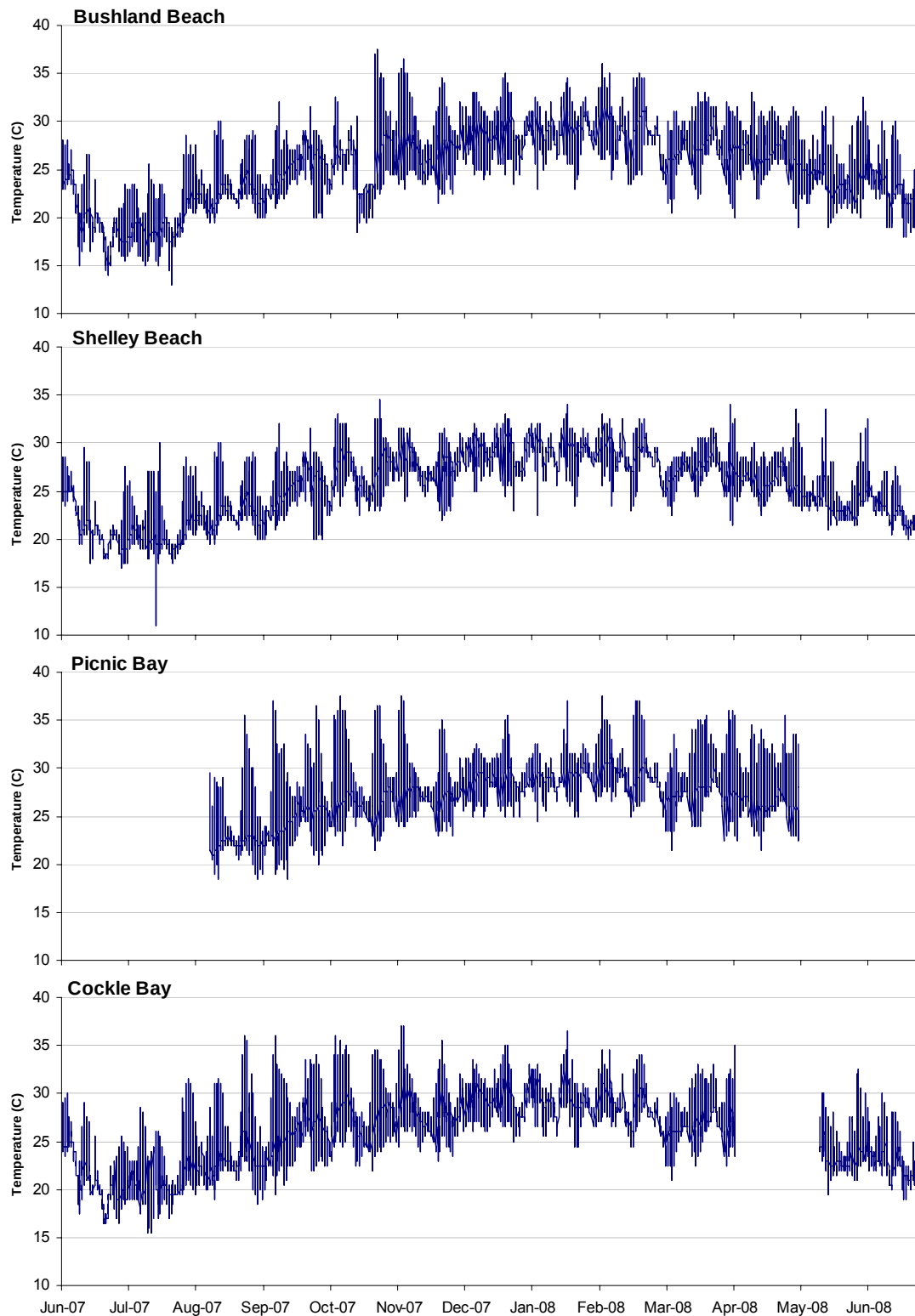


Figure 66. *Within seagrass canopy temperature (°C) at coastal (Bushland Beach and Shelley Beach) and offshore fringing-reef (Picnic Bay and Cockle Bay, Magnetic Island) intertidal meadows within the Burdekin Dry Tropics region over the 2007/2008 monitoring period.*

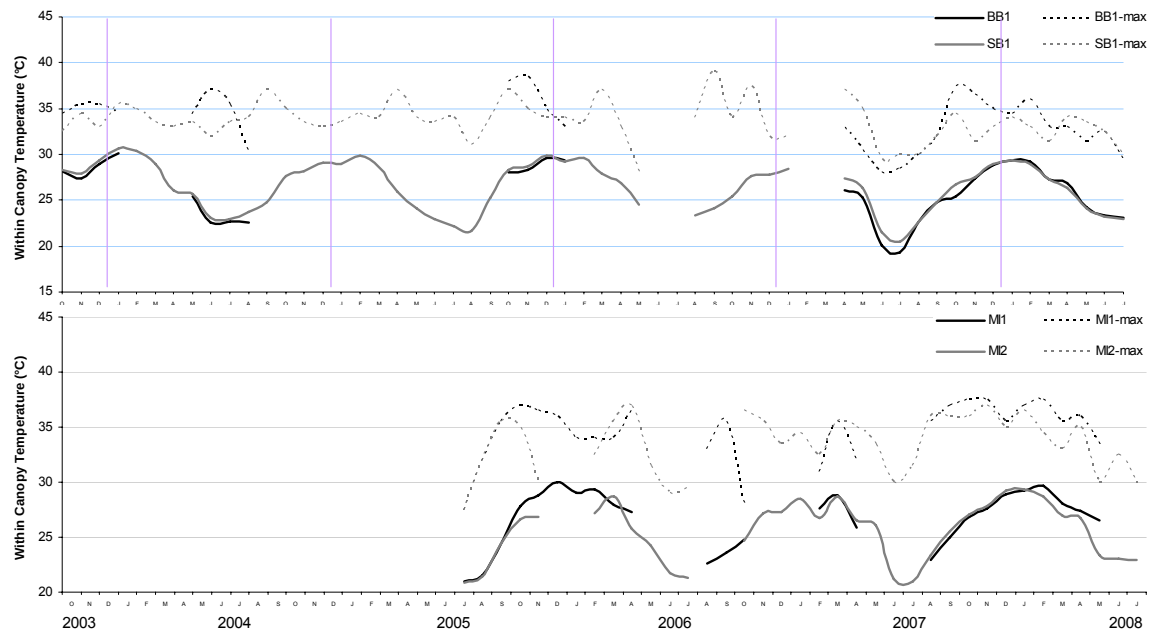


Figure 67. Monthly mean and maximum within seagrass canopy temperature (°C) at intertidal meadows in coastal (Bushland Beach and Shelly Beach) and offshore fringing-reef (Picnic Bay and Cockle Bay, Magnetic Island) habitats within the Burdekin Dry Tropics region.



Mackay Whitsunday

The Mackay Whitsunday region comprises an area of almost 940,000 ha. It includes the major population centres of Mackay, Proserpine, Airlie Beach and Sarina, and encompasses the Proserpine, O'Connell, Pioneer and Plane Creek river systems (NRM 2007d). 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 68).

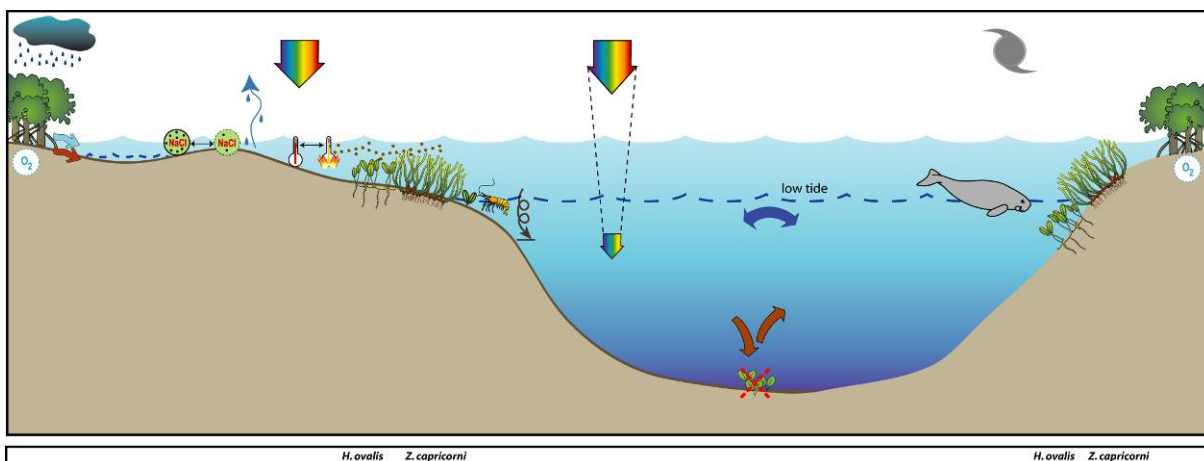


Figure 68. *Conceptual diagram of estuary habitat in the Mackay Whitsunday region: general habitat and seagrass meadow processes (See Figure 2 for icon explanation).*

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 69). Monitoring sites of intertidal coastal seagrass habitat were located on the sand/mud flats adjacent to Cannonvale in southern Pioneer Bay.

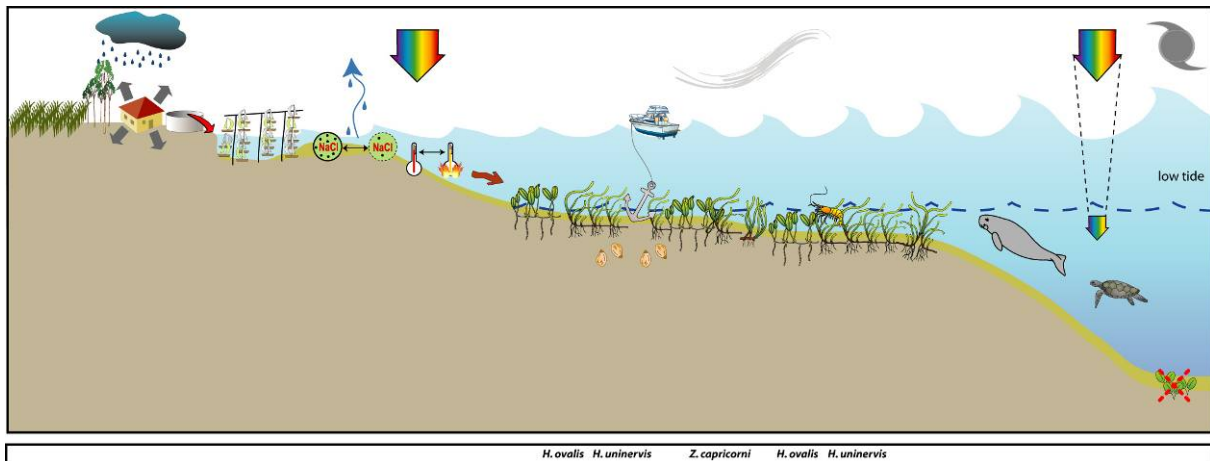


Figure 69. Conceptual diagram of coastal habitat in the Mackay Whitsunday region – major control is shelter and temperature extremes: general habitat, seagrass meadow processes and threats/impacts (See Figure 2 for icon explanation)

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 70). Major threats would be increased tourism activities including marina and coastal developments.

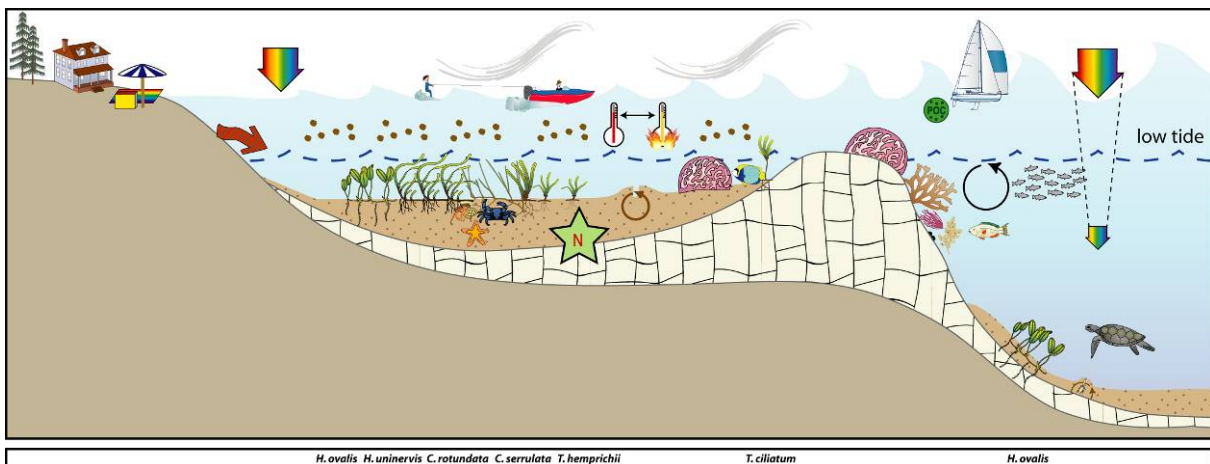


Figure 70. Conceptual diagram of reef habitat in the Mackay Whitsunday region - major control is light and temperature extremes: general habitat, seagrass meadow processes and threats/impacts (See Figure 2 for icon explanation).

Seagrass cover and composition

The coastal seagrass monitoring sites were located on intertidal sand/mud flats adjacent to Cannonvale in southern Pioneer Bay. The meadows cover approximately 60ha and were dominated by *Halodule uninervis* and *Zostera capricorni* mixed with *Halophila ovalis*. Species composition remained relatively stable over the monitoring period and total abundance indicated natural seasonal patterns (Figure 71). Percent cover at this location has remained relatively stable (trend line, Figure 72), even though fluctuations are apparent between years indicating disturbance regimes at longer time periods than annually (Figure 73).

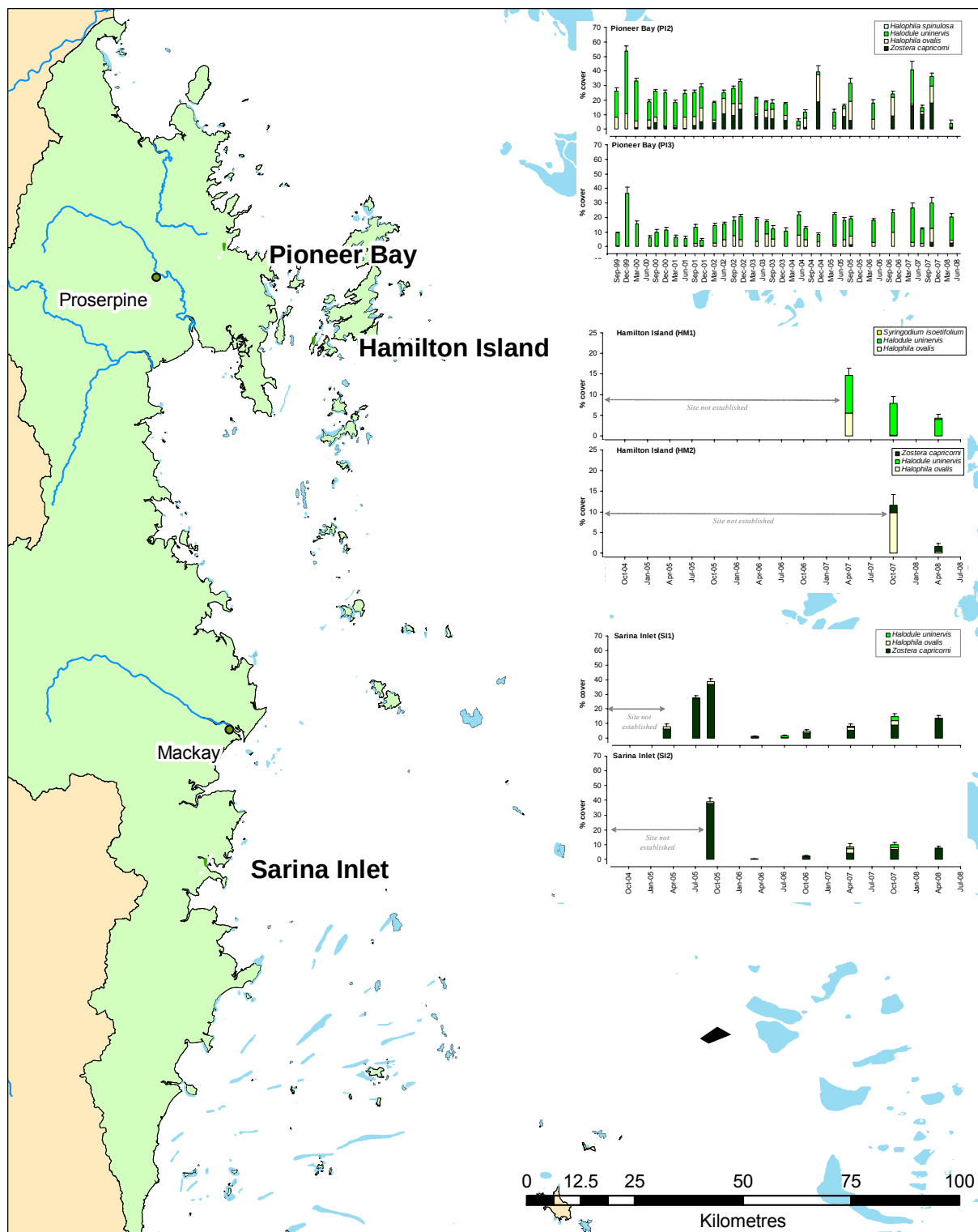


Figure 71. Mean percentage cover for each seagrass species at Seagrass-Watch long-term monitoring sites in the Mackay Whitsunday region (+ Standard Error). NB: if no sampling conducted then x-axis is clear.

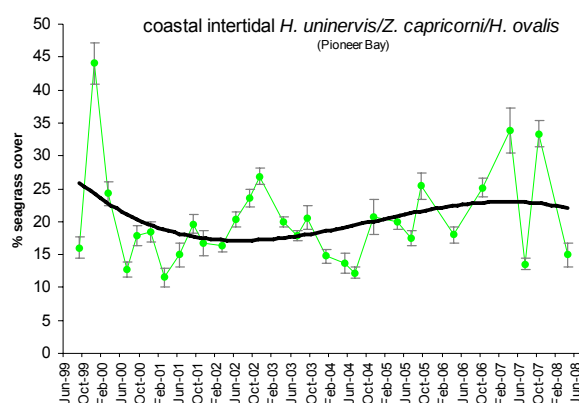


Figure 72. Change in seagrass abundance (percentage cover) at the coastal intertidal meadows at Pioneer Bay, in the Mackay Whitsunday region.

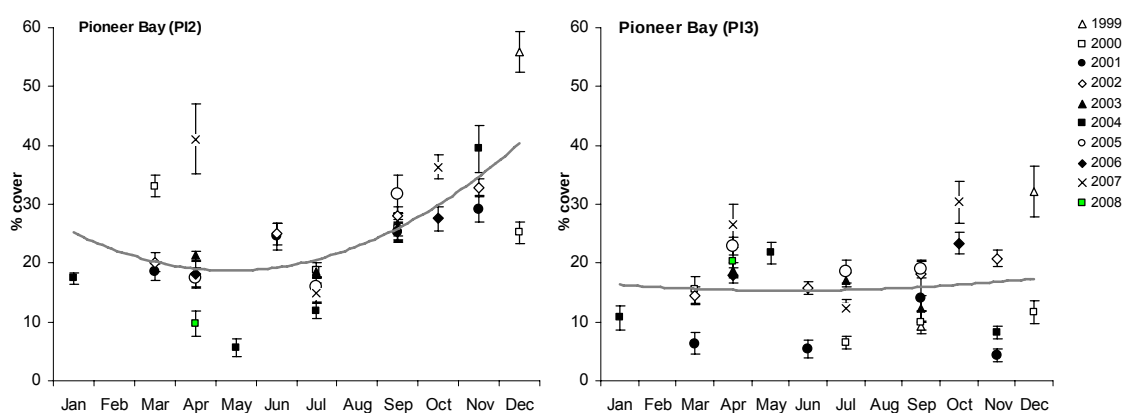


Figure 73. Mean percentage seagrass cover (all species pooled) ($\pm$ Standard Error) at Pioneer Bay long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.



Dugong feeding trails and monitoring sites at Pioneer Bay (PI3).

The estuarine monitoring sites are located on an intertidal sand/mud bank in Sarina Inlet south of Mackay. This site is dominated by *Zostera capricorni* with some *Halophila ovalis* (Figure 71). Seagrass cover in April 2008 was similar to cover recorded in April 2007 (Figure 74). Seagrass cover in October 2007 was significantly higher than the same time of year previously. Overall the meadow appears to still be recovering from the losses experienced in 2006 and no seasonal patterns are apparent (Figure 75).

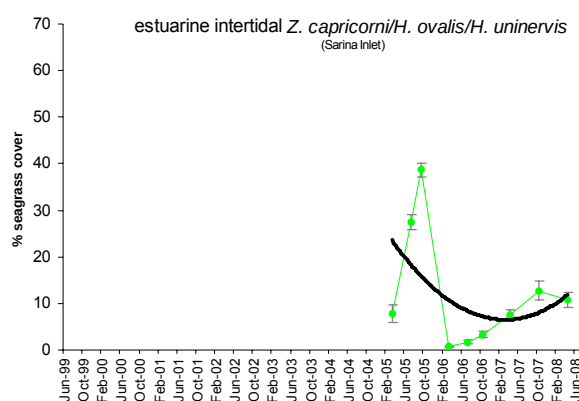


Figure 74. Change in seagrass abundance (percentage cover) at intertidal meadows located in estuaries in the Mackay Whitsunday region.

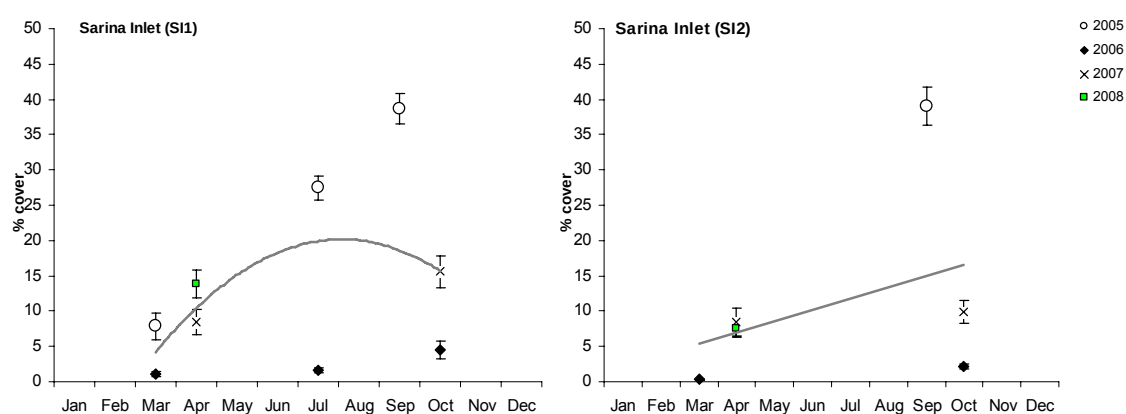


Figure 75. Mean percentage seagrass cover (all species pooled) ($\pm$ Standard Error) at Sarina Inlet long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.



Sarina Inlet monitoring sites; SI1 (above left) and SI2 (above right).

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 71). As the location was only established in 2007, comparisons between years are difficult, although seagrass cover in April 2008 was significantly lower than April 2007 (Figure 76).



Hamilton Island monitoring sites HM1 (left) and HM2 (right) Catseye Bay.

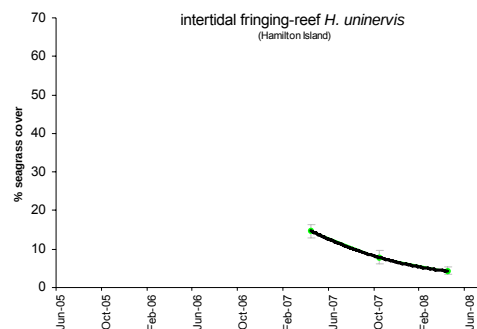


Figure 76. Change in seagrass abundance (percentage cover) at intertidal meadows located on a fringing reef in the Mackay Whitsunday region.

Seagrass reproductive health

All locations in the Mackay Whitsunday Region produced reproductive structures although variable trends among the sites with Pioneer Bay and Sarina Inlet increasing (Figure 77).

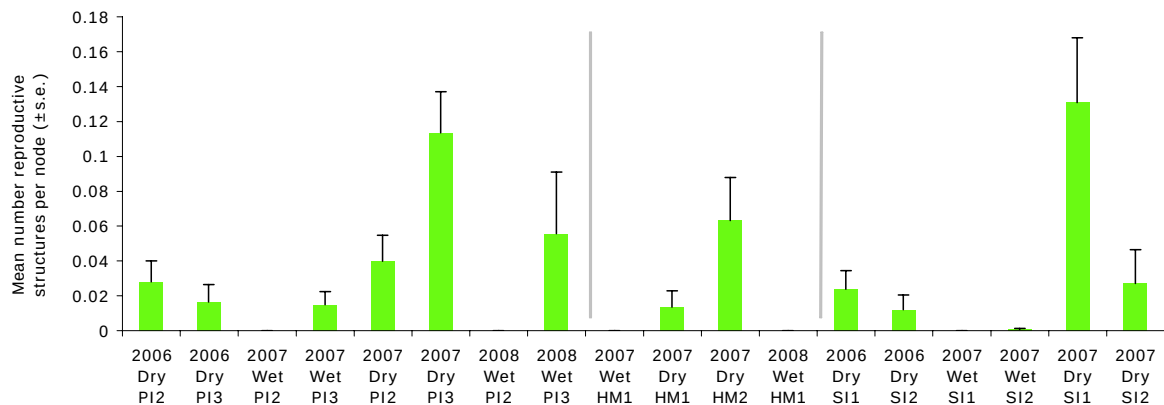


Figure 77. Mean number of reproductive structures (flowers, seeds, or fruits) per node across all seagrass species and all years sampled across sites in the Mackay Whitsunday Region; Pioneer Bay, Hamilton Island and Sarina Inlet (+ Standard Error).

Tissue Nutrients

Halodule uninervis, *Halophila ovalis*, and *Zostera capricorni* were found in the harvested samples collected for nutrient analyses in this NRM. *Zostera capricorni* occurred consistently across years and locations and was even present in samples collected from the reef habitat on Hamilton Island. *Halodule uninervis* was absent from harvested samples during 2006 at

Sarina Inlet. No data for tissue nutrients is recorded for *Halophila ovalis* due to contamination of the samples in 2005, however values are recorded for tissue nutrient ratios as contamination is assumed to be equal across the nutrients and shouldn't affect the calculation of ratios.

Halodule uninervis

Due to unbalanced design caused by a lack of *Halodule uninervis* during 2005 at Sarina Inlet, the data is only presented graphically.

Levels of %C, %N and %P were similar across locations and years with the exception of nutrients recorded at Pioneer Bay during 2005 (Figure 1). As there is no data from 2005 at Sarina to compare it to, it is impossible to determine whether this was an artifact of the year at this Pioneer Bay or a yearly effect.

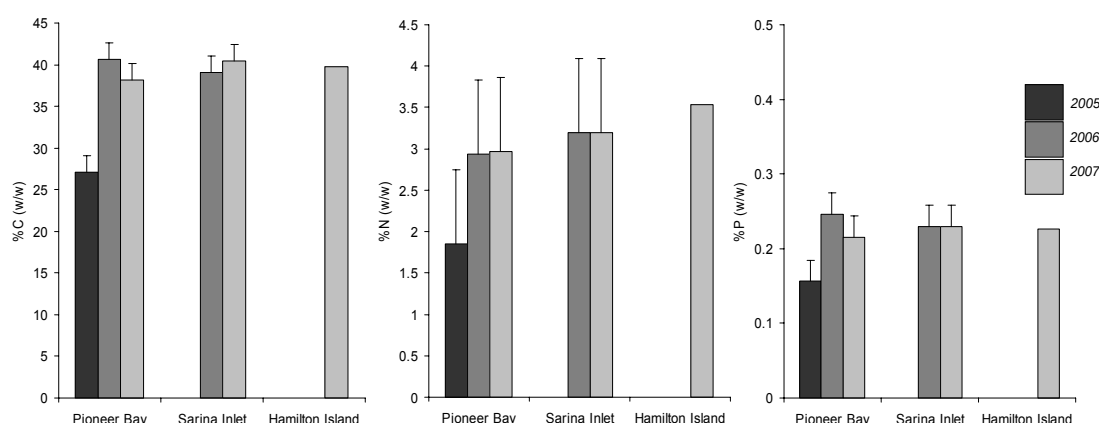


Figure 78. Plant tissue nutrients for *Halodule uninervis* within the Mackay Whitsunday NRM for; a) %C, b) %N and c) %P

Halophila ovalis

As data was absent from Sarina Inlet in 2005, no statistical analyses were not undertaken for this species.

Levels of %C with the exception of values recorded for Pioneer Bay in 2005 were similar across years. Levels of %N also appeared similar across locations, with the exception of quite high levels recorded at Sarina Inlet in 2006. %P was exceedingly high at all locations but was similar across years and locations (Figure 79).

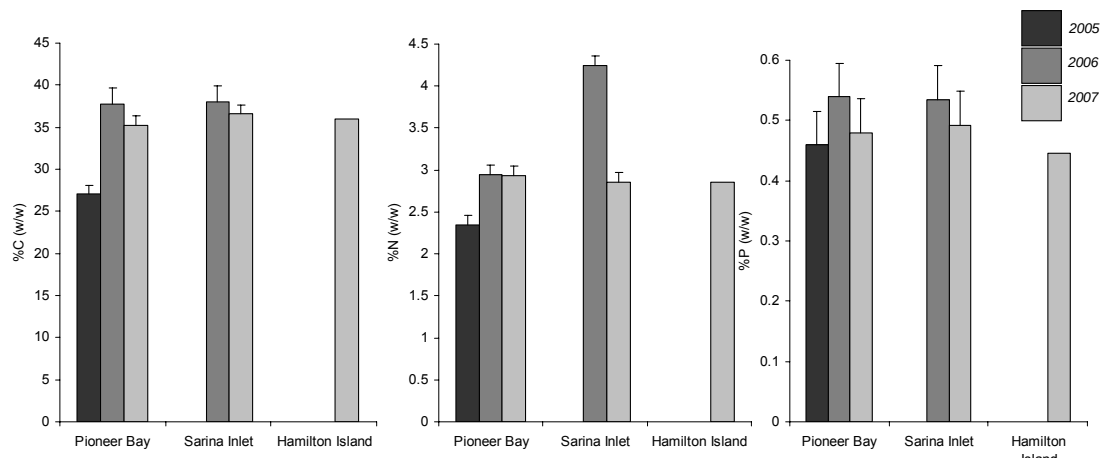


Figure 79. Plant tissue nutrients for *Halophila ovalis* within the Mackay Whitsunday NRM for; a) %C, b) %N and c) %P

Zostera capricorni

Zostera capricorni %C ranged from 24% (Pioneer Bay 2005) to 38.5% (Pioneer Bay 2006) (Figure 80a). A significant interaction was detected between location and year (ANOVA d.f. (2,3) $p = 0.005$). Levels of %C during 2005 recorded at both locations were significantly different from each other and significantly lower than that recorded during any year at any location (Table 26). Hamilton island %C for *Zostera capricorni* was the highest recorded (39% (C)) for 2007, levels more similar to that recorded at the other locations during 2006. (Figure 80a).

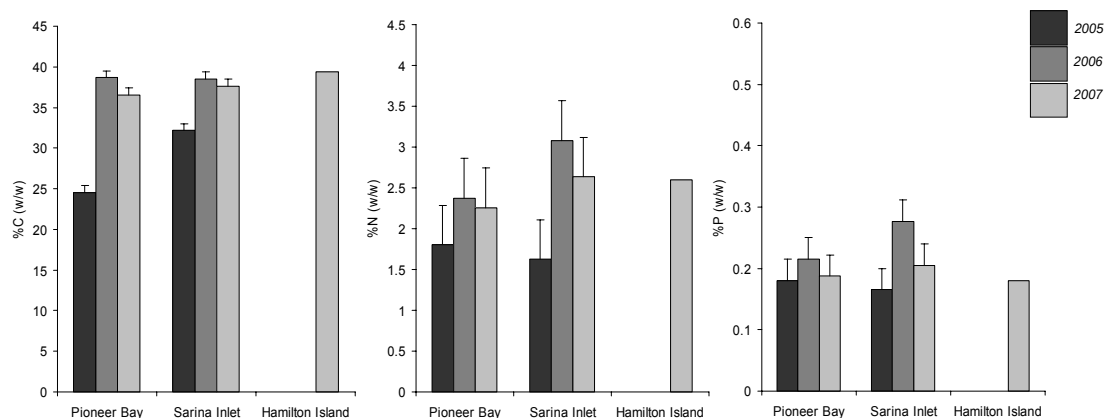


Figure 80. Plant tissue nutrients for *Zostera capricorni* within the Mackay Whitsunday NRM for; a) %C, b) %N and c) %P.

Table 26. *Summary of Least Significant Differences for Zostera capricorni %C from 2005-2007 at Pioneer Bay and Sarina Inlet.*

Location/Year	2005	2006	2007
Pioneer Bay	d	a	b
Sarina Inlet	c	ab	ab

Significant differences between years was evident for %N for this species (ANOVA d.f. (2,3) $p = 0.033$). *Zostera capricorni* at Hamilton Island recorded levels of %N similar to those recorded at the other locations for 2006 and 2007 (Figure 80b). Levels of %N for this species were significantly lower during 2005 (Table 27).

Table 27. *Summary of Least Significant Differences between years for Zostera capricorni % N within the Mackay-Whitsunday NRM.*

Year	Grouping for LSD
2005	b
2006	a
2007	a

Levels of P ranged from 0.16% (Sarina Inlet 2005) up to 0.28% (Sarina Inlet 2006) (Figure 80c). Significant differences were detected between years (ANOVA d.f.(2,3) $p = 0.034$). Levels during 2005 were significantly different from levels recorded in 2006 with 2007 having level similar to both previous years (Table 28). Levels recorded from Hamilton Island for %P were similar to levels recorded from Pioneer Bay but lower than that recorded from Sarina Inlet in 2007.

Table 28. *Summary of Least Significant Differences between years for Zostera capricorni % P within the Mackay-Whitsunday NRM.*

Year	Grouping for LSD
2005	b
2006	a
2007	ab

Halodule uninervis inhabiting the reef habitat recorded the highest %N of all habitats. Levels of %N and %P for this species were higher than the threshold levels calculated by Duarte (1990). *Halophila ovalis* throughout this NRM recorded extremely high %P values. In some instances they were nearly 2.5 times greater than the threshold values determined by Duarte (1990). %N values were also above the threshold value.

%N and %P for *Zostera capricorni* were similar across locations but differed between years. Levels in 2005 were lower through out the NRM. In 2005 levels of %N and %P were below

the threshold levels of 1.8%N and 0.2%P, by 2006 %N was at levels above the threshold and have been maintained there during 2007. Levels of %P rose above this threshold during 2006 but have only been maintained above this level at Sarina Inlet.

Tissue nutrient ratios

Halodule uninervis

Due to unbalanced design caused by a lack of *Halodule uninervis* during 2005 at Sarina Inlet, the data is only presented graphically.

C:N ratios for *Halodule uninervis* ranged from 13:1 (Hamilton Island, 2007) to 17:1 (Pioneer Bay 2005) (Figure 81a). C:N ratios at Pioneer Bay were marginally higher than those recorded at Sarina Inlet. The ratios appeared to be declining with each year of monitoring (Figure 81a). Levels recorded for *Zostera capricorni* at Hamilton Island were the lowest recorded and were substantially lower than C:N ratios recorded at either Pioneer Bay or Sarina Inlet during the monitoring period (Figure 81a).

C:P ratios appeared fairly consistent across locations and years (Figure 81b). N:P ratios in converse to the C:N ratios were higher at Sarina Inlet and appeared to increase across years at Pioneer Bay (Figure 81c). N:P tissue ratios recorded for this species at Hamilton Island in 2007 were the highest recorded at any location.

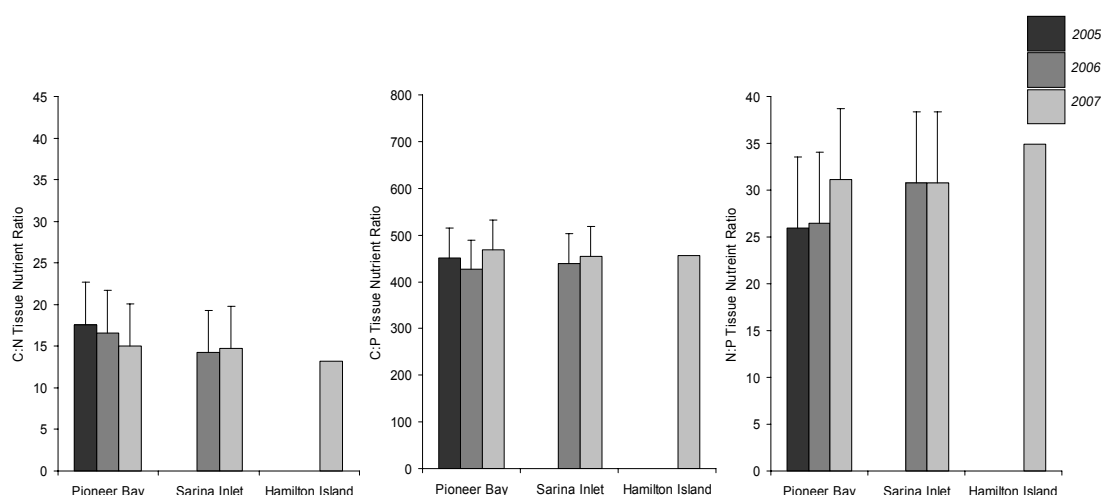


Figure 81. Plant tissue ratios for (a) C:N, (b) C:P and (c) N:P for *Halodule uninervis* at monitored sites within the Mackay –Whitsunday NRM – 2005-2007.

Halophila ovalis

Despite no recording of tissue nutrients for Townsville sites in 2005 (previous section) tissue nutrient ratios were still able to be calculated and analyzed.

Significant differences occurred for all plant tissue nutrient ratio analyses for *Halophila ovalis* (Figure 82). C:N ratios differed significantly between Locations and Years (ANOVA, d.f._(2,3) $\rho = 0.040$). This difference was driven by the high ratio C:N recorded at Sarina inlet during 2005 (Table 29).

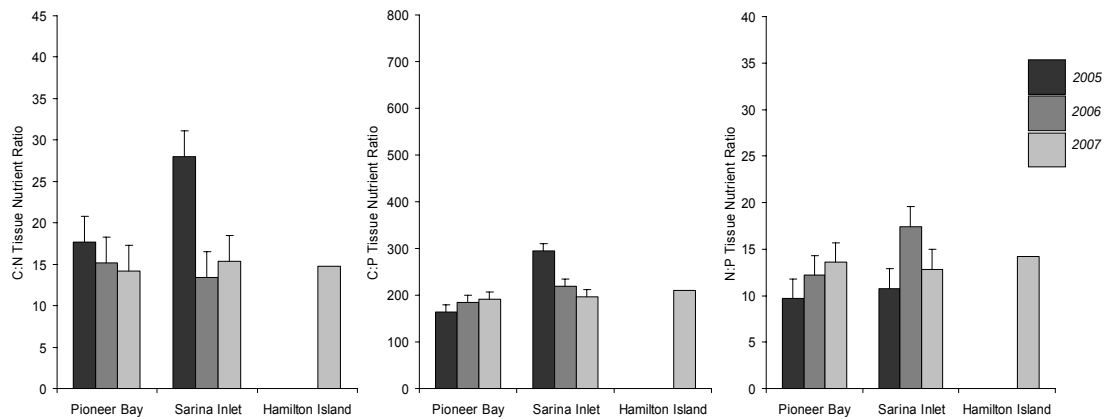


Figure 82. Plant tissue ratios for (a) C:N, (b) C:P and (c) N:P for *Halophila ovalis* at monitored sites within the Mackay –Whitsunday NRM – 2005-2007.

Table 29. Summary of Least Significant Differences for *Halophila ovalis* C:N from 2005-2007 at Pioneer Bay and Sarina Inlet.

Location/Year	2005	2006	2007
Pioneer Bay	ab	b	b
Sarina Inlet	a	b	b

C:P ratios were also significantly different across locations and years (ANOVA, d.f._(2,3) $p = 0.007$. This was driven by the relatively high ratio calculated for C:P during 2005 at Sarina Inlet (Figure 82b, Table 30).

Table 30. Summary of Least Significant Differences for *Halophila ovalis* C:P from 2005-2007 at Pioneer Bay and Sarina Inlet.

Location/Year	2005	2006	2007
Pioneer Bay	b	b	b
Sarina Inlet	a	b	b

N:P ratios differed significantly between years (ANOVA d.f._(2,3) $p = 0.049$. Ratios in 2006 were significantly higher than those recorded during 2005 with ratios in 2007 being intermediate (Figure 82c, Table 31).

Nutrient ratios recorded for *Halophila ovalis* at Hamilton Island are similar to the ratios recorded at other locations/habitats for 2007 (Figure 82).

Table 31. *Summary of Least Significant Differences between years for Halophila ovalis N:P within the Mackay-Whitsunday NRM.*

Year	Grouping for LSD
2005	b
2006	a
2007	ab

Zostera capricorni

C:N ratios differed significantly between locations and years (ANOVA d.f._(2,4) $\rho = 0.045$). In 2005 at Sarina Inlet the C:N ratio was higher than that recorded at Pioneer Bay for any year and significantly higher than any other year at Sarina Inlet recorded for year (Figure 83a, Table 32).

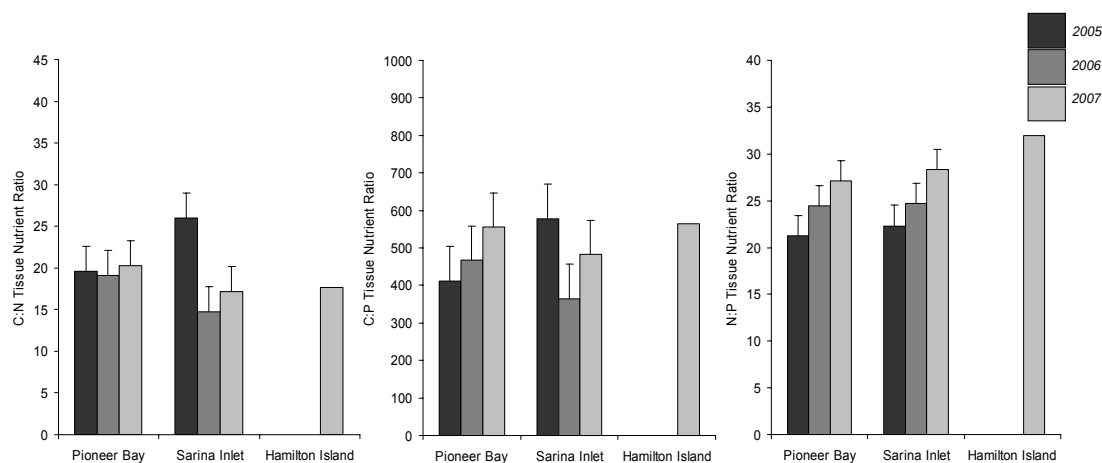


Figure 83. *Plant tissue ratios for (a) C:N, (b) C:P and (c) N:P for Zostera capricorni at monitored sites within the Mackay –Whitsunday NRM – 2005-2007.*

Table 32. *Summary of Least Significant Differences for Zostera capricorni C:N from 2005-2007 at Pioneer Bay and Sarina Inlet.*

Location/Year	2005	2006	2007
Pioneer Bay	ab	ab	ab
Sarina Inlet	a	b	b

No significant differences were detected for C:P ratios. Levels recorded at Hamilton Island (565:1 C:P), were intermediate within the range recorded for this NRM (Figure 83b). N:P ratios differed significantly between years (ANOVA, d.f._(2,4) $\rho = 0.015$). Levels recorded during 2007 being significantly higher than those recorded during 2005 and 2006 (Figure 83c and Table XX). Levels were also significantly different between locations (ANOVA, d.f._(1,2) $\rho = 0.017$). Sarina Inlet consistently recorded higher levels of N:P than Pioneer Bay (Figure 83c, Table 33).

Table 33. *Summary of Least Significant Differences between years for Zostera capricorni N:P within the Mackay-Whitsunday NRM.*

Year	Grouping for LSD
2005	b
2006	b
2007	a

Table 34. *Summary of Least Significant Differences (LSD) for Halodule uninervis C:N for locations monitored within the Mackay Whitsunday NRM.*

Location	Grouping for LSD
Pioneer Bay	b
Sarina Inlet	a

Tissue nutrient ratios for *Halodule uninervis* did not partition plants of this species into different habitats. All C:N ratios were below 20:1, C:P ratios were below 500:1; and N:P were around the 30:1 indicating that all habitats within this region are low light, nutrient rich environments and that *Halodule uninervis* plants are nutrient replete.

In general terms, (exception being Sarina Inlet in 2005) Tissue nutrient ratios for *Halophila ovalis* did not partition plants into different habitats. Like *Halodule uninervis*, ratios for this species describe all seagrass habitats within this NRM as light limited, nutrient rich environments. N:P ratios for this species were well below 30:1 ratio reflecting the high proportion of %P present in the plant tissue signifying that these plants were N limited.

C:N ratios derived from *Zostera capricorni* for this NRM suggest that all locations the light environment is poor. No clear pattern emerged from C:P ratios. At Hamilton Island (reef habitat) C:P ratios signified a nutrient rich environment, while the coastal and estuarine locations oscillated between nutrient rich and nutrient poor regimes according to year. With the exception of Hamilton Island where N:P typified plants that were nutrient replete, N:P ratios for *Zostera capricorni* showed N limitation.

Epiphytes and Macro-algae

Epiphytes cover on seagrass leaf blades at coastal sites was highly variable at both inshore coastal and estuarine sites (Figure 84). Epiphyte cover over the last 12 months was similar to the previous monitoring period and appears seasonal with higher abundance in the Dry season of each year (Figure 84). Percentage cover of macro-algae at coastal sites is also variable, and significantly higher in Pioneer Bay than Sarina Inlet (Figure 84). Epiphyte and macro-algae cover at Hamilton Island is similar at each site (Figure 85). Due to the paucity of data it is not possible to compare between years.

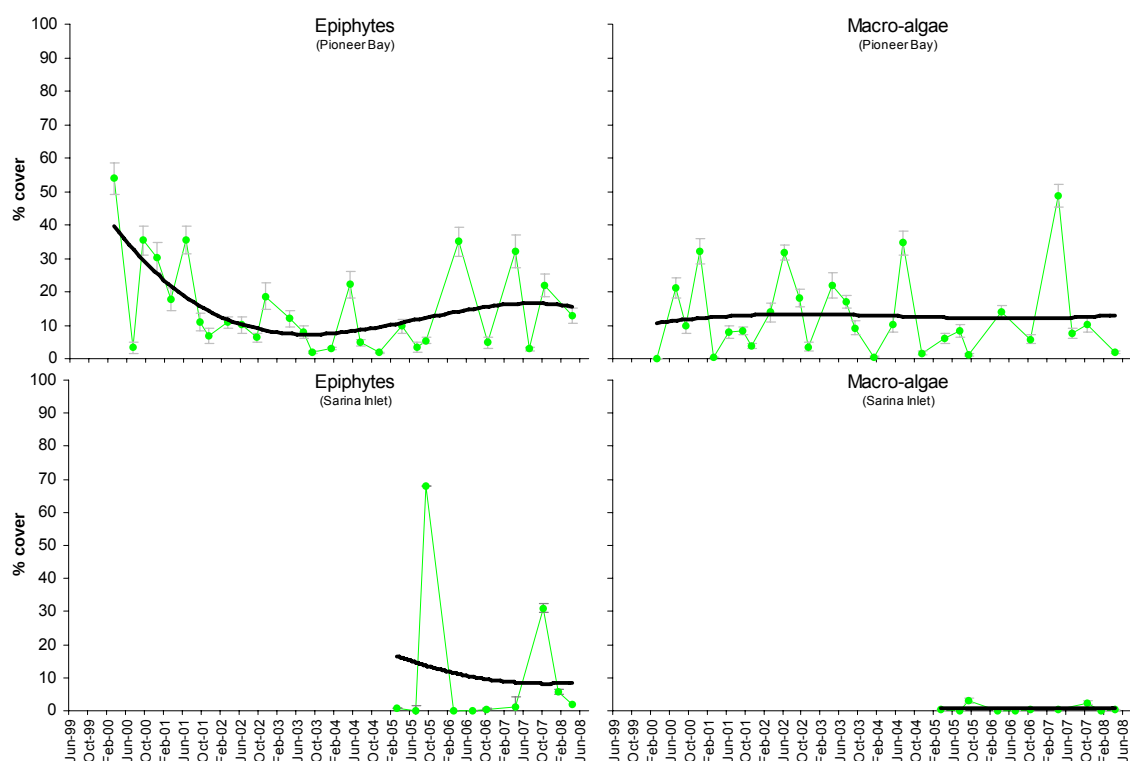


Figure 84. Mean abundance (% cover) ($\pm$ Standard Error) of epiphytes and macro-algae at intertidal coastal (Pioneer Bay) and estuarine (Sarina Inlet) seagrass monitoring locations. NB: Polynomial trendline for all years pooled.

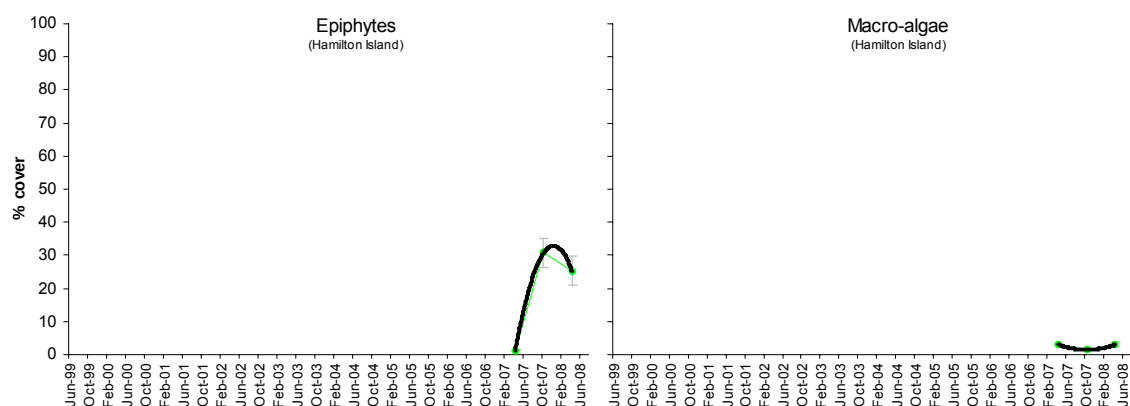


Figure 85. Mean abundance (% cover) ($\pm$ Standard Error) of epiphytes and macro-algae at intertidal reef seagrass monitoring location. NB: Polynomial trendline for all years pooled.

Seagrass meadow edge mapping

Edge mapping was conducted within a 100m radius of all Seagrass-Watch monitoring sites in September/October and March/April of each year (Table 35).

Over the past 12 months, the meadow at Pioneer Bay has remained stable, however the meadow at Sarina Inlet decreased seaward in the late Monsoon (Figure 86). There is insufficient sampling to determine any long-term trends in the meadows at Hamilton Island.

Table 35. Area (ha) of seagrass meadow being monitored within 100m radius of site. Value in parenthesis is % change from October 2005 baseline, and direction of change from previous mapping. Shading indicates decrease in meadow area since baseline. NA=no data available as site not established.

Monitoring Site	October 2005	April 2006	October 2006	April 2007	October 2007	April 2008
PI2	3.432	3.534 (3.0%, increase shoreward)	3.812 (11.1%, increase shoreward)	4.193 (22.2%, increase shoreward)	4.145 (20.8%, decrease seaward)	4.068 (18.5 decrease seaward)
PI3	2.432	2.026 (-16.7%, Decrease shoreward)	3.891 (60%, increase shoreward)	4.418 (81. %, increase shoreward)	4.159 (71%, decrease seaward)	4.183 (72%, increase shoreward)
HM1	NA	NA	NA	NA	0.810	0.917 (13.2 %, increase shoreward)
HM2	NA	NA	NA	NA	0.164	0.05 (69.2%,decrease overall)
SI1	3.374	1.726 (-48.8%, decrease seaward)	4.425 (31.2%, increase shoreward)	4.092 (21.0%, increase shoreward)	4.736 (40.4%, increase overall)	1.608 (52.4%,decrease overall)
SI2	3.747	2.46 (-34. %,3 decrease shoreward)	3.679 (-1.8%, decrease seaward)	3.536 (-5.6%, decrease seaward)	4.739 (26.5%, increase overall)	1.821 (51.4%,decrease overall)

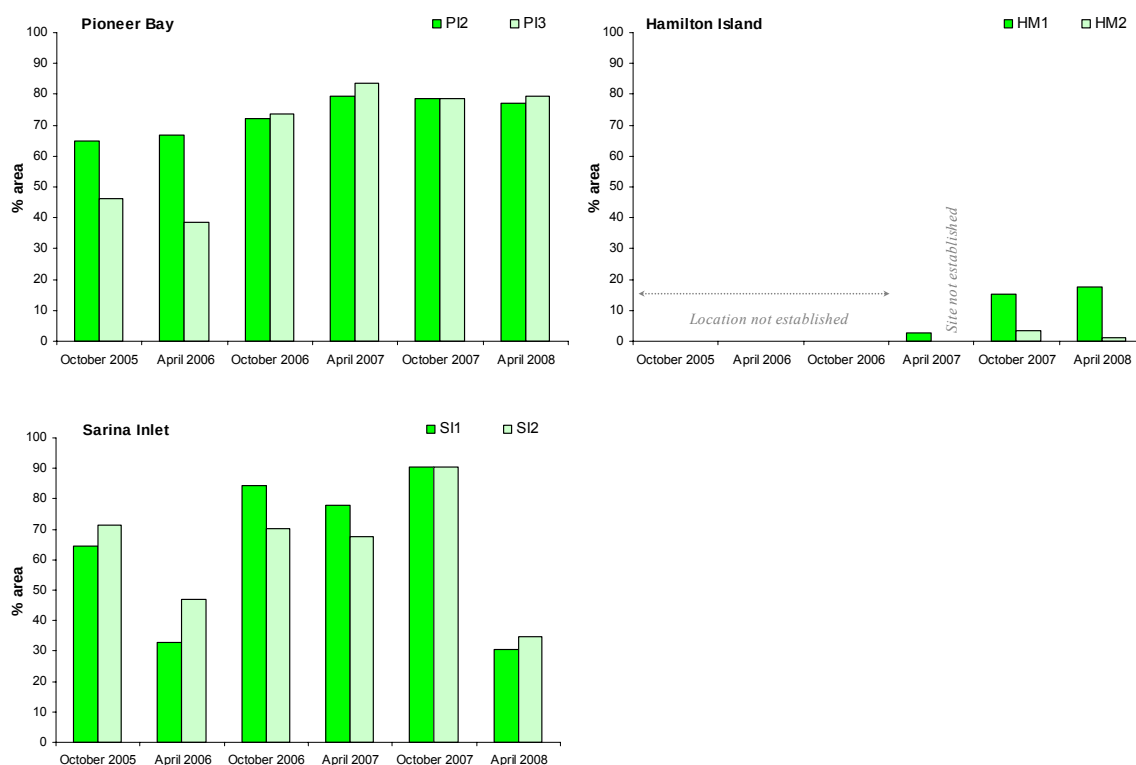


Figure 86. Percentage of area (100m radius of monitoring site) covered by seagrass at each coastal (Pioneer Bay), reef (Hamilton Is) and estuarine (Sarina Inlet) monitoring locations.

Sediment nutrients

Mean levels of adsorbed NH_4^+ for this region ranged from $185 \mu\text{mol} \text{ L}_{\text{sed}}^{-1}$ (Sarina Inlet 2007) to $548 \mu\text{mol} \text{ L}_{\text{sed}}^{-1}$ (Pioneer Bay, 2006). Levels at Hamilton Island were intermediate (Figure 87a). No significant differences were detected between locations or years, despite levels of ammonium being generally higher at Pioneer Bay than that recorded for Sarina Inlet (Figure 87a). There was quite an increase in levels of ammonium ($\sim 200 \mu\text{mol} \text{ L}_{\text{sed}}^{-1}$) recorded at Pioneer Bay in 2007 (Figure 87a).

Levels of adsorbed PO_4^{3-} differed significantly in regard to Location and Year (ANOVA d.f. (1,11) $p = 0.003$). There was a noticeable trend of decreasing phosphate levels through the years for Pioneer Bay and Sarina Inlet (Figure 87b). The declines in levels of phosphate from 2005 to 2006 were substantial at both Pioneer Bay and Sarina Inlet (Figure 87b).

Levels of adsorbed PO_4^{3-} at Pioneer Bay during 2005 were significantly higher than any other recordings during this entire monitoring period (Figure 87b). At this location phosphate levels decreased significantly each year (Figure 87b, Table 36).

At Sarina Inlet levels of phosphate during 2005 were significantly higher than levels recorded at this location for 2006 and 2007 which were similar to each other and to the levels recorded at Pioneer Bay in 2007 (Figure 87). Hamilton island recorded level the highest adsorbed phosphate for 2007 but equivalent to levels recorded inshore at Pioneer Bay in 2006 (Figure 87b).

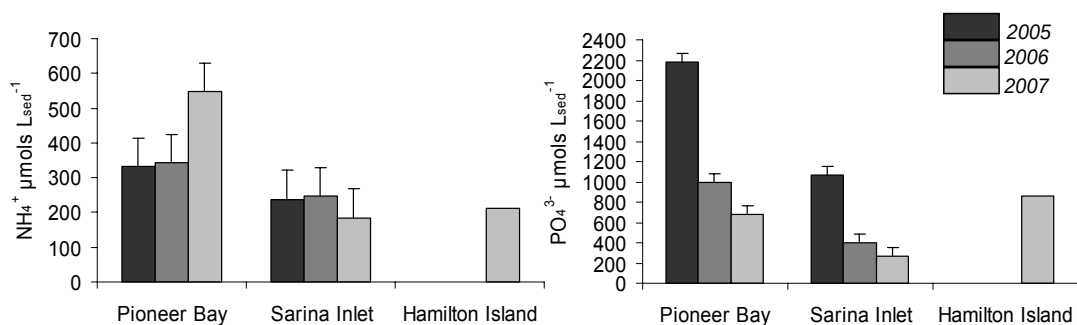


Figure 87. Sediment nutrients levels for a) ammonium, b) phosphate and c) N:P for the monitored sites within the Mackay-Whitsunday NRM: 2005 - 2007.

Table 36. Summary of Least Significant Differences for adsorbed sediment Phosphate from 2005-2007 for Pioneer Bay and Sarina Inlet.

Location/Year	2005	2006	2007
Pioneer Bay	a	b	cd
Sarina Inlet	bc	d	d

The declines in adsorbed PO_4^{3-} at Pioneer Bay and Sarina Inlet over this monitoring period was reflected by increases in the N:P (Figure 87). Sediment N:P ratios ranged from 0.8:1 (Pioneer Bay, 2007 - $\text{N} > \text{P}$) to 0.15:1 (Pioneer Bay, 2005 - $\text{N} < \text{P}$). The location by year interaction was significant (ANOVA d.f. (1,11), $p = 0.018$). N:P during 2007 at both Sarina Inlet and Pioneer Bay were significantly higher than ratios recorded for 2005 and 2006 - Pioneer Bay, and 2005 - Sarina Inlet. Ratios recorded for Sarina Inlet in 2006 were similar to those recorded during 2007 at this location (Table 37).

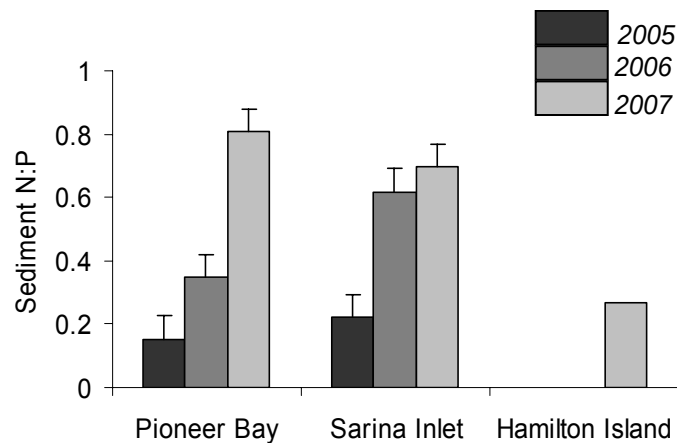


Figure 88. Sediment nutrients levels for N:P for the monitored sites within the MacKay-Whitsunday NRM:2005 - 2007.

Table 37. Summary of Least Significant Differences for adsorbed N:P from 2005-2007 for Pioneer Bay and Sarina Inlet.

Location/Year	2005	2006	2007
Pioneer Bay	d	c	a
Sarina Inlet	d	b	ab

Sediment ammonium at Pioneer Bay was higher than the median level recorded for the GBR. Sarina Inlet and Hamilton Island recorded levels lower than the median.

Significant differences were detected for adsorbed P within this NRM. Levels were substantially higher at Pioneer Bay than they were at Sarina Inlet. There has also been a substantial decline in levels of phosphate at both locations. This has been inversely reflected in increasing levels of N:P ratios.

Sediment herbicides

Diron was the only herbicide detected, and was present at all sites in coastal and estuarine monitoring locations in Post-Wet 2008.

Table 38. Concentration of herbicides ($\mu\text{g kg}^{-1}$) in meadow sediments in post Wet 2008. ND=not detectable, $<0.05 \mu\text{g kg}^{-1}$

Site	Flumeturon	Diuron	Simazine	Atrazine	Desethyl Atraz.	Desisopropyl Atraz.	Hexazinone	Tebuthiuron	Ametryn	Prometryn	Bromacil	Terbutryn	Metolachlor
PI2	ND	0.21	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PI3	ND	0.48	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
HM1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
HM2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SI1	ND	0.32	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SI2	ND	0.27	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Within meadow canopy temperature

Temperature loggers were deployed at all sites monitored in the region, however the loggers from over the 2007/2008 Monsoon were lost from the Hamilton island sites (Figure 89). Within canopy temperature was monitored at coastal and estuarine locations (Figure 89), and generally follows a similar pattern. No extreme temperatures ($>40^{\circ}\text{C}$) 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 of the Dry season at (Figure 89).

Mean within canopy temperature monitored at Pioneer Bay were within the $19 - 29^{\circ}\text{C}$ range, with highest mean temperatures in January 2008. Although data over the last 12 months is limited, they do not indicate temperatures greater than in previous years (Figure 90).

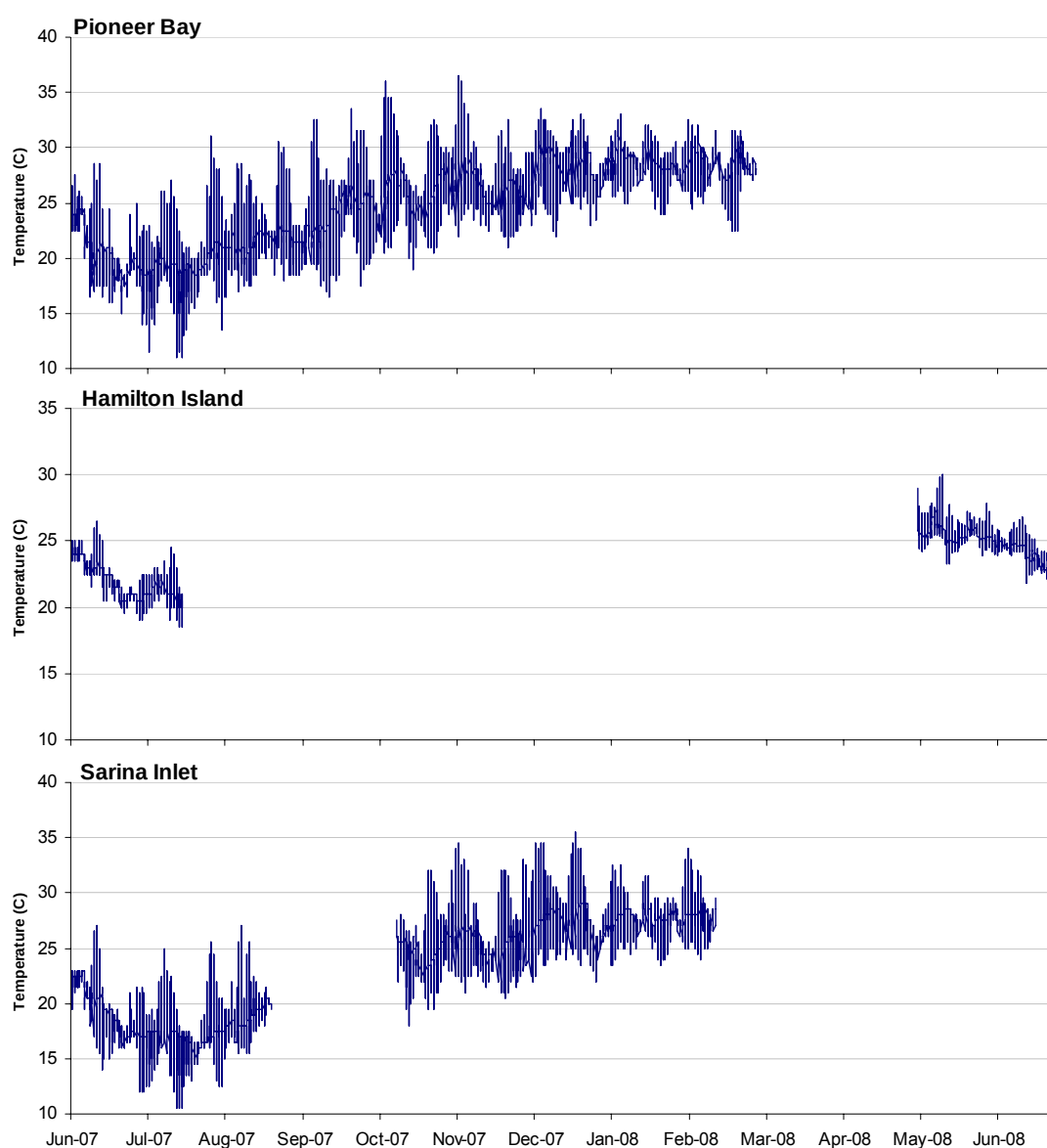


Figure 89. *Within seagrass canopy temperature ($^{\circ}\text{C}$) at coastal (Pioneer Bay), estuarine (Sarina Inlet) and offshore fringing-reef (Hamilton Island) intertidal meadows within the Mackay Whitsunday region over the 2007/2008 monitoring period.*

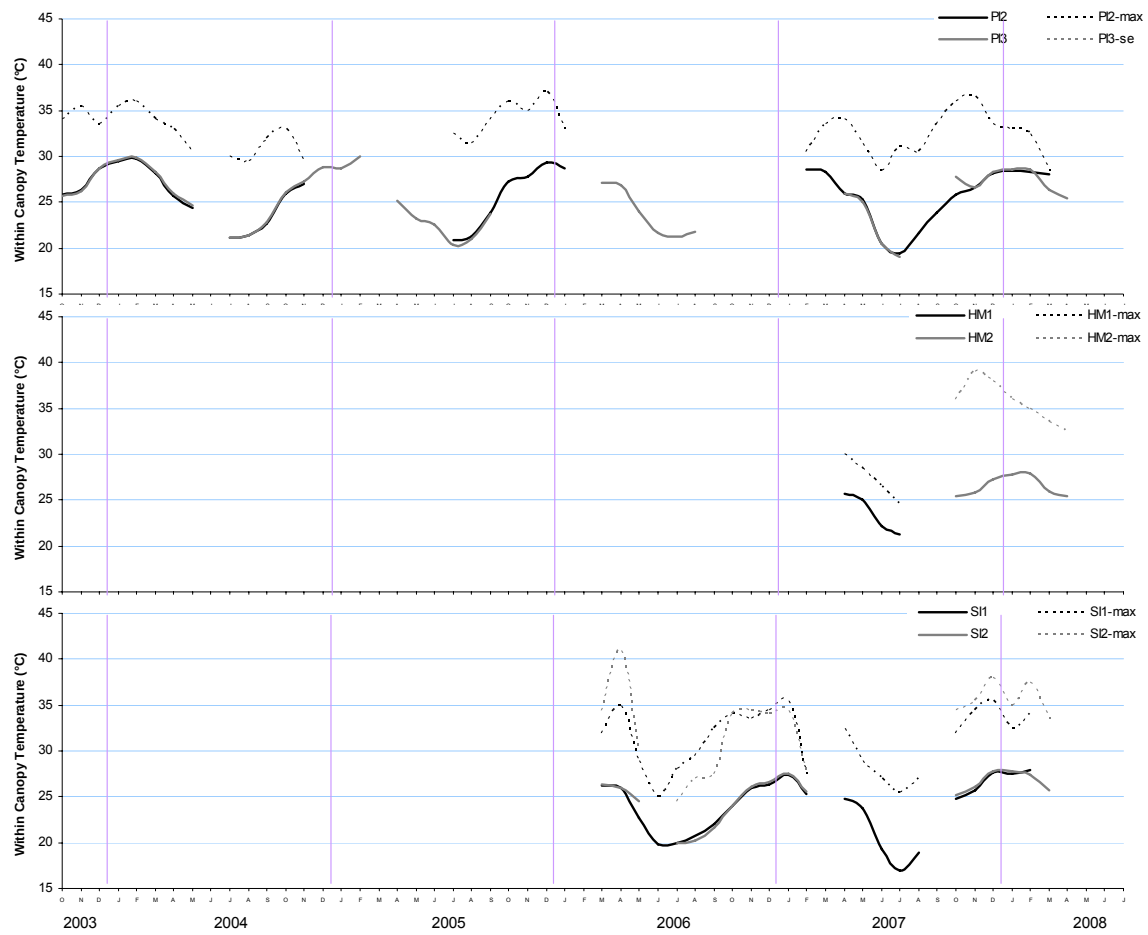


Figure 90. Monthly mean and maximum within seagrass canopy temperature (°C) at intertidal meadows in coastal (Pioneer Bay), fringing-reef (Hamilton Island) and estuarine (Sarina Inlet) habitats within the Mackay Whitsunday region.



Fitzroy

The Fitzroy region covers an area of nearly 300,000 km². 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 (NRM 2007c). 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 GBRWHA 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 GBRWHA 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 NRM 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.

MMP monitoring sites within this NRM 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 from anthropogenic influence. In contrast, the estuarine sites are located within Gladstone Harbour: a heavily industrialized port. Offshore reef sites are located in 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 91). 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 about MSL.

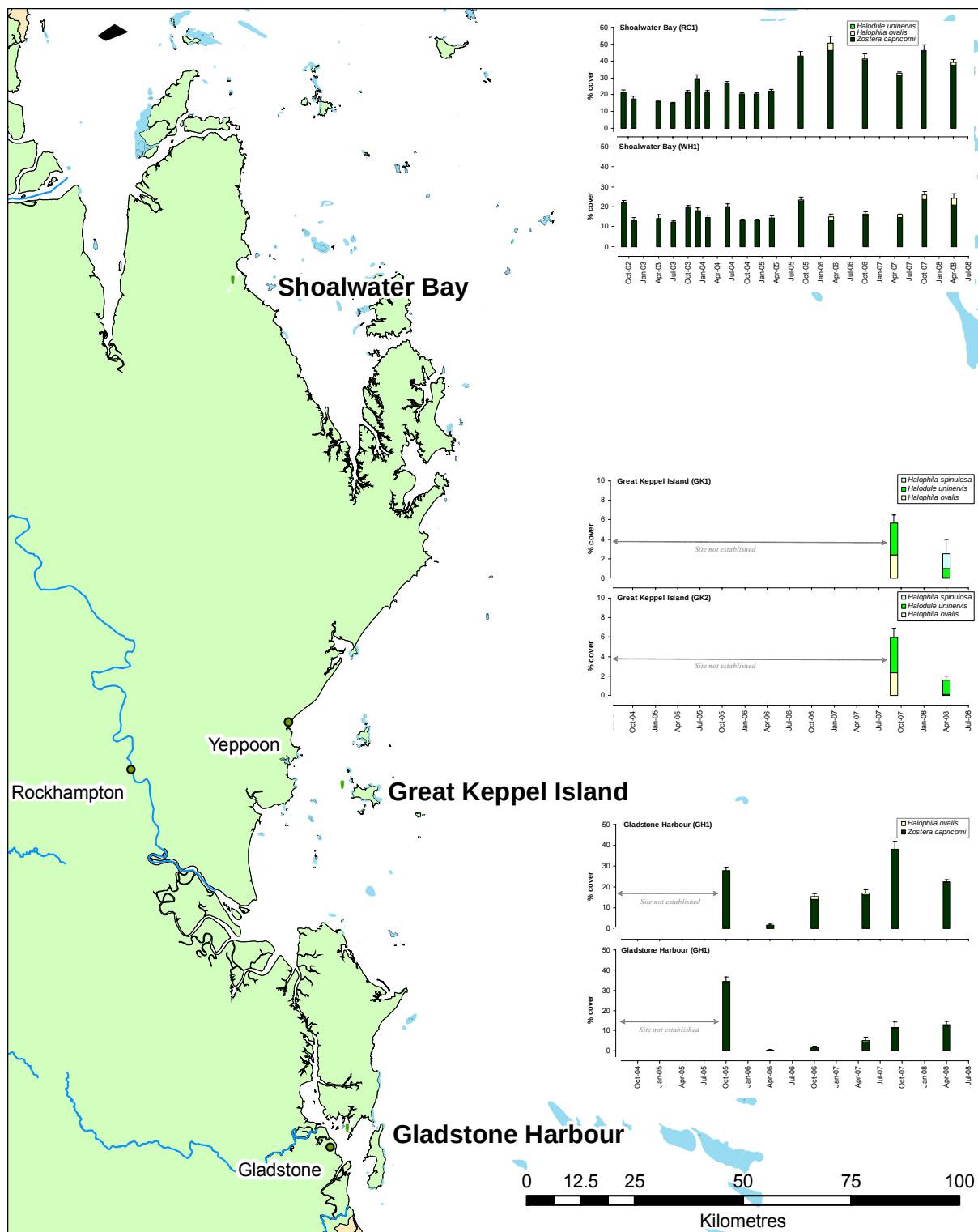


Figure 93. Mean percentage cover for each seagrass species at Seagrass-Watch long-term monitoring sites in the Fitzroy Region (+ Standard Error). NB: if no sampling conducted then x-axis is clear.

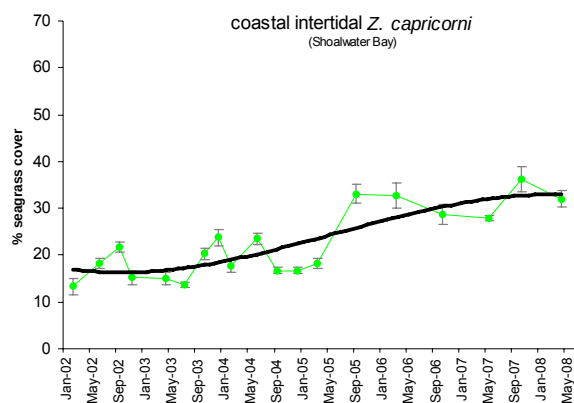


Figure 94. Change in seagrass abundance (percentage cover) at coastal intertidal meadows in Shoalwater Bay (Fitzroy region).



Monitoring sites RC1 (left) and WH1 (right) in Shoalwater Bay.

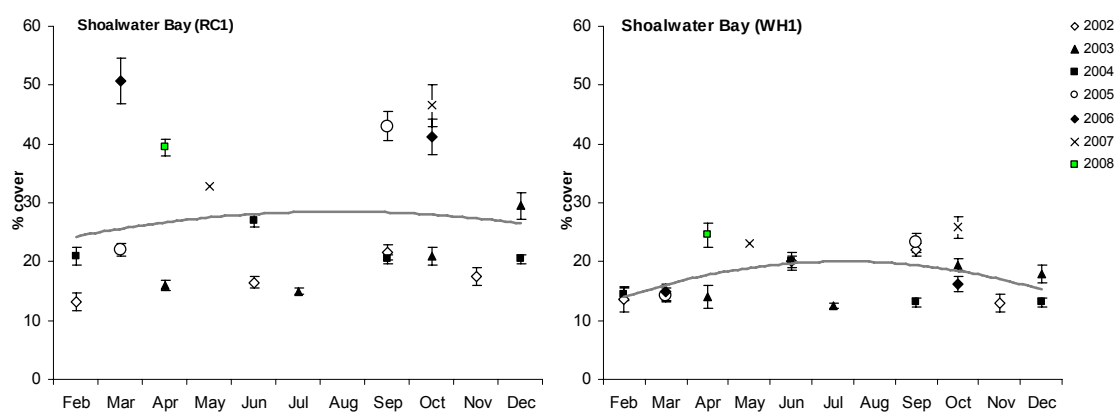


Figure 95. Mean percentage seagrass cover (all species pooled) ($\pm$ Standard Error) at Shoalwater Bay long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.

Gladstone Harbour sites were located in a large *Zostera capricorni* dominated meadow (Figure 93) on the extensive intertidal Pelican Banks south of Curtis Island. Seagrass distribution decreased significantly across the region in early 2006, however the meadow has significantly recovered over the past 18 months (Figure 96).

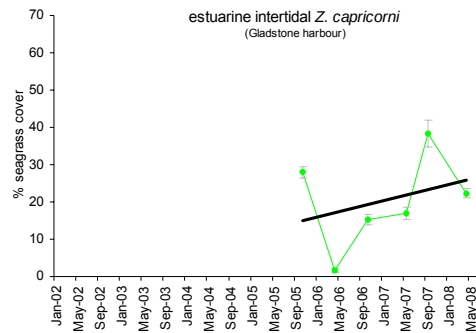


Figure 96. Change in seagrass abundance (percentage cover) at estuarine intertidal meadows in Gladstone Harbour (Fitzroy region).



Intertidal monitoring site on Pelican Banks south of Curtis Island, Gladstone Harbour.

The monitoring sites at Great Keppel Island (GK1 and GK2) were only recently established, and differed from the coastal sites as they were composed predominately of *H. uninervis* on sand substrate (Figure 97).

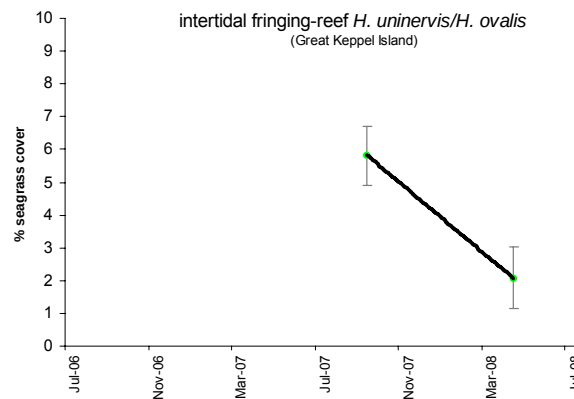


Figure 97. Change in seagrass abundance (percentage cover) at intertidal fringing –reef meadows at Great Keppel Island (Fitzroy region).



Monitoring at Monkey Beach, Great Keppel Island.

Seagrass reproductive health

Evidence of reproductive effort was found at all sites although was very low on Great Keppel Island (Figure 98). Gladstone Harbour was increasing its reproductive effort, mostly due to meadow recovery from a decline in 2006 (see change in cover above). This recovery of reproductive effort demonstrates resilience to disturbance at this site. The increase in reproductive effort in Shoalwater Bay (RC, Figure 98) does not appear to correspond to any particular factor.

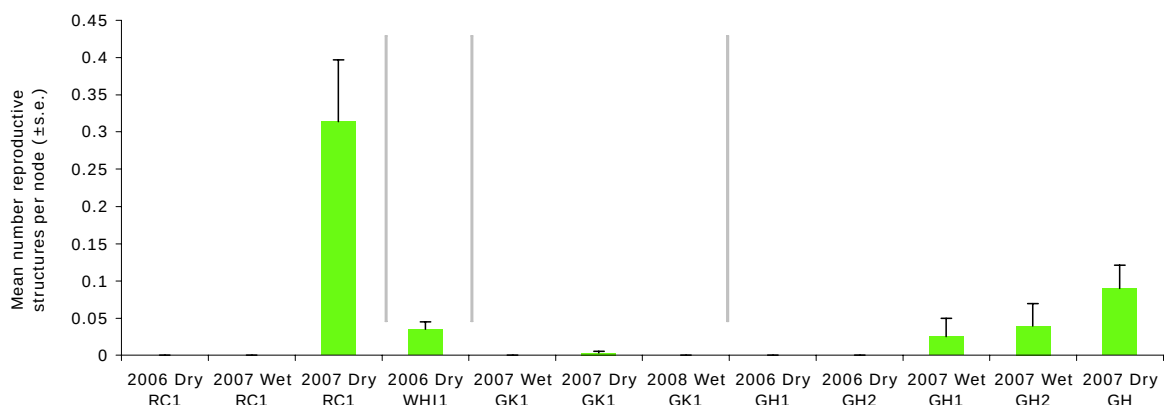


Figure 98. *Mean number of reproductive structures (flowers, seeds, or fruits) per node across all seagrass species and all years sampled across sites in the Fitzroy Region; Ross Creek, Wheelans Hut, Great Keppel Island and Gladstone Harbour (+ Standard Error).*

Seagrass tissue nutrients

Great Keppel Island was included in the monitoring of intertidal seagrass meadows for the first time in October 2007. The inclusion of this site extends the monitoring within this NRM to now include three seagrass habitat types (estuarine, coastal and reef). The three habitat types had different sediments. The estuarine habitat (Gladstone Harbour) had sediments that were a mixture of sand and mud, while the coastal habitat (Shoalwater Bay) was predominantly mud and Great Keppel Island (reef habitat) was characterized by sand sediments.

Halodule uninervis

No values were recorded during 2005 due to contamination. *Halodule uninervis* was absent from harvested samples during 2006.

Values of %C and %N recorded from *Halodule uninervis* at Great Keppel Island were higher than those recorded at Shoalwater Bay (Figure 99a,b). Levels of %P for this species were similar across the locations (Figure 99c).

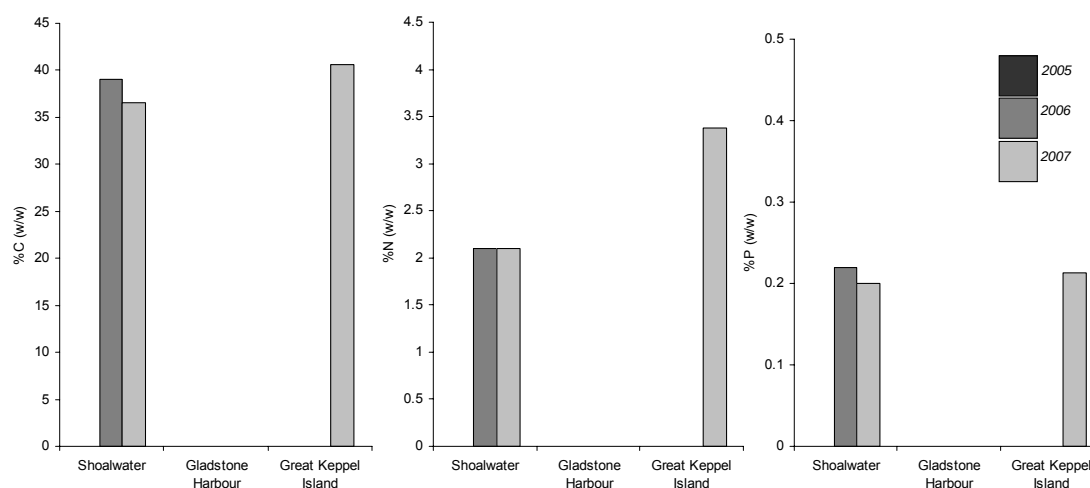


Figure 99. Plant tissue nutrients for *Halodule uninervis* within the Fitzroy NRM for; a) %C, b) %N and c) %P

Halophila ovalis

There are no records from our established monitoring sites for 2005 due to contamination of samples during the grinding process. This was further compounded by the lack of sufficient biomass at one of the Shoalwater sites during 2007. The data is only shown graphically (Figure 100).

There appears to be trend of increasing percentages of all nutrient tissues (Figure 100). Tissue nutrient levels at Gladstone Harbour were much higher than those recorded at Shoalwater in 2006 (Figure 100). By 2007 Shoalwater nutrients were at levels comparable to those recorded at Gladstone Harbour in 2006 (Figure 100). Nutrient levels at Monkey Beach, Great Keppel Island were at similar levels for %C (Figure 100a), slightly higher for %N (Figure 100b) and much lower for %P (Figure 100c).

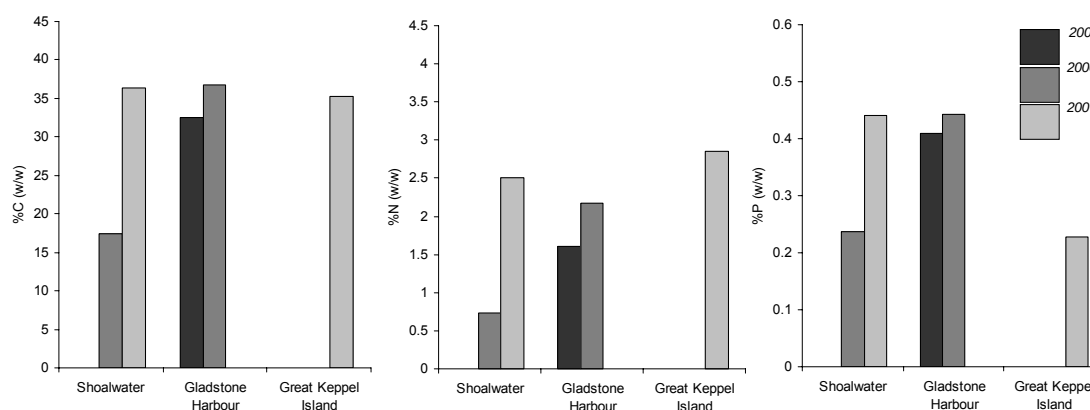


Figure 100. Plant tissue nutrients for *Halophila ovalis* within the Fitzroy NRM for; a) %C, b) %N and c) %P

Zostera capricorni

Zostera capricorni at Great Keppel during 2007 recorded the highest %C (40%) for any location or year monitored (Figure 101a). This level was not that much greater than levels recorded in 2006 and 2007 at Shoalwater and Gladstone Harbour which was greater than values recorded during 2005 at these locations. October 2007 was the first time that any monitoring had occurred at Monkey Beach Great Keppel. This location was not included in the subsequent analyses. Significant yearly effects were detected for %C, for those Locations included in the analyses (ANOVA d.f. (2,2) $p = 0.024$). Levels of %C for *Zostera capricorni* during 2005 were significantly lower than those recorded for 2006 and 2007 (Table 39). No significant differences were detected for either %N or %P for this species. %N ranged from 3% (Great Keppel Island 2007) to 1.2% (Shoalwater, 2005) (Figure 101b). Levels of %P ranged 0.23% (Great Keppel Island, 2007) to 0.13% (Gladstone Harbour and Shoalwater, 2005)(Figure 101c).

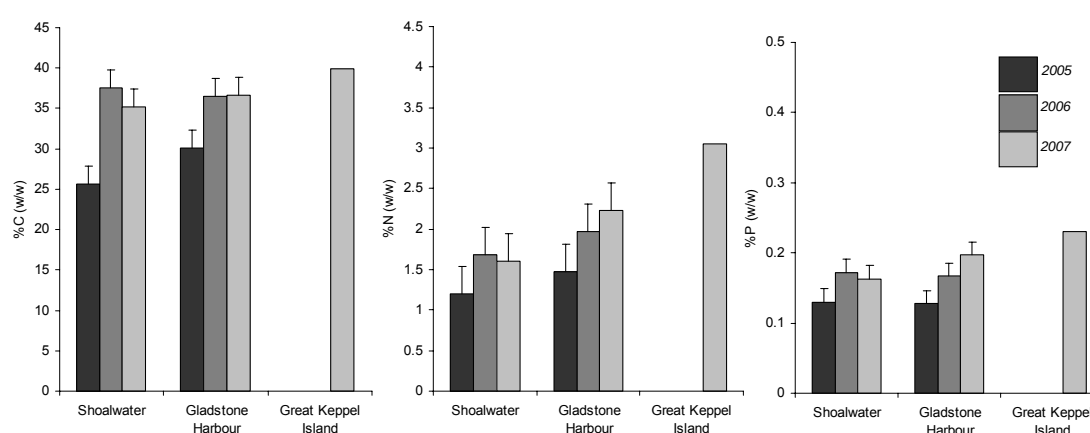


Figure 101. Plant tissue nutrients for *Zostera capricorni* within the Fitzroy NRM for; a) %C, b) %N and c) %P

Table 39. Summary of Least Significant Differences between years for %C of *Zostera capricorni* at within the Fitzroy NRM.

Year	Grouping for LSD
2005	b
2006	a
2007	a

Tissue nutrient ratios

There were too many missing values of the tissue nutrient ratios for both *Halophila ovalis* and *Halodule uninervis* for any meaningful statistical analyses to be performed. Tissue nutrient ratios for these species are presented graphically. The number of samples for *Zostera capricorni* while not great was adequate to allow for the ANOVAs to proceed.

Halodule uninervis

At Shoalwater Bay (the only location with a full suite of data), there has been a major decline in tissue nutrient ratios between 2005 and 2006 with 2007 levels being maintained at similar amounts to 2006 (Figure 102). At Great Keppel Island C:N ratios are the much lower than those recorded at Shoalwater (Figure 102a) while C:P and N:P ratios are higher than those recorded for the same monitoring period(Figure 102 b,c). N:P ratios are particularly high.

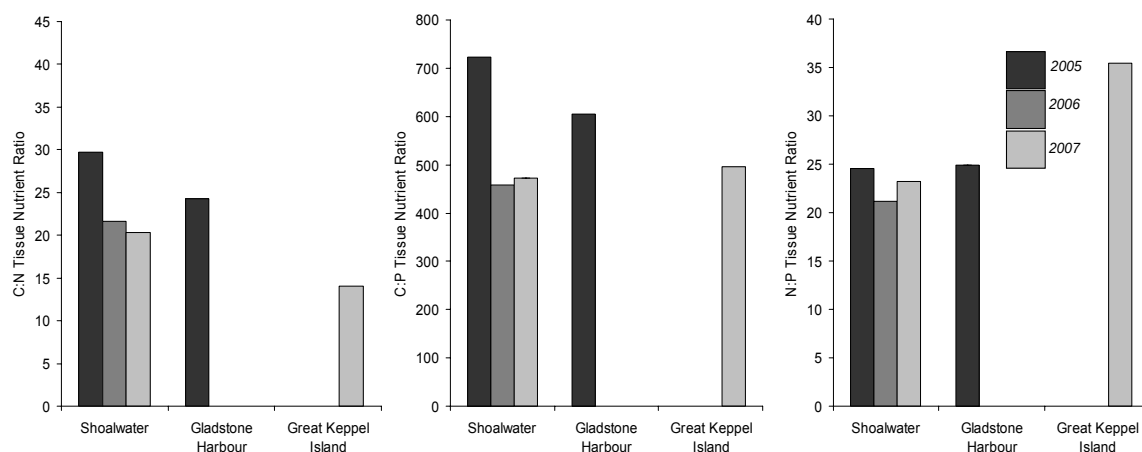


Figure 102. Plant tissue ratios for (a) C:N, (b) C:P and (c) N:P for *Halodule uninervis* at monitored sites within the Fitzroy NRM – 2005-2007.

Halophila ovalis

Like the results for *Halodule uninervis* C:N ratios have declined since monitoring began in 2005 (Figure 103a). Ratios are quite low for those locations that had recordings in 2007. C:P ratios are extraordinarily low for this species at both Shoalwater and Gladstone Harbour (Figure 103b). N:P values are also low at these two locations (Figure 103c). The highest plant N:P ratios was recorded from plants at Great Keppel Island.

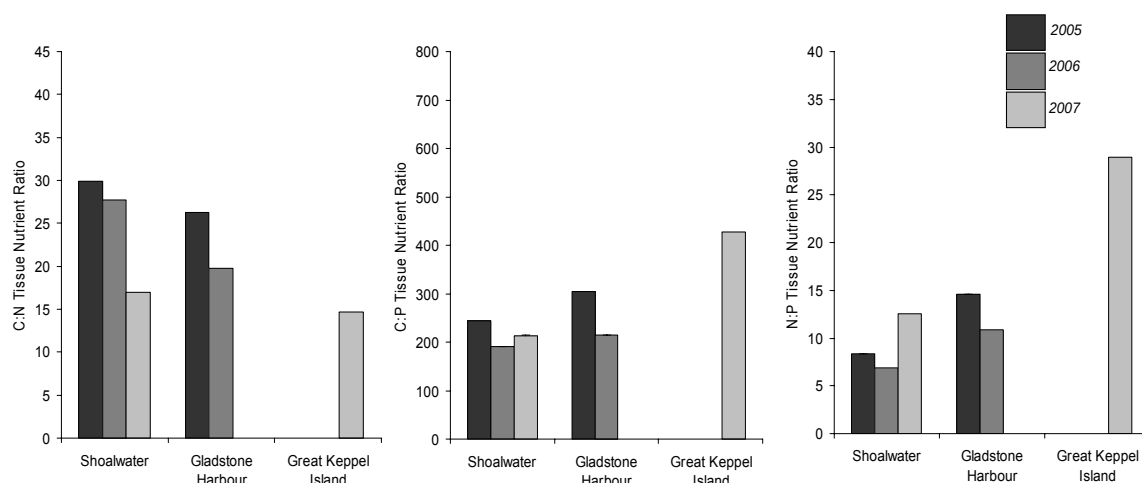


Figure 103. Plant tissue ratios for (a) C:N, (b) C:P and (c) N:P for *Halophila ovalis* at monitored sites within the Fitzroy NRM – 2005-2007.

Zostera capricorni

C:N and N:P ratios did not differ significantly between years or locations for this species. Significant differences in C:P ratios were detected between locations and within locations across years (ANOVA d.f._(2,3) $p = 0.040$) (Figure 104b). C:P at Gladstone Harbour during 2005 was significantly higher than ratios recorded at Shoalwater (2005) and at Gladstone Harbour (2007) (Table 40).

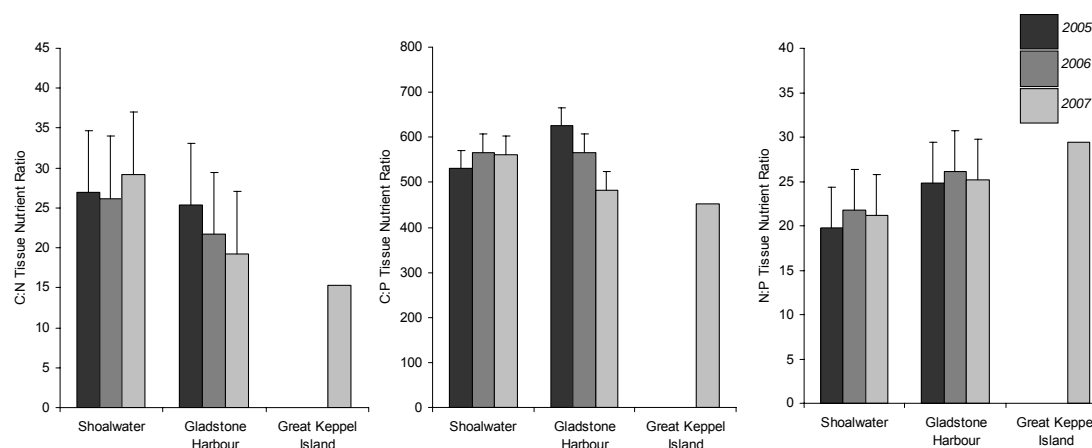


Figure 104. Plant tissue ratios for (a) C:N, (b) C:P and (c) N:P for *Zostera capricorni* at monitored sites within the Fitzroy NRM – 2005-2007.

Table 40. Summary of Least Significant Differences for *Zostera capricorni* C:P from 2005-2007 at locations being monitored in the Fitzroy NRM.

Location/Year	2005	2006	2007
Shoalwater	bc	ab	ab
Gladstone Harbour	a	ab	c

Epiphytes and Macro-algae

Epiphytes cover on seagrass leaf blades at coastal sites were relatively low but higher and more variable at estuarine sites (Figure 105). Epiphyte cover over the last 12 months was similar to the previous monitoring period and appears seasonal with higher abundance in the Dry season of each year (Figure 105). Percentage cover of macro-algae at coastal sites has decreased over the last monitoring period, but is very highly variable at estuarine sites (Figure 105).

Epiphyte and macro-algae cover at Great Keppel Island is similar at each site, however due to the paucity of data it is not possible to compare between years (Figure 106).

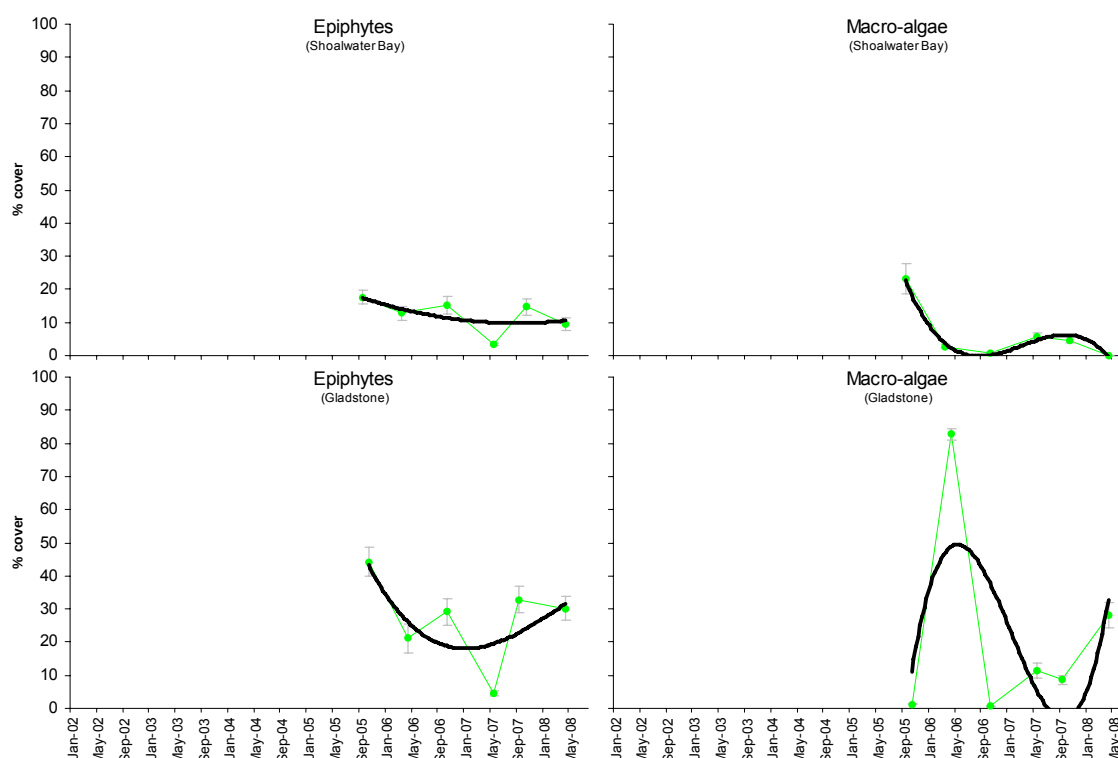


Figure 105. Mean abundance (% cover) ($\pm$ Standard Error) of epiphytes and macro-algae at intertidal coastal (Shoalwater Bay) and estuarine (Gladstone Harbour) seagrass monitoring locations. NB: Polynomial trendline for all years pooled.

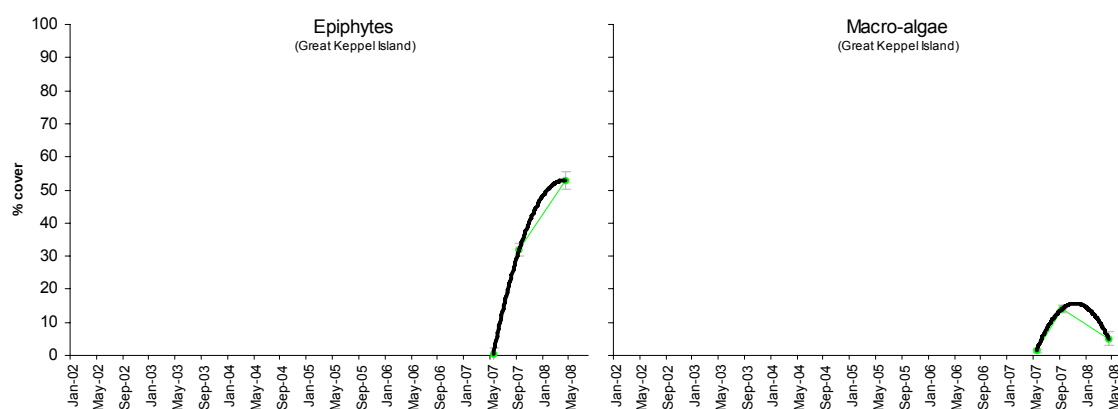


Figure 106. Mean abundance (% cover) ($\pm$ Standard Error) of epiphytes and macro-algae at the intertidal offshore reef (Great Keppel Island) seagrass monitoring location. NB: Polynomial trendline for all years pooled.

Seagrass edge mapping

Edge mapping was conducted within a 100m radius of all Seagrass-Watch monitoring sites in September/October and March/April of each year (Table 41). The coastal meadows in Shoalwater Bay have remained stable since monitoring began, however the estuarine meadow at Gladstone Harbour has fluctuated greatly over the same period (Figure 107). In early 2006 the Gladstone Harbour meadow was absent, but recovered in distribution by October 2006. In the late Dry 2007 the meadow decreased in size due to the prevalence of drainage channels forming within 100m of the monitoring sites across the intertidal banks (Table 41, Figure 107).

Table 41. Area (ha) of seagrass meadow being monitored within 100m radius of site. Value in parenthesis is % change from October 2005 baseline, and direction of change from previous mapping. Shading indicates decrease in meadow area since baseline. NA=no data available as site not established.

Monitoring Site	October 2005	April 2006	October 2006	April 2007	October 2007	April 2008
RC1	5.38	5.38 (No change)	5.396 (0.3%, increase shoreward)	5.384 (0.01%, increase shoreward)	5.396 (0.3%, negligible)	5.396 (0.3%, negligible)
WH1	5.397	5.397 (No change)	5.397 (No change)	5.397 (No change)	5.397 (No change)	5.397 (No change)
GH1	5.394	0 (-100% Meadow absent)	5.394 (Meadow recovered)	5.394 (Meadow recovered)	4.179 (-22.5%, decrease overall)	4.487 (-16.8%, increase overall)
GH2	5.174	0 (-100% Meadow absent)	5.394 (4.3%)	5.174 (0.01%)	4.733 (-8.5%, decrease seaward)	5.087 (-1.7%, increase shoreward)
GK1	NA	NA	NA	NA	2.513	0.526 (-79.1%, decrease overall)
GK2	NA	NA	NA	NA	3.998	2.368 (-40.8%, decrease overall)

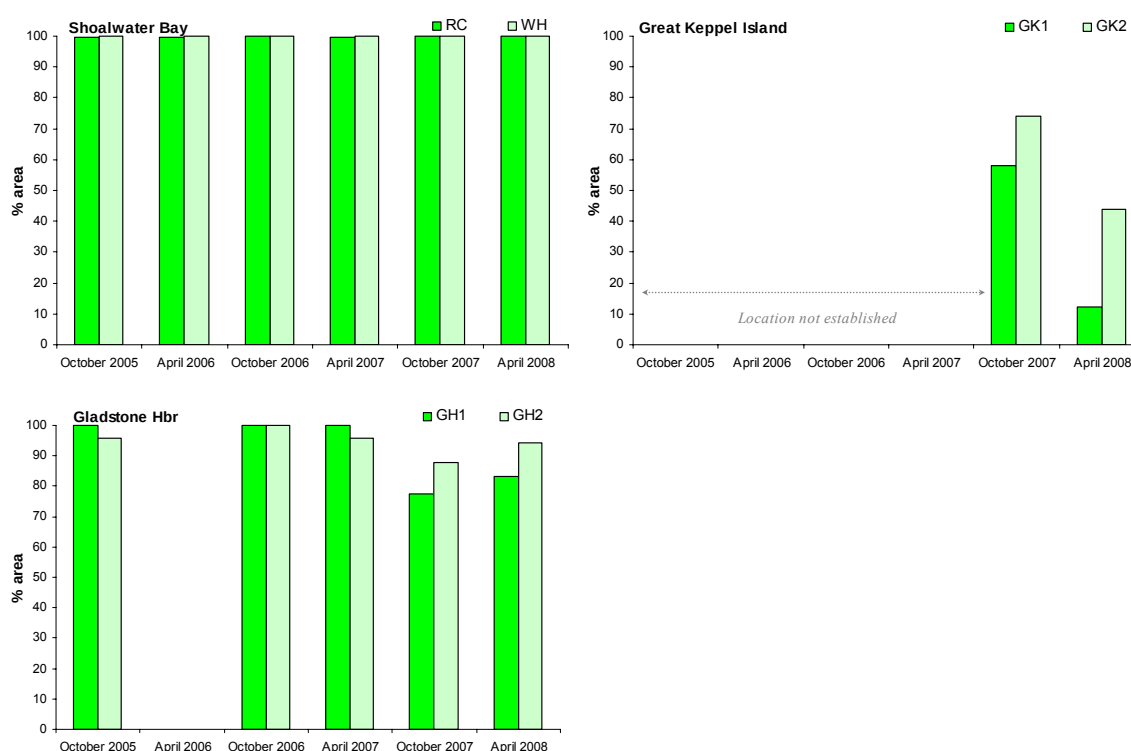


Figure 107. Percentage of area (100m radius of monitoring site) covered by seagrass at each monitoring site at Shoalwater Bay, Great Keppel Island and Gladstone Harbour locations.

Sediment nutrients

Levels of NH_4^+ did not differ between locations. Levels recorded at Great Keppel however were extremely low in comparison to the other locations (Figure 108a). Levels of adsorbed

phosphate were significantly different between years (ANOVA, d.f. (2,3) $p = 0.003$). Adsorbed phosphate was significantly higher in 2005 than levels recorded during 2006 and 2007 (Figure 108b, Table 42). Adsorbed phosphate at Great Keppel Island was much lower than levels recorded at any other location (Figure 108b).

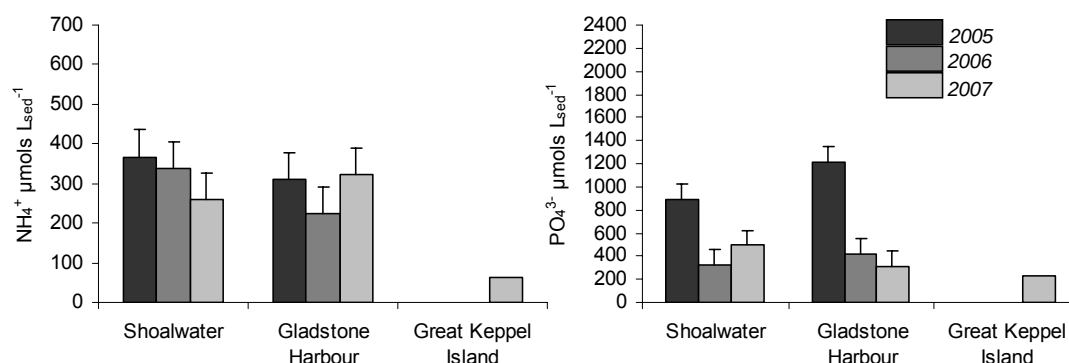


Figure 108. *Sediment nutrients levels for a) ammonium, b) phosphate and for the monitored sites within the Fitzroy NRM:2005 - 2007.*

Table 42. *Summary of Least Significant Differences between years for adsorbed phosphate within the Fitzroy NRM.*

Year	Grouping for LSD
2005	a
2006	b
2007	b

This decreases in adsorbed phosphate were reflected in the increasing sediment N:P ratios (Figure 109). Great Keppel recorded the lowest ratio in 2007.

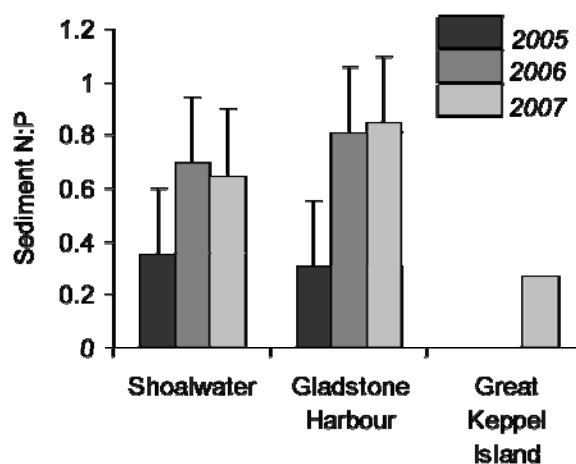


Figure 109. *Sediment N:P for the monitored sites within the Fitzroy NRM:2005 - 2007.*

With the exception of Gladstone Harbour in 2006 and Great Keppel Island (2007), all other recordings of sediment ammonium in this region were above the median value. Recordings of

Great Keppel were extremely low and were the lowest ever recorded for this monitoring program.

Sediment phosphate at Shoalwater during 2006 represents the median ammonium levels for the GBR since monitoring commenced in 2005. Levels recorded at Gladstone Harbour (2006) and Shoalwater (2007) are below this median value. All other years and locations recorded values above this median. There has been a significant decline in the levels of sediment phosphate at both Shoalwater and Gladstone Harbour since monitoring commenced. This has been inversely reflected in increasing levels of N:P ratios.

Sediment herbicides

Diuron was the only herbicide detected, and was present at only one estuarine site (Gladstone Harbour) in Post-Wet 2008.

Table 43. *Concentration of herbicides ($\mu\text{g kg}^{-1}$) in meadow sediments in post Wet 2008.*
ND=not detectable, $<0.05 \mu\text{g kg}^{-1}$

Site	Flumeturon	Diuron	Simazine	Atrazine	Desethyl Atraz.	Desisopropyl Atraz.	Hexazinone	Tebuthiuron	Ametryn	Prometryn	Bromacil	Terbutryn	Metolachlor
RC1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WH1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
GH1	ND	0.24	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
GH2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
GK1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
GK2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Within meadow canopy temperature

Temperature loggers were deployed at Shoalwater Bay and Great Keppel Island over the monitoring period. Paired loggers were deployed in Shoalwater Bay at each site, however one of the paired loggers failed at each site which resulted in an incomplete dataset (Figure 110). As the loggers deployed in April 2008 have yet to be collected, no data is currently available for either location in 2008.

High temperatures were recorded during the low spring tides in the Dry season, however none of the maximum temperatures were extreme. There is insufficient data to compare between years (Figure 111).

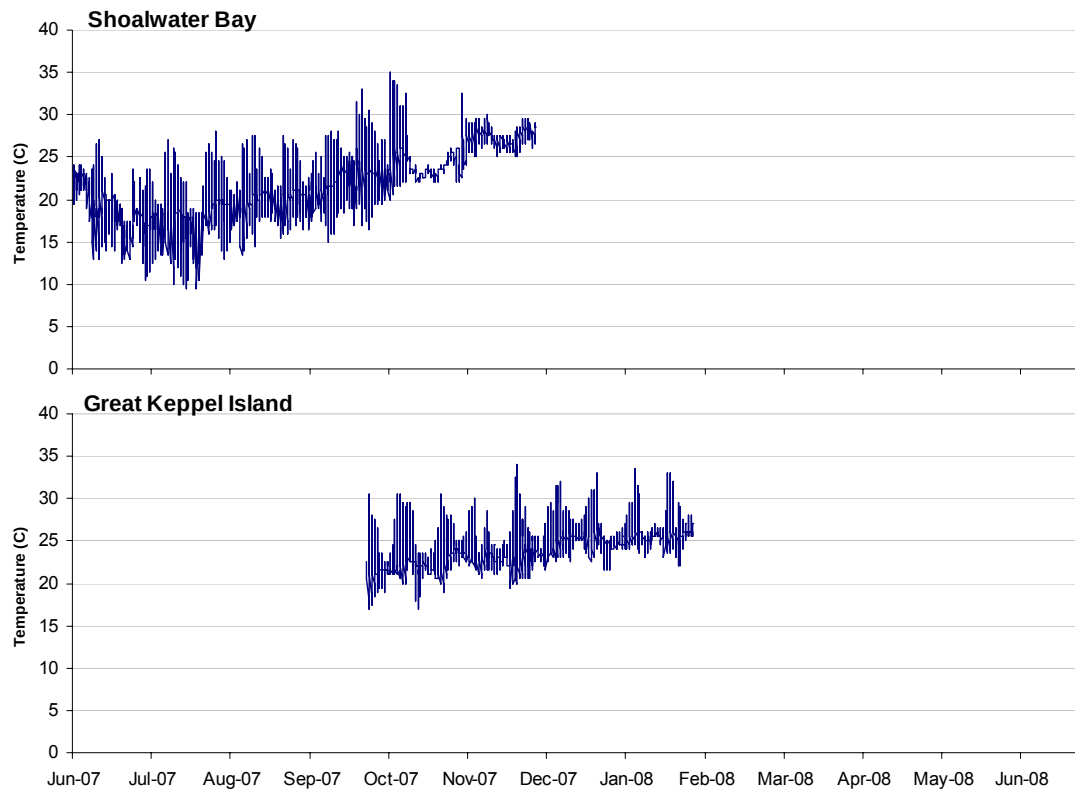


Figure 110. *Within seagrass canopy temperature (°C) at coastal (Shoalwater Bay) and offshore fringing-reef (Great Keppel Island) intertidal meadows within the Fitzroy region over the 2007/2008 monitoring period.*

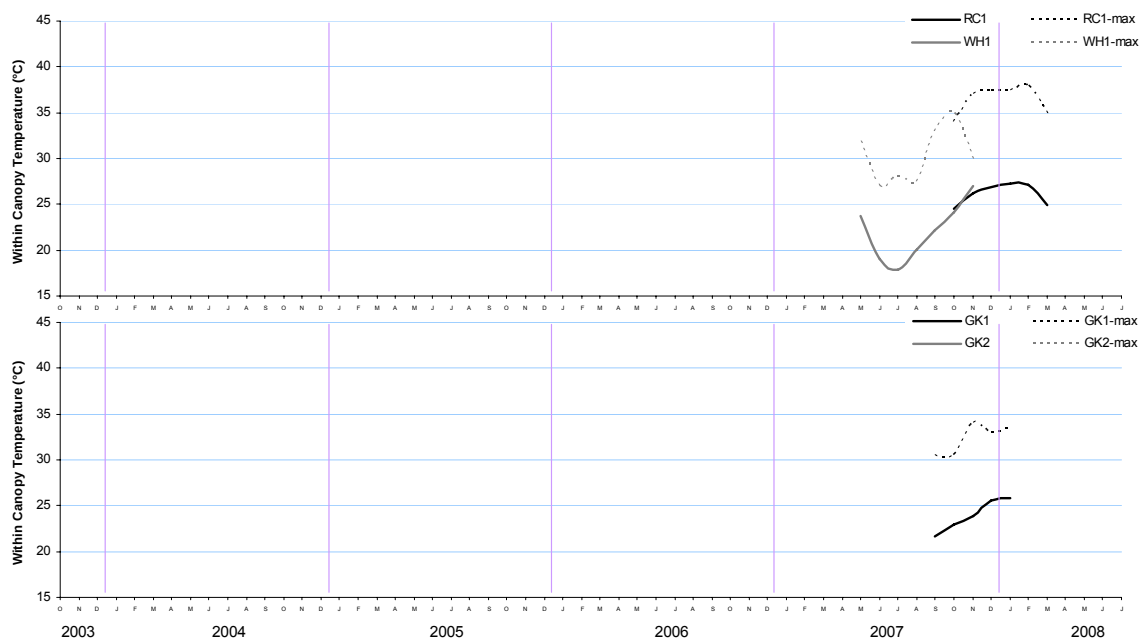


Figure 111. *Monthly mean and maximum within seagrass canopy temperature (°C) at intertidal meadows in coastal (Shoalwater Bay) and fringing-reef (Great Keppel Island) monitoring habitats within the Fitzroy region.*



Burnett Mary

The Burnett-Mary region covers an area of 88,000km² 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 (Burnett Mary Report card 2004). Only the northern most catchment, the Baffle Basin, is within the GBRWHA. Meadows in this Basin generally face low levels of anthropogenic threat, and monitoring sites were recently established within Rodd's Bay, within the Burnett Mary NRM. The only other location that is monitored within this NRM is at Urangan (Hervey Bay). This site is adjacent to the Urangan marina and in close proximity to 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 112).

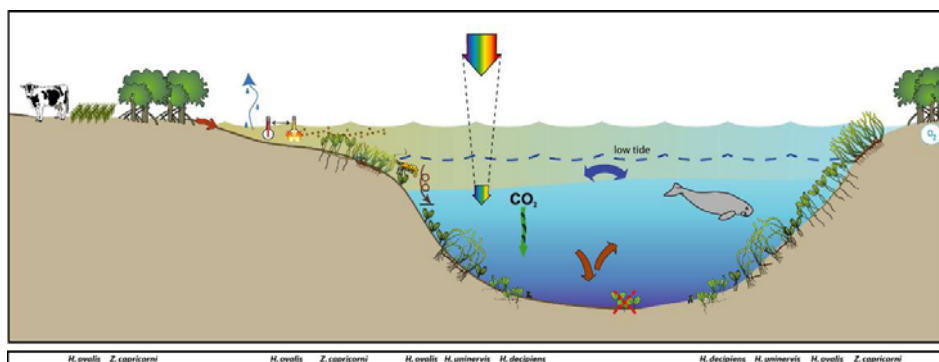


Figure 112. Conceptual diagram of Estuary habitat in the GBRWHA section of the Burnett Mary region – major control is shelter from winds and physical disturbance: general habitat and seagrass meadow processes (See Figure 2 for icon explanation).

Seagrass cover and species composition

The Urangan sites in 2005 were dominated by *Zostera capricorni* with minor components of *Halophila ovalis* and some *Halodule uninervis* (Figure 113). In early 2006 the meadow declined and seagrass was absent until April 2007, when a few isolated plants were found scattered across the intertidal banks. In late Dry 2007 isolated patches of *Zostera capricorni* were scattered across the intertidal banks, with a few patches falling within the monitoring sites. By late Monsoon 2008, the patches had expanded in size and aggregated. Seagrass cover increased slightly over the last 12 months, but mean cover still remained <1% (Figure 114).

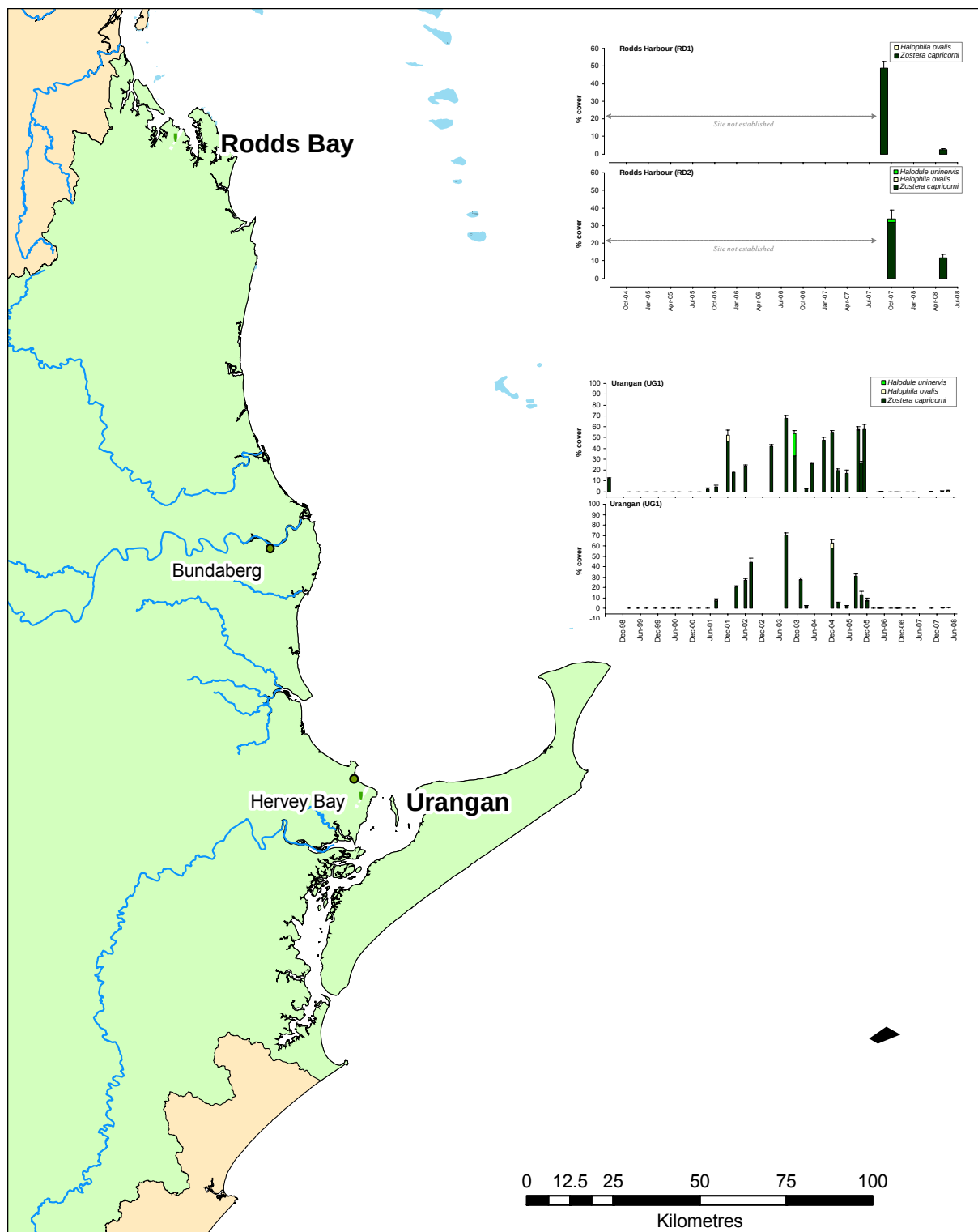


Figure 113. Mean percentage cover for each seagrass species at Seagrass-Watch long-term monitoring sites in the Burnett Mary Region (+ Standard Error). NB: if no sampling conducted then x-axis is clear.

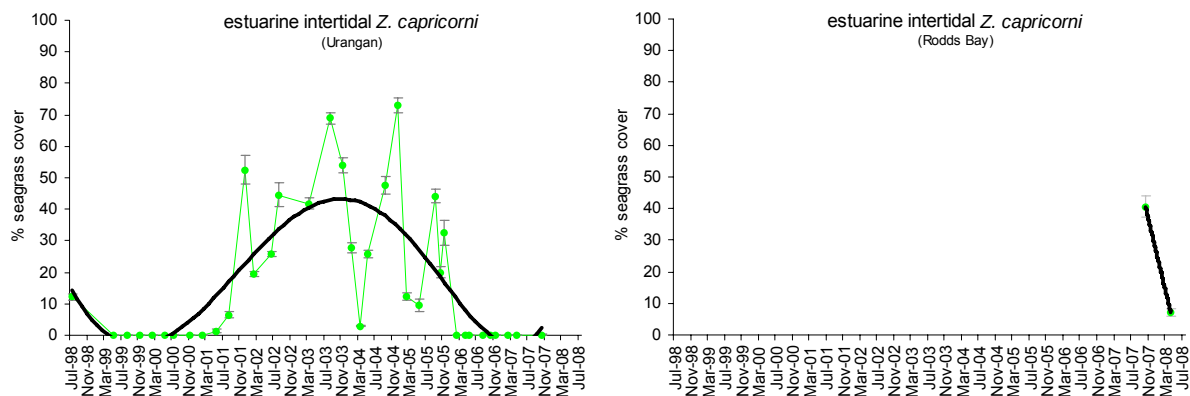


Figure 114. Change in seagrass abundance (percentage cover $\pm$ Standard Error)) at estuarine (Urangan and Rodds Bay) intertidal seagrass meadows in Burnett Mary region.

The seagrass cover at Rodds Bay was significantly lower in the late Monsoon compared to the 2007 late Dry season, however it is unknown if this change is seasonal (Figure 114)

Since monitored was established at this location in 1998, the Urangan meadow has come and gone on an irregular basis. It is known if this is a long-term pattern. With years however, a seasonal pattern is apparent across both sites, with greater abundance in the late Dry season (Figure 115).

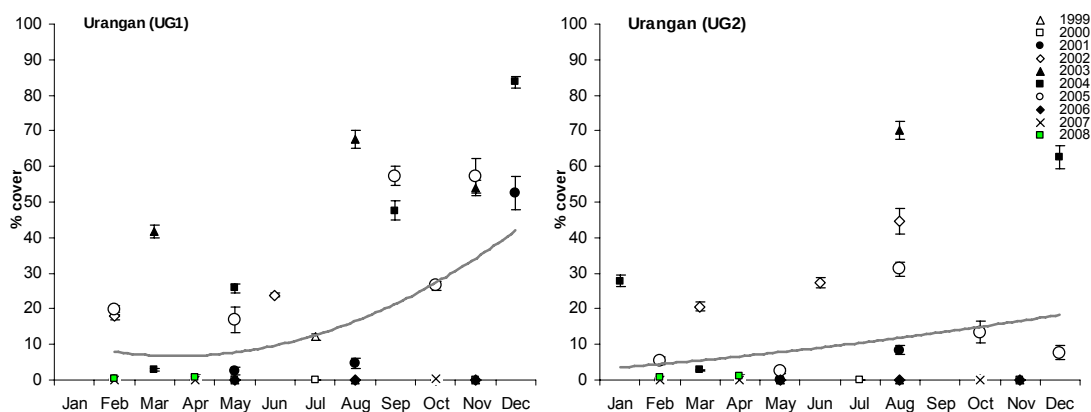


Figure 115. Changes in above-ground biomass and distribution of estuarine intertidal *Zosteria* meadows monitored in the Mary/Burnett region from 2002 to 2008.



Intertidal seagrass meadows recovering at Urangan in April 2008.

Seagrass reproductive health

Seagrasses in both locations were observed to produce significant numbers of reproductive structures (Figure 116). Hervey Bay sites (Urangan) were recovering from seagrass loss and the increasing presence of reproductive structures is positive sign of resilience in this location.

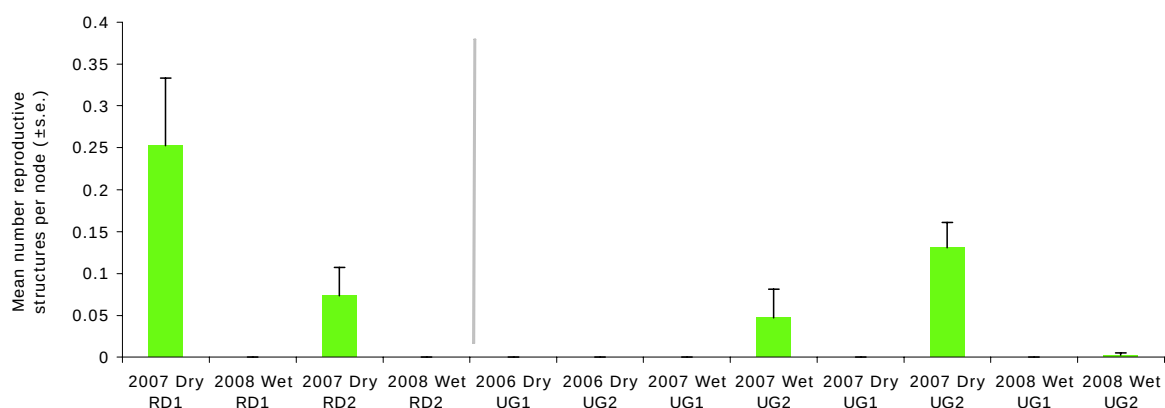


Figure 116. Mean number of reproductive structures (flowers, seeds, or fruits) per node across all seagrass species and all years sampled across sites in the Burnett-Mary Region; Rodds Bay and Hervey Bay (+ Standard Error).

Seagrass tissue nutrients

Halophila ovalis and *Zostera capricorni* were the two species collected from Urangan and Rodds Bay, the two locations currently being monitored within this NRM region. Rodds Bay was sampled for the first time in 2007.

At Urangan, *Halophila ovalis* was present in 2005 and 2007 samples, but absent in 2006. *Zostera capricorni* was present in all years but not at all sites. It was present in 2006 but in such small quantities, there was not enough biomass proceed with the wet chemistry for the plant tissue analyses.

Contamination of samples during the grinding process precluded 2005 samples from both sites for *Halophila ovalis* and from one site for *Zostera capricorni*. Due to these problems creating a non-orthogonal data set, the data is only represented graphically.

Halophila ovalis

Halophila ovalis at Rodds Bay recorded higher %C and %P than at Urangan (Figure 117 a,c). Levels of %N were similar between sites (Figure 117 b).

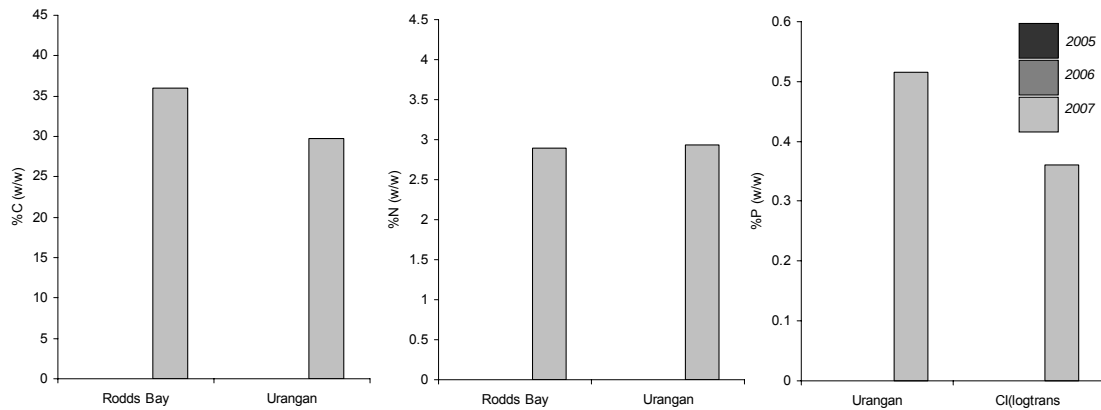


Figure 117. Plant tissue nutrients for *Halophila ovalis* within the Burnett Mary NRM for ;(a) %C, (b) %N, (c) %P.

Zostera capricorni

There has been an increase the amount of %C recorded for *Zostera capricorni* at Urangan with levels in 2007 being similar (~36%C) between locations for this species (Figure 118a). Levels of %N and %P have dramatically increased (almost doubled) at Urangan since 2005 (Figure 118 b.c). %N and %P levels recorded at Urangan were higher than those recorded at Rodds Bay for 2007 (Figure 118).

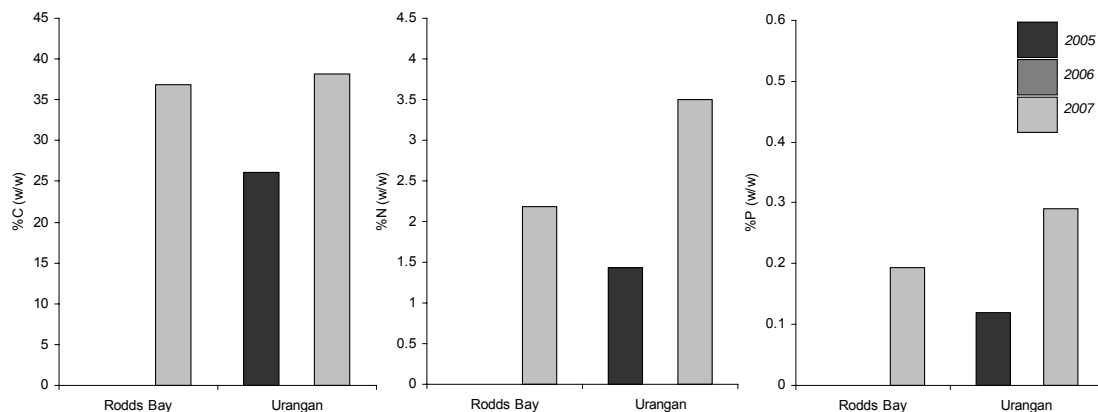


Figure 118. Plant tissue nutrients for *Zostera capricorni* within the Burnett Mary NRM for;(a) %C, (b) %N, (c) %P.

Tissue nutrient values for *Halophila ovalis* at both locations were above the threshold values calculated by Duarte (1990). %P for *Halophila ovalis* at Urangan in 2005 was almost three times greater than the threshold value of 0.2%P(Duarte 1990). In contrast tissue nutrients for *Zostera capricorni* at Urangan transformed from being below the threshold in 2005 to being above the threshold in 2007. Values recorded from Rodds Bay were below the threshold values that differentiate plants that respond to increases in nutrients and those that don't (Duarte 1990).

Seagrass Tissue Nutrient Ratios

Halophila ovalis

C:N ratios at Urangan declined 23:1 to 12:1 (Figure 119a). *Halophila ovalis* at Rodds Bay recorded a higher C:N ratio than that recorded at Urangan in 2007. C:P ratios were similar across locations and within locations (b). At Urangan, *Halophila ovalis* N:P doubled between 2005 and 2007 (Figure 119c).

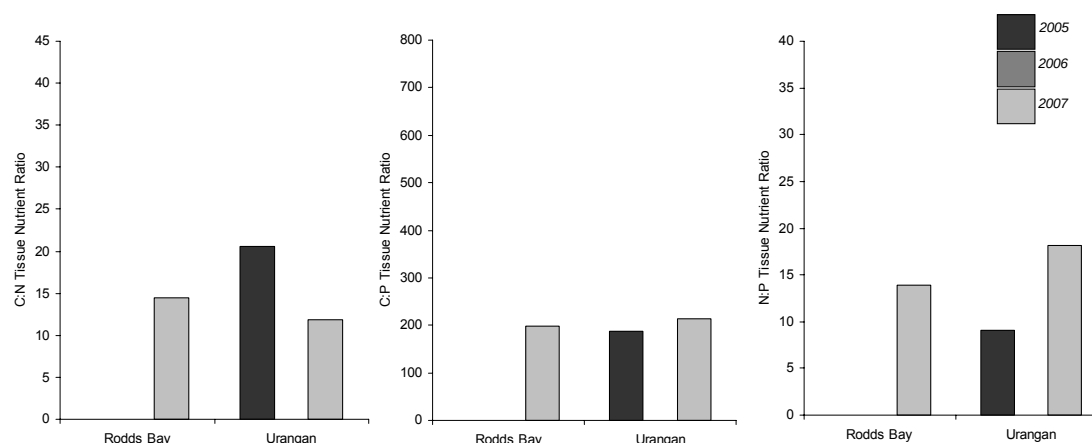


Figure 119. Plant tissue nutrients: a) C:N, b) C:P and c) N:P for *Halophila ovalis* at Urangan and Rodds Bay.

Zostera capricorni

C:N ratios for *Zostera capricorni* followed a similar pattern as that of *Halophila ovalis*. An obvious decline in this ratio occurred between 2005 and 2007 at Urangan (Figure 120a). C:N ratios at Rodds Bay were also higher in 2007 than that recorded for Urangan.

Unlike the patterns observed for *Halophila ovalis*, *Zostera capricorni* C:P ratios declined at Urangan, while N:P ratios remained static between years (Figure 120b,c).

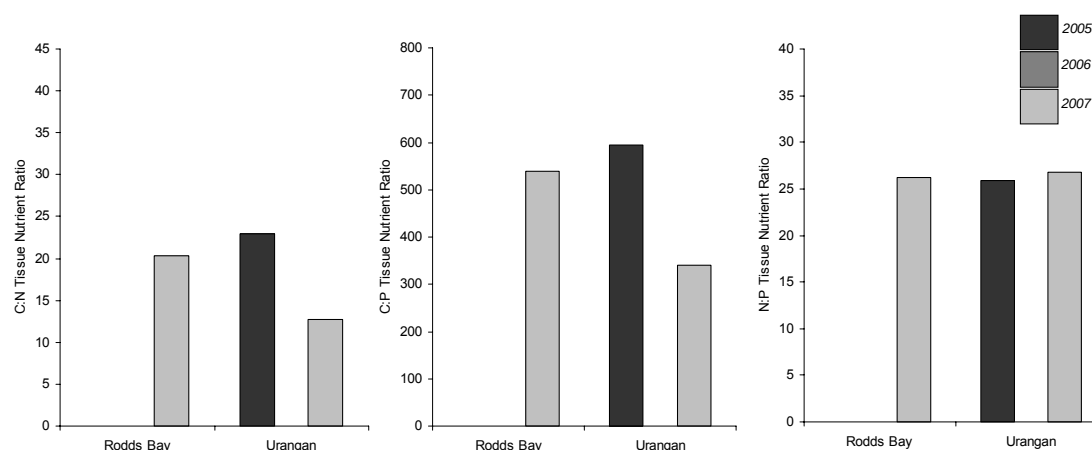


Figure 120. Plant tissue nutrients: a) C:N, b) C:P and c) N:P for *Zostera capricorni* at Urangan and Rodds Bay

Halophila ovalis tissue nutrient ratios describe a meadows in this region as having a low light nutrient rich environment with plants that are N limited. Ratios derived from *Zostera capricorni* indicate that conditions at the Urangan meadow have changed from a moderate light to a low light environment. The habitat has been nutrient rich with plants on the verge

of nutrient repletion. Plant ratios for this species at Rodds Bay depict a habitat that has a marginal light environment, is nutrient poor, with plants also on the verge of nutrient repletion.

Epiphytes and Macro-algae

Epiphytes cover on seagrass leaf blades at Urangan were highly variable over the years of monitoring, however was low over the last 12 months (Figure 121). Percentage cover of macro-algae has continued to remain low (Figure 121).

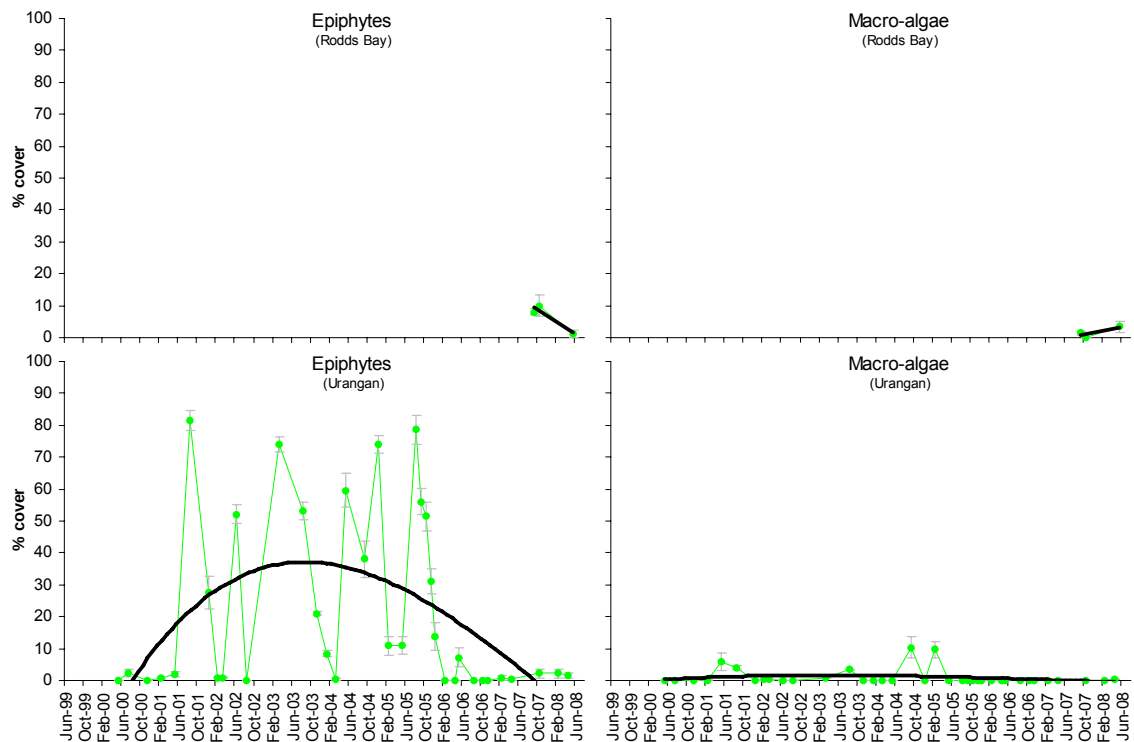


Figure 121. Mean abundance (% cover) ($\pm$ Standard Error) of epiphytes and macro-algae at intertidal estuarine (Rodds Bay and Urangan) seagrass monitoring locations. NB: Polynomial trendline for all years pooled.

Edge mapping

Over the last 12 months the seagrass meadow at Urangan has begun to recover from its absence since early 2006 (Table 44). In April 2007, only a few isolated plants were found scattered across the intertidal banks, however by April 2008 large aggregated patches of seagrass were located within the 100m of the monitoring sites.

Table 44. Area (ha) of seagrass meadow within 100m radius of 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.

Monitoring Site	October 2005	April 2006	October 2006	April 2007	October 2007	April 2008
UG1	5.266	0 (meadow absent)	0 (meadow absent)	0 (meadow absent)	0.003 (-99.9%, increase overall)	0.386 (-92.7%, increase overall)
UG2	5.326	0 (meadow absent)	0 (meadow absent)	0 (meadow absent)	0 (meadow absent)	1.559 (-70.7%, increase overall)
RD1	NA	NA	NA	NA	0.96	1.291 (34.5%, increase seaward)
RD2	NA	NA	NA	NA	3.573	3.511 (-1.7%, decrease shoreward)

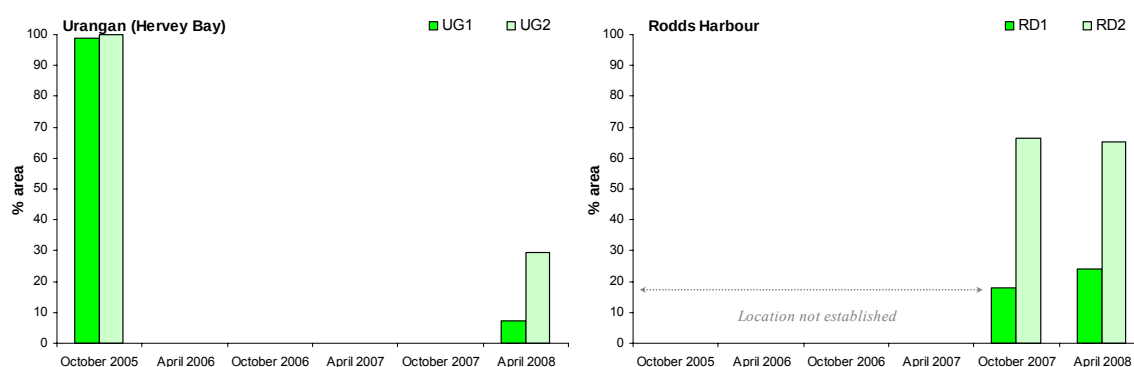


Figure 122. Percentage of area (100m radius of monitoring site) covered by seagrass at each monitoring site at Rodds Bay and Urangan locations.

Sediment Nutrients

The nutrient state of seagrass meadows within this NRM are represented by the intertidal meadows at Rodds Bay and Urangan. Both these locations represent estuarine habitats. No other habitat type is monitored within this NRM. Both these sites are characterized by mud sediments. Porosity measurements differ between these locations with values from Rodds Bay suggesting a higher silt clay fraction than the sediments at Urangan. Rodds Bay was monitored for the first time in 2007. It is not included in any subsequent statistical analyses, but is represented graphically.

Significant differences were detected in levels of sediment nutrients of both ammonium and phosphate (NH_4^+ , ANOVA, d.f.(2,3) $p = 0.033$; ANOVA, PO_4^{3-} , ANOVA, d.f.(2,3), $p = 0.012$). Levels of sediment ammonium and phosphate were significantly higher in 2005 than in 2006 and 2007 (Figure 123 a,b, Table 45). In 2007 sediment nutrients were higher at Rodds Bay than at Urangan (Figure 123 a,b).

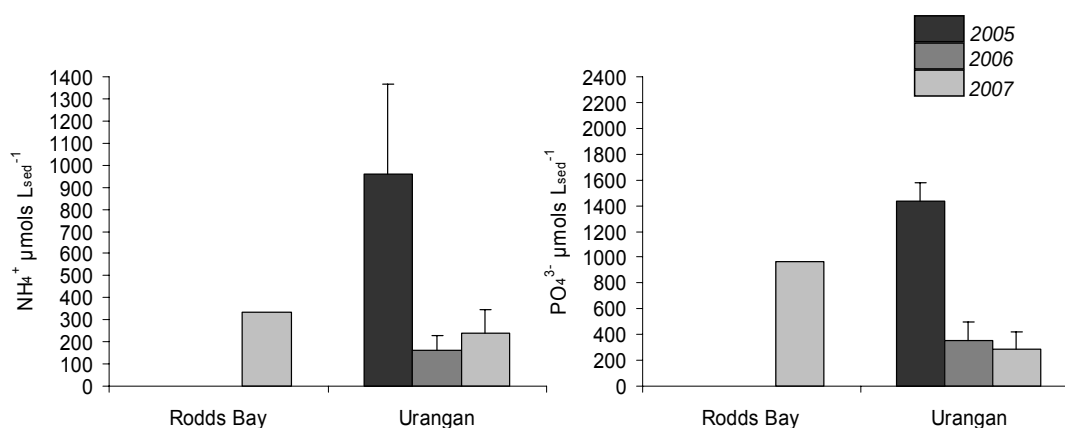


Figure 123. Adsorbed sediment nutrients ;(a) NH_4^+ , (b) PO_4^{3-} , (c) N:P at Urangan and Rodds Bay.

Table 45. Summary of Least Significant Differences between years adsorbed nutrients at Urangan, Burnett Mary NRM.

Year	Grouping for LSD
2005	a
2006	b
2007	b

The sediment nutrient ratios were not significantly different between years, with ratios representing a nutrient pool larger in PO_4^{3-} than NH_4^+ . This relationship was mirrored by the sediment nutrient pool of the rhizosphere at Rodds Bay (Figure 124)

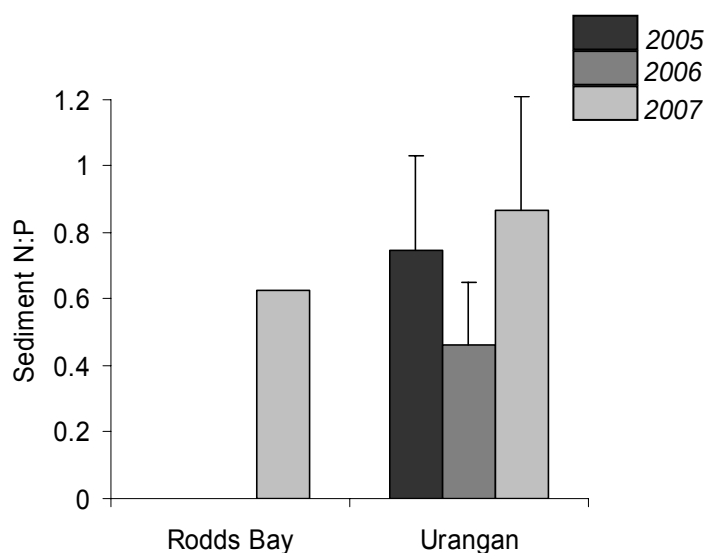


Figure 124. Adsorbed sediment nutrients N:P at Urangan and Rodds Bay.

In 2005 Urangan recorded the highest level of adsorbed ammonium, across locations and between years. Since then levels of ammonium at this location have declined to below the median value based on this monitoring program. This decline however was not significant.

Sediment phosphate at Urangan has also declined below the median value during 2006 and 2007. This decline was significant. At Rodds Bay, sediment ammonium and phosphate levels were higher than those recorded at Urangan for the same period. These changes in the sediment nutrient pool are reflected in the changes of sediment N:P ratio.

Sediment herbicides

Diuron was the only herbicide detected, and was present at only one coastal site (Urangan) in Post-Wet 2008.

Table 46. *Concentration of herbicides ($\mu\text{g kg}^{-1}$) in meadow sediments in post Wet 2008.*
ND=not detectable, $<0.05 \mu\text{g kg}^{-1}$.

Site	Flumeturon	Diuron	Simazine	Atrazine	Desethyl Atrz.	Desisopropyl Atrz.	Hexazinone	Tebuthiuron	Ametryn	Prometryn	Bromacil	Terbutryn	Metolachlor
RD1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RD2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
UG1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
UG2	ND	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Within canopy temperature

Within canopy temperature was monitored at Rodds Bay and Urangan over the past 12 months (Figure 125). Discontinuity in the data reflects the late replacement of the logger after the memory was full. Although extreme temperatures ($>40^{\circ}\text{C}$) were not recorded in the region, very high (39.5°C) within canopy temperatures were recorded at Rodds Bay in February 2008 (Figure 125).

Mean within canopy temperature monitored at Urangan was within the $15 - 27^{\circ}\text{C}$ range, with highest mean temperatures in the February – March periods. The 2007/2008 sampling period was cooler than the 2006/2007 sampling period (Figure 126). At Rodds Bay, mean within canopy temperatures ranged from $24 - 27^{\circ}\text{C}$ between late Dry 2007 and late Monsoon 2008 (Figure 126).

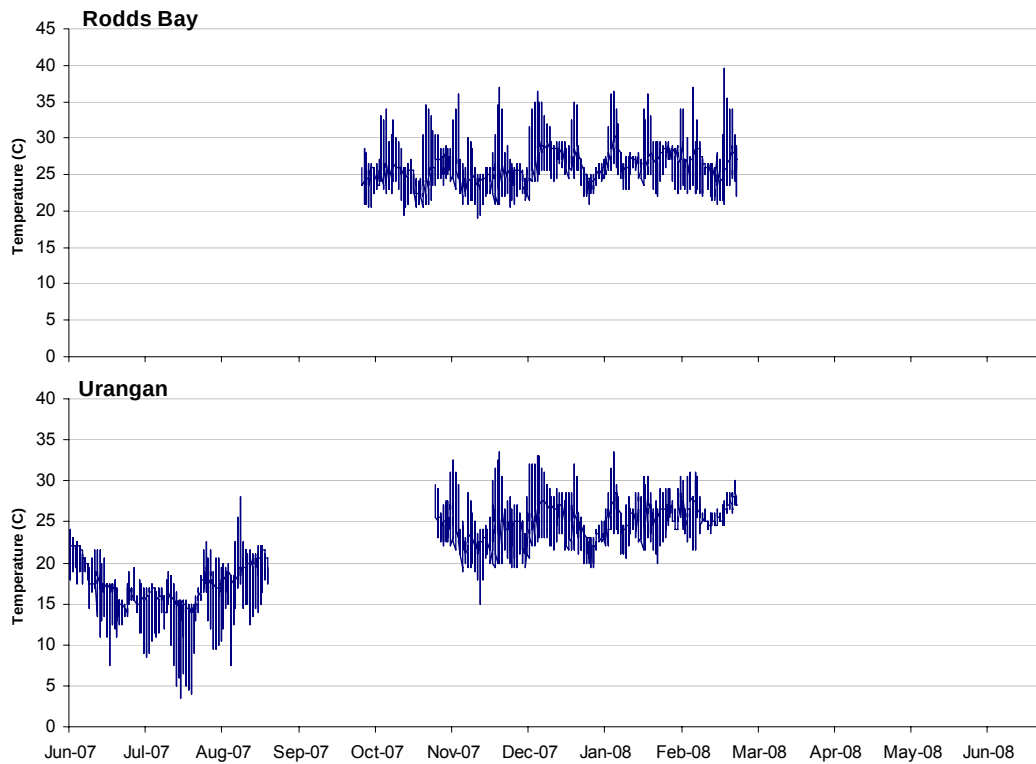


Figure 125. *Within seagrass canopy temperature (°C) at Rodds Bay and Urangan intertidal meadows over the 2007/2008 monitoring period.*

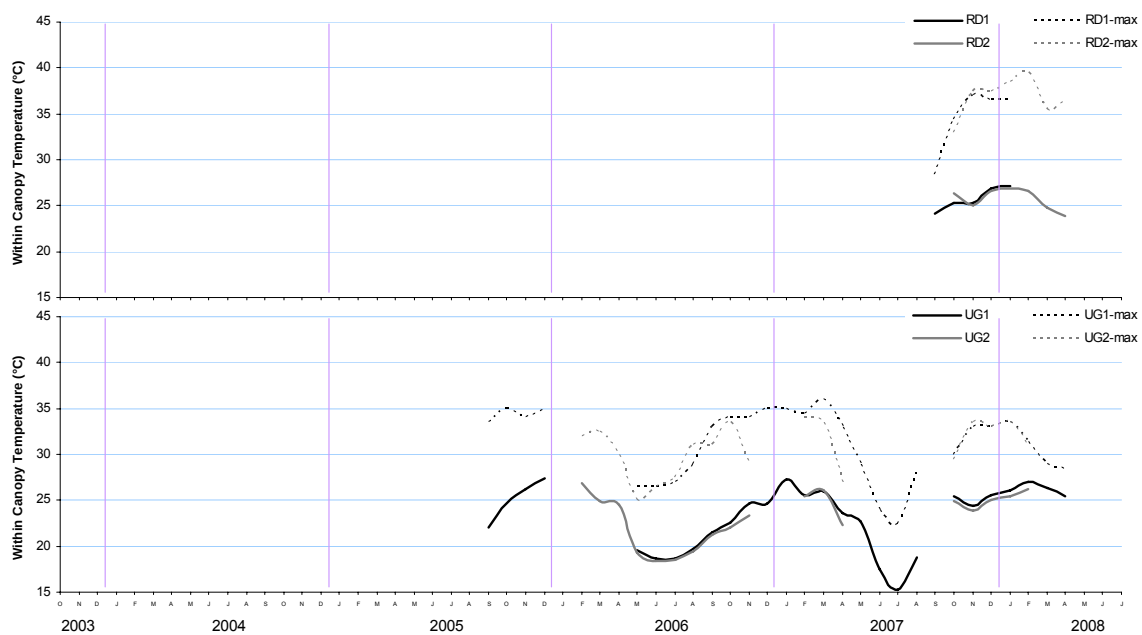


Figure 126. *Monthly mean and maximum within seagrass canopy temperature (°C) at intertidal meadows in estuarine (Rodds Bay and Urangan) monitoring habitats within the Burnett Mary region.*

GBR Summary

The overall trend in seagrass cover across the GBR monitoring locations indicated that most are increasing or recovering since late Dry 2005 (Table 47). Only two locations show a declining trend (Archer Point and Townsville), however this appears to be more a consequence of physical disturbance (Table 47). These declining locations also have increasing seed reserves (Table 47), suggesting they have the ability to recover in the near future should physical disturbance abate.

The average seagrass percent cover (over the past 9 years of Seagrass-Watch monitoring) at each of the intertidal seagrass habitats within the GBRWHA are relatively similar: 21% for estuarine, 20% for coastal, and 26% for reef. However the patterns of abundance over the years are very different, depending on habitat (Figure 127).

Intertidal estuarine locations were only monitored in the Mackay Whitsunday, Fitzroy and Burnett Mary NRMs over the past 12 months. Seagrass abundance at estuarine monitoring sites increased significantly in 2007 (Figure 127), reversing the declining trend from early 2006. Abundances show a dramatic decline in late Monsoon 2008, possibly a consequence of the flooding in the Mackay Whitsunday region, but this is not significant compared to similar times in previous years (Figure 127).

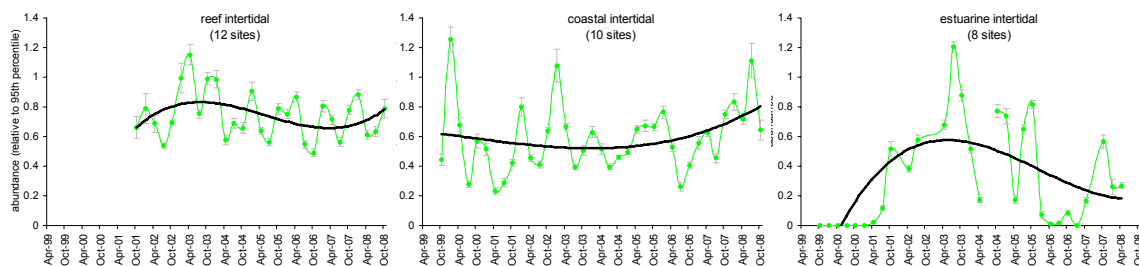


Figure 127. Generalised trends in seagrass abundance for each habitat type (sites pooled) relative to the 95th percentile (equally scaled). The 95th percentile is calculated for each site across all data.

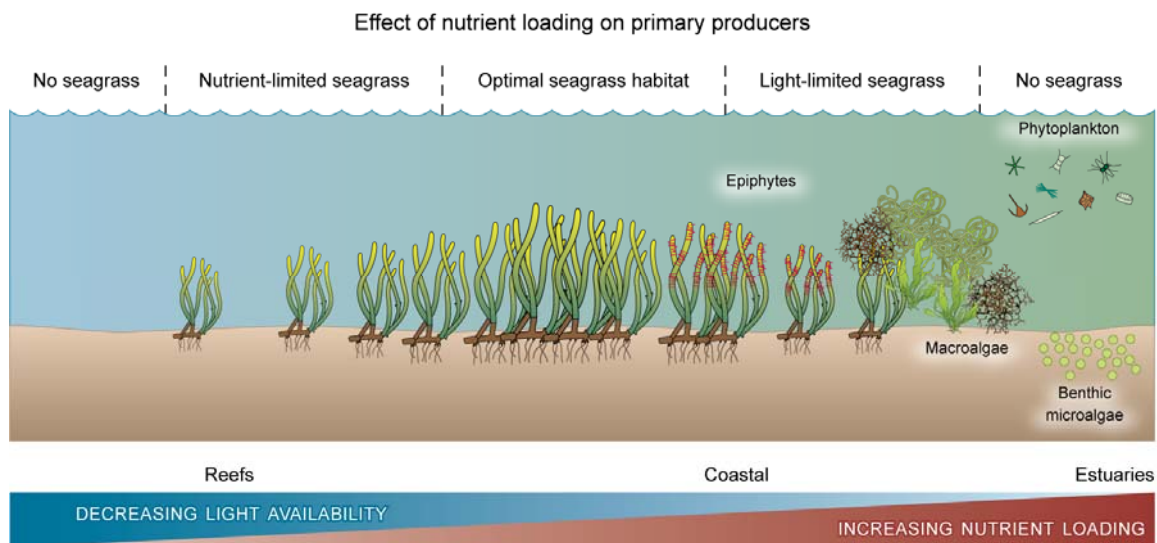
Coastal seagrass meadows are more predominate and consequently more sites were monitored. Intertidal coastal sites were monitored in the Wet Tropics, Burdekin Dry Tropics, Mackay Whitsunday and Fitzroy NRMs over the past 12 months. Seagrass abundance at coastal intertidal seagrass meadows has remained relatively stable over the years of monitoring, however it appears to have increased significantly in the late Dry 2007 (Figure 127, Table 47).

Six reef habitat locations were monitored by the MMP within the GBRWHA in the Cape York, Wet Tropics, Burdekin Dry Tropics and Mackay Whitsunday NRMs over the past 12 months. The more dominant seagrass species in reef habitats of the Great Barrier Reef include *Cymodocea rotundata*, *Thalassia hemprichii*, and the colonising species *Halophila ovalis* and *Halodule uninervis*. Although one location is near-shore (Archer Point), most are located on offshore reef-platforms. Seagrass abundance has fluctuated at intertidal reef-platform seagrass meadows in the last eight years, but has increased over the last couple of years (Figure 127). Within years, seagrass abundance fluctuates greatly between seasons.

Examination of the overall trends across each seagrass habitat monitored suggests a gradient nutrient loadings (Figure 129). In general, nutrient limited reef habitats showed some increase in seagrass abundance, coastal seagrass habitats were fairly stable and the estuarine seagrass habitats fluctuated greatly or declined (compare Figure 127 and Figure 128).

Table 47. Summary of seagrass condition and overall trend at each monitoring location (sites pooled) for each Season. Cover = % seagrass cover, Seeds = seeds per m2 sediment surface, meadow = edge mapping within 100m of monitoring sites, epiphytes = % cover on seagrass leaves, macro-algae = % cover. Overall trend data values presented as Oct07 – Apr08 (long term average in parenthesis). NA= insufficient data as sites established within last 12-18 months.

NRM	Catchment	Location	% cover Long Term Average	% cover 2007	% cover Late-Dry % Difference 2007 to 2006	% cover Post-Wet 2008	% Difference 2008 to 2007	Overall trend since Late-Dry 2005				
								Seagrass Cover	Seagrass Seeds	Meadow	Epiphytes	Macro-Algae
Cape York	Endeavour	Archer Point	19.2 ±1.6	14.8 ±1.6	>20% decrease	12.7 ±1.2	>20% increase	decline	323 - 255 (162) increase	increase	29 - 11 (23) decline	7 - 2 (9) decline
Wet Tropics	Barron Russell / Mulgrave Johnstone	Yule Point	14.5 ±1.1	15.4 ±0.8	>20% increase	29.3 ±1.4	>20% increase	increase	526 - 382 (429) stable	increase	15 - 51 (17) increase	<1 (2) variable
		Green Is	41.6 ±2.3	37.5 ±1.9	similar	34.0 ±1.7	similar	increase	nil	stable	7 - 25 (24) increase	5 - 5 (4) stable
	Tully – Murray	Lugger Bay	4.4 ±0.6	4.4 ±0.5	>20% increase	6.1 ±0.8	>20% increase	recovering	0 - 17 (14) decline	recovering	5 - 1 (3) variable	0 (<1) variable
		Dunk Is	11.5 ±1.2	12.4 ±1.2	NA	14.7 ±1.2	>20% increase	NA	4 - 42 (9) NA	NA	7 - 10 (10) NA	6 - 8 (7) NA
Burdekin Dry Tropics	Burdekin	Townsville	19.1 ±2.2	24.1 ±2.1	>20% increase	13.5 ±1.4	similar	decline	4793 - 7388 (3227) increase	decline	7 - 23 (17) decline	6 - 1 (4) decline
		Magnetic Is	35.1 ±3.1	42.7 ±2.0	>20% increase	55.5 ±2.5	similar	increase	14 - 8 (34) decline	stable	51 - 54 (42) stable	21 - 6 (8) stable
Mackay Whitsunday	Proserpine	Pioneer Bay	20.2 ±1.5	33.4 ±2.1	>20% increase	14.9 ±1.8	>20% decrease	increase	166 - 225 (279) increase	increase	22 - 13 (15) decline	10 - 2 (13) stable
		Hamilton Is*	9.1 ±1.3	9.6 ±1.6	NA	3.0 ±0.6	NA	NA	nil	NA	31 - 25 (23) NA	1 - 3 (2) NA
	Pioneer	Sarina Inlet	14.2 ±1.4	12.7 ±1.4	>20% increase	10.7 ±1.2	>20% increase	recovering	0 (66) variable	variable	31 - 2 (16) variable	2 - <1 (1) variable
Fitzroy	Fitzroy	Shoalwater	26.9 ±1.8	36.2 ±2.4	>20% increase	32.0 ±1.5	similar	increase	nil	stable	15 - 10 (12) decline	5 - <1 (6) decline
		Great Keppel	3.2 ±0.7	5.8 ±0.6	NA	2.1 ±0.8	NA	NA	nil	NA	32 - 53 (34) NA	14 - 5 (8) NA
	Boyne	Gladstone	15.7 ±1.4	24.9 ±2.8	>20% increase	17.6 ±1.2	>20% increase	recovering	nil	recovering	33 - 30 (27) variable	9 - 28 (22) stable
Burnett Mary	Burnett	Rodds Bay	23.8 ±2.2	40.6 ±3.3	NA	7.0 ±1.2	NA	NA	0 - 8 (4) NA	NA	9 - 1 (5) NA	1 - 3 (2) NA
	Mary	Urangan	15.7 ±1.0	0.2 ±0.1	>20% increase	0.8 ±0.3	>20% increase	recovering	nil	recovering	2 - 1 (19) decline	<1 (1) variable



Seagrass reproductive effort

The total reproductive effort per node was highly variable across all sampling sites (Figure 130). All locations exhibited some evidence of reproduction, however the higher per node reproduction values were found in the high disturbance-recovery sites in Cleveland Bay around Townsville.

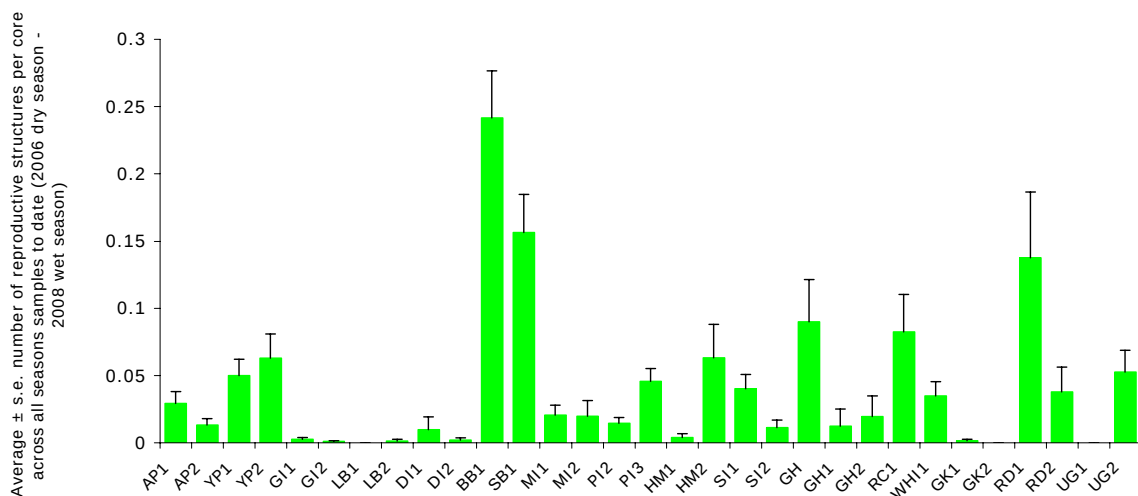


Figure 130. Mean number of reproductive structures (flowers, seeds, or fruits) per node across all seagrass species and all years sampled across sites in the Great Barrier Reef Marine Monitoring Program (+ Standard Error).

When analysed across all seasons and all locations in particular habitat types sampled (i.e. reef, coastal and estuarine), the coastal habitats have a higher number of reproductive structures per node, although not statistically different to the estuarine sites (Figure 131). The lower number of reproductive structures observed in reef sites is most likely due to the lower nutrient to light availability at these locations limiting resources for flowering.

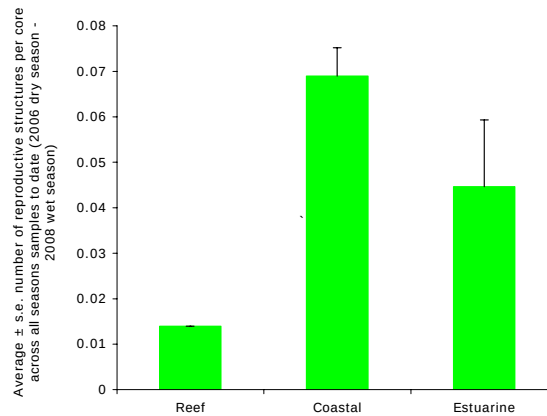


Figure 131. Mean number of reproductive structures (flowers, seeds, or fruits) per node across all seagrass species and all years sampled grouped across sites of similar habitat in the Great Barrier Reef Marine Monitoring Program (+ Standard Error).

Seagrass tissue nutrients

Tissue nutrient concentrations were extremely variable between years, across locations and within locations between years. By pooling locations by species and across habitat types, some trends are apparent (Figure 132). C:N ratios <20 and C:P <500 indicate low light nutrient rich environments, which was present in estuary and coastal habitats (Figure 132). C:N ratios >20, C:P > 500 detected at reef habitats indicate moderate light and nutrient poor environments: N:P <30 nutrient limited; 30 replete; >30 saturated.

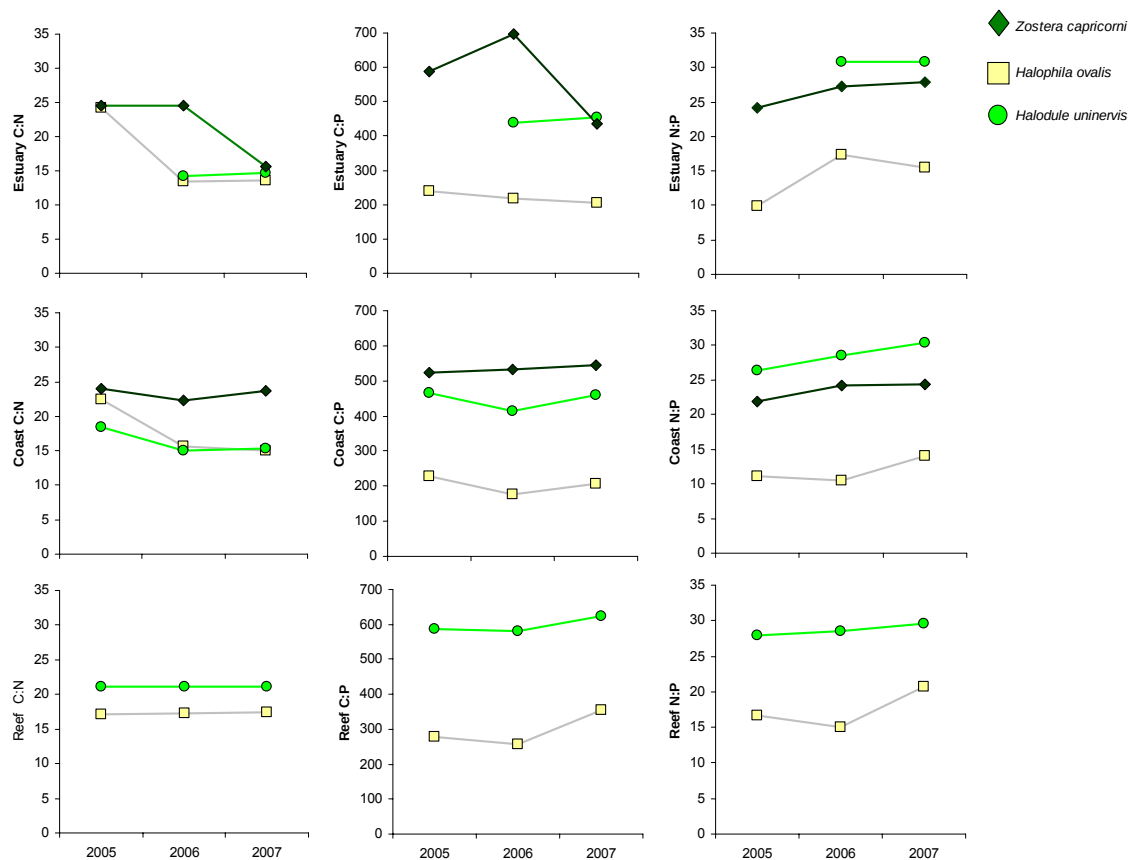


Figure 132. Atomic ratio of seagrass leaf tissue C:N, N:P and C:P for each seagrass habitat and targeted species each year ($\pm 95\%$ CI).

Sediment nutrients

Most locations monitored had a smaller N pool relative to P, with adsorbed ammonium varying between years and regions and adsorbed phosphate lower in 2006 and 2007 (Figure 133). Seagrasses in estuarine habitats were predominately *Zostera capricorni* and these sites had relatively high sediment adsorbed N.

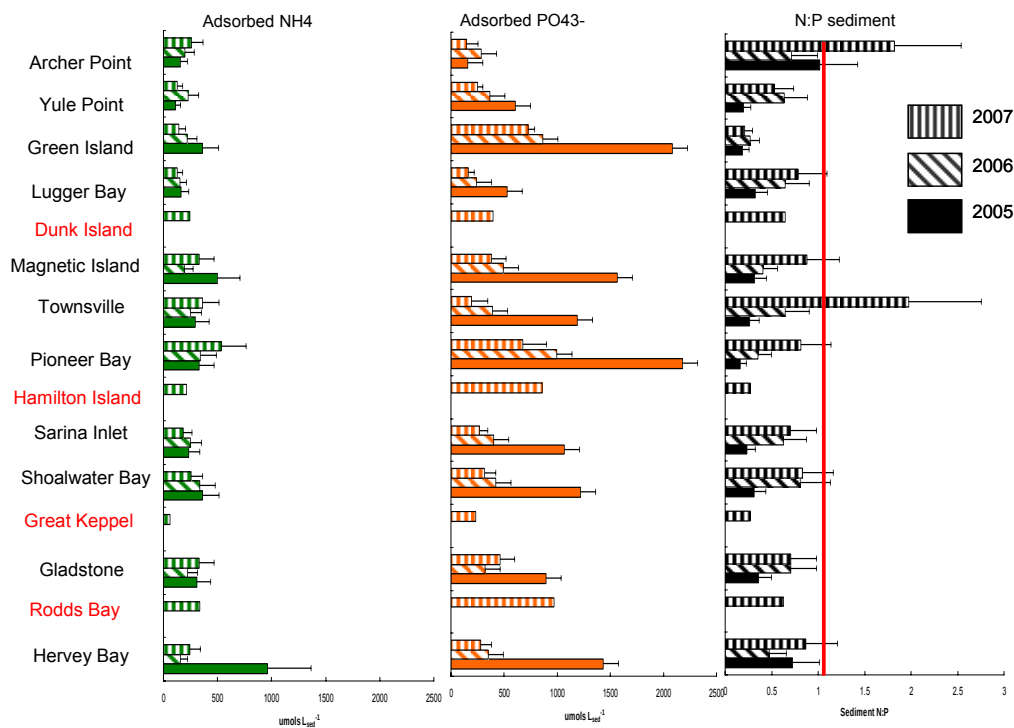


Figure 133. Sediment adsorbed NH_4^+ and PO_4^{3-} concentrations ($\mu\text{mol L}_{\text{sed}}^{-1}$) for each long-term monitoring location (sites pooled), and ratio of pools ($\pm 95\%$ CI). Highlighted locations were only established in 2007.

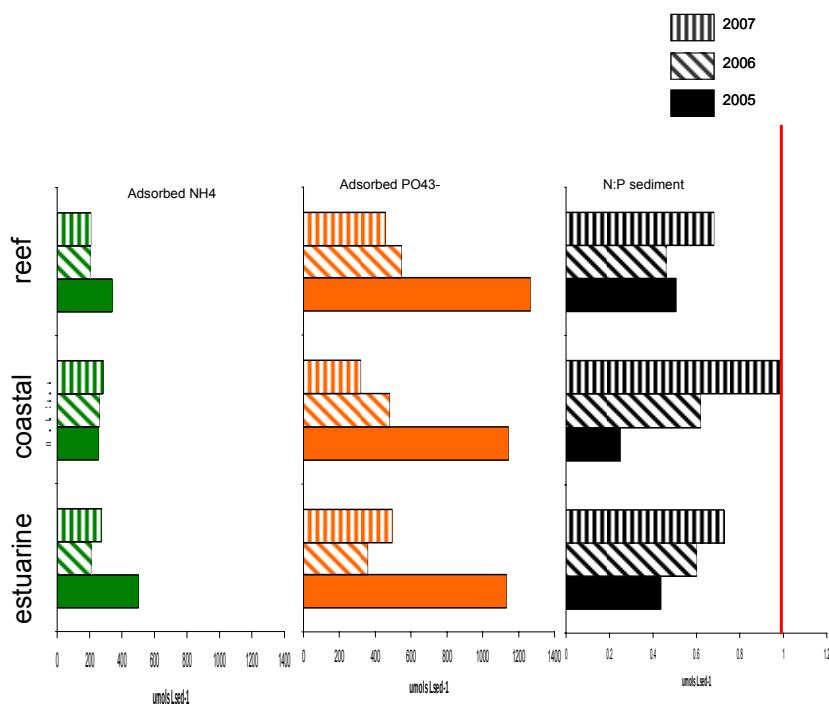


Figure 134. Sediment adsorbed NH_4^+ and PO_4^{3-} concentrations ($\mu\text{mol L}_{\text{sed}}^{-1}$) for each seagrass habitat monitored (sites pooled), and ratio of pools ($\pm 95\%$ CI).

Trends in the nutrient environment and seagrass for each NRM

Cape York

Nutrients in this coastal fringing reef habitat have increasing nitrogen in the sediments while phosphate has been declining. This was mirrored in the significant increase in sediment N:P in 2007. Plant tissue variables indicate a habitat with improving light quality, nutrient poor conditions with two of the three species inhabiting this seagrass community exhibiting nitrogen limitation. The exception to this is the N:P ratios derived from *Halodule uninervis*. While plant N:P ratios declined in 2007 for this species, they did not decline to a level which would suggest nitrogen limitation.

Wet Tropics

Within this NRM a distinction in nutrient state could be made between low light, nutrient rich (coastal habitats) and moderate light nutrient poor (reef habitats) in relation to plant tissue C:N and C:P ratios. Within habitats a decline across years in C:N and C:P ratios coupled with an increase in plant tissue N:P was noted. This is suggestive of a moderate decline in water quality, despite declines recorded in levels of adsorbed sediment nutrients for this region. The tissue nutrient content of seagrass plants was indicative of being replete.

Burdekin Dry Tropics

A clear distinction between reef and coastal seagrass habitats where nitrogen does not appear to differ but adsorbed phosphate are distinct, which is reflected in their N:P ratios.

The two pioneering seagrass species found at all locations within this NRM recorded plant tissue nutrients that suggested nutrient repletion. In contrast the structurally larger seagrasses that occurred in the reef habitats of this NRM were generally nutrient limited.

Halodule uninervis plant tissue nutrients indicated a distinction between reef habitats and coastal habitats, defining reef habitats as higher in light and lower in nutrients. In contrast ratios derived for *Halophila ovalis*, indicated both habitats had low light, nutrient rich environments.

Mackay Whitsunday

On a GBR wide basis, ammonium levels at Pioneer Bay were at the high end of the continuum, as were levels of phosphate. Levels of phosphate at Hamilton Island were also above the median value for adsorbed phosphate for the GBR. There has been an overall decline in sediment phosphate within this NRM. This is reflected in increasing values of sediment N:P as the sediment phosphate pool declines.

In general, tissue nutrient ratios did not separate plants or species into different habitat types. Ratios for these species typically characterized all habitats as environments low in light, and rich in nutrients. Interpretation of plant N:P ratios indicated that for the dominant species the plants were P limited or replete.

Burnett Mary

On a GBR wide basis, the estuarine habitat at Urangan had sediment nutrients below the median value with the exception of the extraordinarily high values recorded during 2005. The decline in phosphate levels was significant. Sediment nutrient values for Rodds Bay were higher than the GBR median value.

Plant tissue nutrients for *Halophila ovalis*, suggest that Rodds Bay and Urangan meadows are in low light, nutrient rich environments with plants that are N limited. C:N for *Zostera capricorni* support the notion of a low light environment at these locations, as depicted by the *Halophila ovalis* C:N ratios. C:P ratios, however differentiated the two locations, suggesting that Urangan was nutrient rich while Rodds Bay was a nutrient poor environment. N:P ratios at both locations suggested plants that were N limited.

Edge mapping

Intertidal seagrass meadow distribution has changed little since monitoring was established. Some localised changes have occurred (e.g. early 2006), but there is no general trend overall (Figure 135).

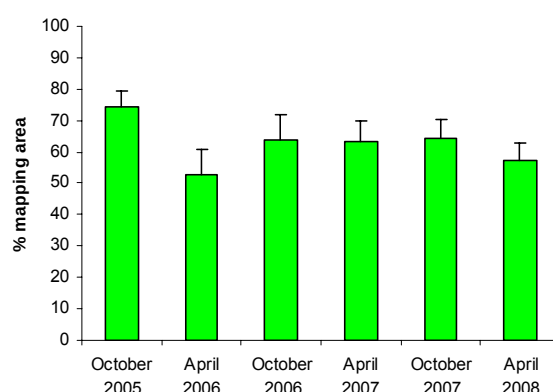


Figure 135. Percentage of seagrass meadow covering the area within 100m radius of monitoring sites (all sites pooled).

Epiphytes

Although epiphyte cover is lower in the late Monsoon (15%) compared to the late Dry (21%), it is not significant (all sites pooled) (T-test $T=1.56$, $d.f.=58$, $p=0.12$). Generally trends in epiphyte cover are similar to seagrass abundance (Table 47), but amplitudes differ between habitats.

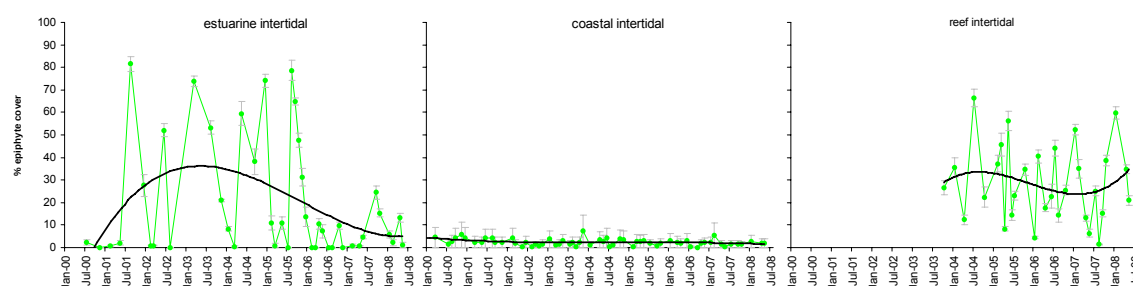


Figure 136. Epiphyte abundance (% cover) at each seagrass habitat monitored (sites pooled) ($\pm 95\%$ SE).

Macro-algae

Some macro-algal overgrowth was reported at monitoring sites, but abundance was not as high as epiphytes. Since monitoring began, macro-algal abundance has remained stable or declined at reef locations, varied or remained stable at coastal locations (Table 47), particularly in coastal/reef meadows and slightly increased over time in estuary meadows

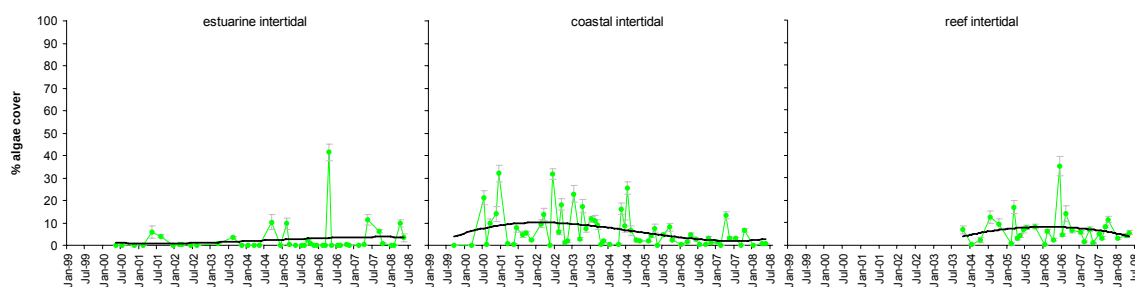


Figure 137. Macro-algal abundance (% cover) at each seagrass habitat monitored (sites pooled) ($\pm 95\%$ SE).

Sediment herbicides

Of the thirteen herbicides (organics) analysed only diuron was found above detectable limits in the sediments of the seagrass monitoring sites during the post Monsoon. It was detected at 10 of the 30 sites examined. Diuron was detected in the sediments at all Townsville sites (Magnetic Island, Bushland and Shelley Beach), and coastal sites in the Mackay Whitsundays (Pioneer Bay, Sarina Inlet), Fitzroy (Gladstone Harbour) and Burnett Mary (Urangan). The highest concentrations in post Monsoon 2008 were in the Mackay Whitsundays at Pioneer Bay and Sarina Inlet, 0.48 and 0.32 $\mu\text{g/kg}$ respectively (Figure 138).

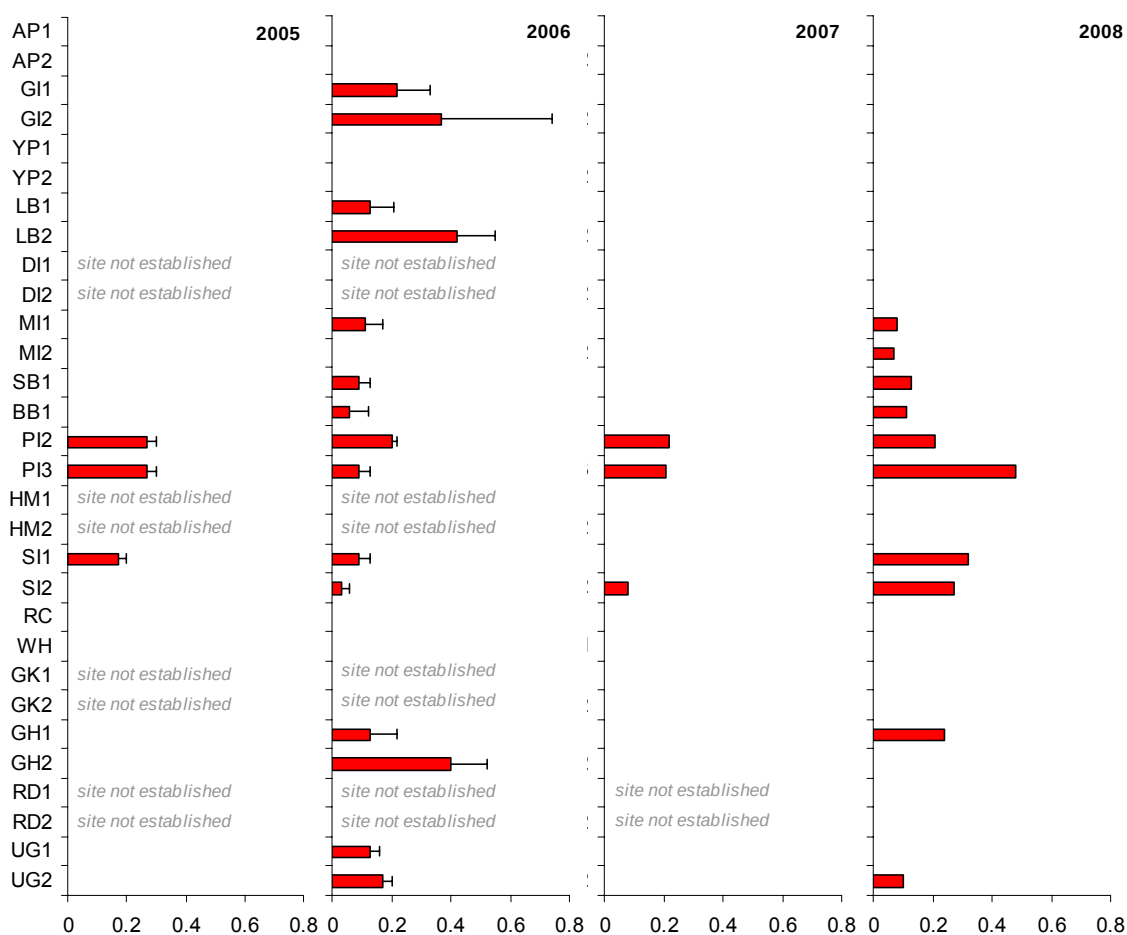


Figure 138. Concentration of Diuron ($\mu\text{g/kg DW}$) in sediments of intertidal monitoring sites during the late Monsoon.

3. Discussion

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).

Water quality and ecological integrity of some coastal waters of the GBRWHA are affected by material originating in adjacent catchments as a result of human activity, including primary industries and urban and industrial development. Delivery of sediments and nutrients to rivers discharging into Great Barrier Reef waters is estimated to have increased four times since 1850 (Schaffelke *et al.*, 2005).

The six NRM regions that abut the GBR lagoon are affected by different climate regimes, demographic and catchment groupings and are unequal in size and coastline. This requires some care when making between region comparisons. Particularly as locations/seagrass habitat type within these NRM regions are at least as important as the region in understanding how a seagrass meadow may respond to external pressures.

The types of influences/pressures on seagrass differ for each region. Our conceptual models synthesise the key driving influences and pressures and conceptual models are a powerful way of visualising how each system works. Anthropogenic affects are far more important in regions such as the Wet Tropics with its port activities and intensive coastal agriculture. This region is well monitored and loss or any change at least in shallow waters would be quickly noticed. North on the Cape, such impacts are less likely but changes could occur over time that would not be noticed due to the lack of the spatial extent of monitoring in this region.

Intertidal seagrass monitoring (Seagrass–Watch) has demonstrated that despite some temporary losses, intertidal seagrass in Queensland remain in relatively good condition (www.seagrasswatch.org).

Seagrass cover and distribution

The distribution of seagrass species monitored in this programme is representative of the intertidal meadows in GBRWHA (Coles *et al.* 2007; Lee Long *et al.*, 1993). While *Zostera* communities are found all along the coast of Queensland this species predominates in southern intertidal meadows.

Studies of tropical and subtropical seagrass communities have found distinct seasonal patterns with maximum cover usually occurring in spring/summer and minima in winter (McKenzie, 1994; Lanyon and Marsh, 1995). This seasonal pattern is likely to be driven by a combination of climatic and environmental parameters, particularly rainfall, water and air temperature, and solar irradiance (Mellors *et al.*, 1993; McKenzie, 1994).

The only notable changes in species composition occurred at Pioneer Bay in the Mackay Whitsunday region, and Cockle Bay, in the Burdekin Dry Tropics. At Pioneer Bay the meadow is becoming more *Zostera* dominated, and the sediments more mud dominated. This is likely to be a normal successional event. At Cockle Bay, the composition of *Cymodocea serrulata* is increasing, which may suggest a changing light environment as this species appears more tolerant to reduced light (Catherine Collier, JCU. Pers. Comm.). Community composition also changes in a successional manner and this may be reflected at this site (Birch and Birch 1984).

Herbicides

Herbicides have been detected in the water column in GBR waters and concentrations have been found up to 60 km offshore in the wet season and in low but detectable concentrations in the dry season (Brodie *et al.* 2008).

Low but detectable concentrations of diuron were recorded in sediments across a number of intertidal seagrass monitoring locations over the last sampling period, suggesting wide spread contamination possibly from diffuse sources. The highest concentrations were in the Mackay Whitsundays at Pioneer Bay and Sarina Inlet, 0.48 and 0.32 $\mu\text{g/kg}$ respectively. These figures are well below the maximum concentrations recorded by Haynes *et al.* (2000) (1.7 $\mu\text{g/kg}$ in intertidal sediments at Cardwell).

Herbicides have an uncertain half life in marine sediments as they have been developed purely for terrestrial application. Atrazine has a short half life of three to 30 days and diuron 120 days, but toxic breakdown products may extend the time these chemicals can cause damage (Ralf *et al.* 2006; Haynes *et al.* 2000). There are two pathways that herbicides may enter the marine environment; transportation in the water column or adsorbed to terrestrial particulate matter. If their origins are in the water column, they are more likely to remain there as they have poor adsorption to sediments once in the marine environment. Thomas *et al.* (2001) notes that despite poor sediment adsorption of herbicides, concentrations in sediments may provide the best history of previous exposure.

There are few examples of a definite causal link between seagrass loss and herbicides, and none in Queensland. Based on laboratory based aquarium studies, it is estimated that diuron concentrations of $\sim 10 \mu\text{g kg}^{-1}$ in sediments inhibit seagrass photosynthesis (Haynes *et al.*, 2000b). The most detailed work in Queensland was from Haynes *et al.* (2000b) who demonstrated concentrations of diuron in nearshore environments along the Queensland coast of 1-10 $\mu\text{g kg}^{-1}$. Although there have been post flood losses of seagrass in Queensland, these are more likely to be the result of light loss than from chemical contaminants (Preen *et al.*, 1995). Duke (2001) recorded concentrations of between 0.2 and 4.0 $\mu\text{g/kg}$ in mangrove sediments at Mackay. Those figures are around 300 to 1300 times less than the application rates used by sugar cane farmers.

Herbicides also originate from other agricultural activities, urban weed control and possibly from sources such as antifouling paints. The key influence on the presence of herbicides in coastal sediments is likely to be significant rainfall shortly after application. Higher concentrations of herbicides have been reported in the water column over seagrass meadows immediately following flow events (McMahon *et al.* 2005).

The occurrence of diuron every late Monsoon in the sediments of Pioneer Bay although of some concern, does not appear to be at a level to be significantly impacting the seagrass meadows on the location. Also, chronic low concentrations of diuron in Sarina Inlet may be of concern particularly as this estuarine location has showed large fluctuations in seagrass presence and abundance.

Seagrass nutrients

Examination of the plant tissue nutrient ratios and their deviation from the “Seagrass Redfield Ratio” (500:30:1, Atkinson and Smith 1983) distinguished coastal meadows from reef top meadows. This distinction is based on the premise that values below the “Redfield Ratio” especially that of C:N and C:P characterize seagrasses living in low light, high nutrient environments (*sic.* coastal) as opposed to comparatively lower nutrient higher light environments (*sic.* reef) (Atkinson and Smith 1983, Duarte 1990, Johnson *et al.* 2006).

Seagrass resilience

The majority of seagrass habitats surveyed in the MMP are prone to physical disturbance so their ability to recover following such disturbance is linked to their ability to produce seeds. Evidence of significant amounts of reproductive effort across the majority of sites in the MMP suggests the maintenance of reproductive effort in the seagrass meadows surveyed. In addition, several sites are seen to be recovering following disturbance based on changes in seagrass cover. Thus, at present, most sites appear to be resilient.

4. Conclusions

There are considerable pressures on seagrass meadows along the urban coast from river discharge water quality and urban and industrial development. With increasing urban and catchment development further research will be required to understand the synergistic effects between high nutrient availability and exposure to pollutants, and between water quality parameters and other disturbances or factors that influence health and production of seagrass.

At the spatial scales of locations and sites, there is considerable variability in meadow cover but at a GBRWHA scale there is no evidence of sustained losses or gains where monitoring has occurred. Most changes are likely linked to short term environmental events and local scale impacts.

We cannot generalize trends in seagrass tissue nutrients across the GBR as they are the result of their local nutrient environment. We do observe trends at the NRM scale. The Wet Tropics show seagrasses are nutrient replete. The Burdekin Dry Tropics show a separation between habitat type, coastal and reef. In the Mackay/Whitsunday region, coastal sites are replete or P limited suggesting saturating levels of nitrogen. The Fitzroy also show a dichotomy between habitat types. The Burnett Mary region are N limited.

Additional information on light availability to seagrasses (PAR) within these meadows will increase our ability to develop predictive models on the dynamics of seagrasses that reflect GBRWHA environment.

Monitoring indicates intertidal seagrasses are influenced primarily by the availability of light and nutrients for primary production.

- **Estuary** seagrass meadows – high nutrient availability, low light regimes (*due to highly turbid waters and overgrowth by epiphytes & macro-algae*). GBR estuarine seagrasses are showing signs of high fluctuations and decline.
- **Coast** seagrass meadows - generally adequate light and nutrients available for growth. Subject to periods of elevated temperatures and disturbance from winds generated turbidity, waves and floods. GBR coastal seagrasses showing short term declines and increases but generally steady trend.
- **Reef** seagrass meadows - high light availability and low nutrients. GBR reef top seagrasses showing signs of increasing cover, which may be attributable to localised nutrient inputs and increased loads of nutrients reaching the inshore GBR.

The seagrass monitoring component of the MMP within the GBRWHA has been successful in monitoring seagrass condition at a variety of locations and habitats. It is one of the most comprehensive seagrass programs outside the east coast of north America. Some regions however are less well monitored than others and this needs to be addressed.

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