Reef Rescue

Marine Monitoring Program
Intertidal Seagrass

FINAL REPORT

For the Sampling Period 1st September 2008 – 31st May 2009

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Executive summary

- This report presents the findings of results from the 2008/2009 monitoring period.
- Seagrass abundance was significantly lower (>20% difference) in the 2008/2009 monitoring period compared to 2007/2008 at two thirds of the locations examined across the Great Barrier Reef. These locations were south of the Wet Tropics. Half of these locations show an overall decline in abundance since 2005.
- Seagrass at the location in the Cape York region which was reported to be declining in 2007/2008 has recovered. This was expected as the location had relatively large seed banks and low epiphytes / macro-algae.
- Seagrass seed banks (reserves) south of the Whitsundays are low or non-existent, suggesting reduced ability (low resilience) to recover from loss.
- Intertidal seagrass meadow distributions declined in late-Monsoon 2009, however remain higher than the losses experienced in 2006. Some localised losses have occurred, particularly in the estuarine habitats in the Burnett Mary region. Losses also occurred at coastal habitats in the Burdekin and Mackay Whitsunday regions; however these were restricted to a few sites and appear primarily the result of natural physical disturbance (sediment movement).
- Seagrass epiphyte cover was lower in the late Monsoon 2009 compared to the late Dry 2008. Trends in epiphyte cover were similar to trends in seagrass abundance, although amplitudes differed between habitats. Epiphyte abundances over the 2008/2009 monitoring period were within the levels previously experienced at all habitats.
- Macro-algae abundance was generally low across the locations monitored, but variable in coastal/reef meadows and increased slightly in estuary meadows compared to previous monitoring periods.
- Seagrass leaf tissue nutrients varied between locations, species, habitats and years. Examination of the overall trends suggest decreasing C:N ratios within all habitats (estuarine, coastal and reef) since 2005, possibly indicating reduced light availability.
- GBR wide tissue nutrient levels indicate that all habitats were generally nutrient rich (low C:P ratio), with estuarine and reef habitats becoming richer. Coastal habitats, although nutrient rich were mostly unchanged.
- Seagrass leaf tissue N:P levels of 25-30 indicate seagrass to be nutrient replete, and potentially eutrophic, at 50% of the seagrass locations examined. Tissue N:P ratios have consistently increased within coastal habitats since 2005, indicating nitrogen enrichment. Such a trend is consistent with historical patterns of increasing nitrogen observed in the Wet and Dry Tropics. GBR wide levels within reef and estuary habitats remained mostly unchanged from 2005 to 2008, however significant increases have occurred at mid-shelf reef habitats in Wet and Dry Tropics over the last 15 years.
- Seagrass condition indicated degraded water quality at three coastal locations in the Wet and Dry Tropics. Seagrass tissue elemental ratios at Yule Point, Lugger Bay and Townsville indicated plants were growing in generally low light environments, with a relatively large P pool and an excessive N pool.
- The C:N ratio (an indicator of light availability) explained 58% of the variability between sites in terms of % seagrass cover, suggesting light is a major factor influencing between site variability.

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Summary of condition and overall trend at each seagrass monitoring location, values are ***Oct08 – Apr09*** *(refer to Table 16) 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. Plant elemental C:N is a surrogate for light where moderate = adequate light availability on average required for growth (C:N>20:1), low = less available light on average than required for growth (C:N<20:1); C:P is a surrogate for nutrient status of the habitat where, rich = relatively large P pool (C:P <500:1), poor = relatively small P pool (C:P >500:1); N:P is the overall nutrient availability to the plant, where N limited = N:P <25, replete N:P = 25 to 30; P limited = N:P >30.*

NRM *(Board)*	Catchment	Location *(habitat)*	Seagrass Cover (%)	Seagrass Seeds (no. m^{-2})	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)*	14 – 21 *(19)* stable	76 - 229 (138) increase	variable	19 - 14 (26) decline	3 - 1 (10) decline	low *(CR)*	rich *(CR)*	replete	N↓P↑ (N<P)
Wet Tropics *(Terrain)*	Barron Russell / Mulgrave Johnstone	Yule Pt *(coast)*	23 – 27 *(16)* increase	170 - 679 (424) increase	increase	30 -53 (20) increase	2 - 1 (2) decline	low *(HU)*	rich *(HU)*	P limited	N↑P↓ (N<P)
		Green Is *(reef)*	28 – 36 *(41)* stable	nil	stable	27 - 63 (26) increase	3 - 4 (4) stable	moderate *(HU)*	poor *(HU)*	N limited	N↑P↑ (N<P)
	Tully – Murray	Lugger Bay *(coast)*	8 – 4 *(4)* variable	0 - 0 (4) variable	variable	2 (3) variable	0 (<1) stable	low *(HU)*	rich *(HU)*	P limited	N↑P↓ (N<P)
		Dunk Is *(reef)*	15 – 14 *(12)* stable	0 - 0 (1) variable	stable	27 - 70 (25) increase	7 – 7 (6) stable	moderate *(HU)*	rich *(HU)*	N limited	N↑P↑ (N<P)
Burdekin *(Burdekin Dry Tropics)*	Burdekin	Townsville *(coast)*	9 – 6 *(19)* decline	2348 – 1715 (2113) stable	decline	7 - 15 (17) decline	2 - 1 (4) variable	low *(HU)*	rich *(HU)*	P limited	N↓P↑ (N<P)
		Magnetic Is *(reef)*	32 – 21 *(36)* variable	34 - 34 (41) variable	stable	38 - 2 (42) decline	13 - 4 (7) stable	low *(HU)*	rich *(HU)*	replete	N↓P↓ (N<P)
Mackay Whitsunday *(Mackay Whitsunday)*	Proserpine	Pioneer Bay *(coast)*	27 – 24 *(20)* variable	59 - 136 (247) variable	increase	4 - 20 (14) stable	1 (11) stable	low *(HU)*	rich *(HU)*	N limited	N↓P↑ (N<P)
		Hamilton Is* *(reef)*	8 – 2 *(7)* decline	nil	variable	15 - 14 (17) decline	3 - 6 (3) stable	low *(HU)*	rich *(HU)*	replete	N↓P↑ (N<P)
	Pioneer	Sarina Inlet *(estuary)*	2 – 5 *(15)* variable	0 (41) decline	variable	68 - 2 (14) variable	<1 (2) variable	low *(ZC)*	rich *(ZC)*	replete	N↓P↑ (N<P)
Fitzroy *(Fitzroy Basin Association)*	Fitzroy	Shoalwater *(coast)*	26 – 22 *(23)* variable	nil	stable	21 - 8 (13) stable	5 - <1 (6) decline	moderate	poor	replete	N↑P↓ (N<P)
		Great Keppel *(reef)*	2 – 1 *(3)* decline	nil	variable	17 - 22 (31) variable	7 - 1 (7) decline	low *(HU)*	rich *(HU)*	replete	N↓P↑ (N<P)
	Boyne	Gladstone *(estuary)*	35 – 13 (18) variable	nil	variable	45 - 6 (27) variable	<1 (17) decline	low *(ZC)*	rich *(ZC)*	replete	N↓P↓ (N<P)
Burnett Mary (Burnett Mary Regional Group)	Burnett	Rodds Bay *(estuary)*	30 – 2 *(20)* decline	0 (2) NA	decline	21 - 1 (8) variable	2 - 1 (2) stable	moderate *(ZC)*	rich *(ZC)*	N limited	N↓P↓ (N<P)
	Mary	Urangan *(estuary)*	3 – 1 *(16)* variable	nil	decline	7 - 1 (20) variable	<1 (1) stable	low *(ZC)*	rich *(ZC)*	replete	N↑P↑ (N<P)

Summary of condition and overall trend at each seagrass monitoring location in the ***Oct07 – Apr08*** *monitoring period. From McKenzie, L.J., Mellors, J.E. and Waycott, M. (2008). Great Barrier Reef Water Quality Protection Plan (Reef Rescue) – Marine Monitoring Program, Intertidal Seagrass for the Sampling Period 1st September 2007 – 31st May 2008. 127pp.*

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)
	Tully – Murray	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)

- Rhizosphere sediment N:P ratios in late Dry 2008 within coastal and estuary habitats were low relative to previous years. N:P ratios within these habitats have mostly declined since 2005, indicating these meadows have become richer in P relative to N. In reef environments the N:P ratio has increased since 2006, and in 2008 had a higher ratio than coastal and estuary habitats.
- No herbicides were found above detectable limits in the sediments of seagrass monitoring sites during the late Monsoon 2009.
- Within canopy temperatures over the past 12 months were warmer at northern locations and cooler at southern locations compared to the previous monitoring period. The only location to experience maximum temperatures above 40°C during the past 12 months was Picnic Bay (Magnetic Island).

1. Introduction

A key component of Reef Rescue is the implementation of a long-term water quality and ecosystem monitoring program in the Great Barrier Reef lagoon. The Great Barrier Reef Marine Park Authority (GBRMPA) has responsibility for implementation of this program. Fisheries Queensland (FQ) 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 Reef Rescue by the Queensland and Australian community.

Background

Seagrass are considered coastal canaries or coastal sentinels that can be monitored to detect human influences to coastal ecosystems (Orth *et al*., 2006). Since 1990, seagrasses globally have been declining at a rate of 7% per year (Waycott *et al*., 2009). Multiple stressors are the cause of this decline, the most significant being degraded water quality. Much of the connectivity in reef ecosystems depends on intact and healthy non-reef habitats, such as seagrass meadows. These non-reef habitats are particularly important to the maintenance and regeneration of populations. Therefore, monitoring changes in seagrasses meadows can provide an indication of coastal ecosystem health and be used to improve our capacity to predict expected changes to reefs, mangroves and associated resources upon which coastal communities depend (Heck *et al*., 2008).

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

One of the paramount requirements of the Reef Rescue Marine Monitoring Program, 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 Rescue (previously know as the Reef Plan), that the existing Seagrass-

Watch program was an excellent opportunity on which the inshore seagrass monitoring component could be based. It was designed such that the ongoing monitoring activities were enhanced through; value adding by collecting other information by scientists in the field, and where stakeholder/community groups can not monitor FQ staff and fee for service trained personnel collect the data.

FQ 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. Scientifically trained participants 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 official Seagrass-Watch website at www.seagrasswatch.org.

In late 2004 all Seagrass-Watch data was supplied to Glenn De'ath (Senior Statistician, AIMS) for independent review. De'ath (2005) 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 from 6 regions (Cooktown, Cairns, Townsville, Whitsundays, Hervey Bay, Great Sandy Strait). Results concluded that the Seagrass-Watch monitoring was providing valuable information about long-term trends and spatial differences, with changes in seagrass cover occurring at various spatial and temporal scales. The report recommended that the value of the monitoring would be greatly enhanced by adding more widely spread locations to the regions.

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

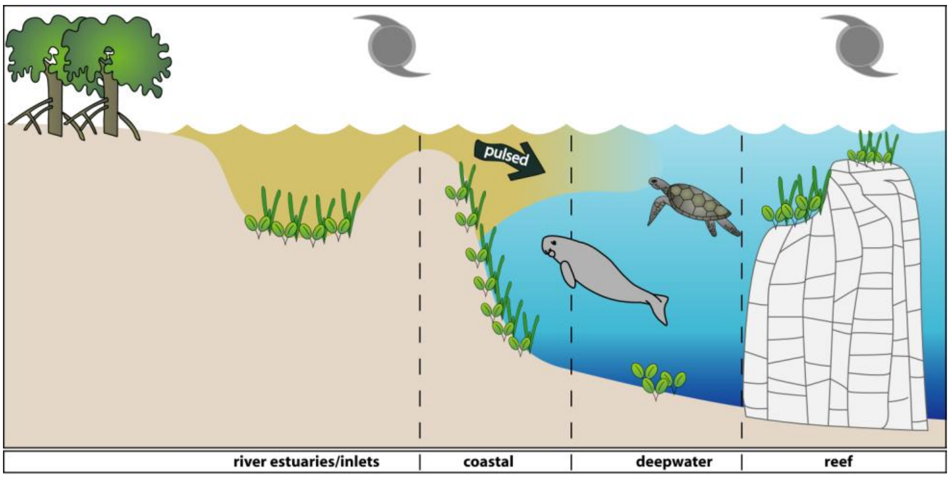


Figure 1. *General conceptual model of seagrass habitats in north east Australia (from Carruthers et al. 2002)*

2. Methodolgy

[Note: detailed documentation of methods was provided to RRRC/GBRMPA in a separate report in May 2009: *Water Quality and Ecosystem Monitoring Programs - Reef Water Quality Protection Plan: Methods and Quality Assurance/Quality Control Procedures*.]

Thirty sites were monitored as scheduled (Table 1). This included nine inshore (intertidal coastal and estuarine) 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.*, 2007; see also www.seagrasswatch.org). At each location, sampling included two sites nested in a location and three 50m transects nested in each site. A site was defined as a 50m x 50m area within a relatively homogenous section of a representative seagrass community/meadow (McKenzie *et al* 2000). Monitoring at the sites identified for the Reef Rescue MMP long-term intertidal monitoring in late Dry and late Monsoon of each year was conducted by a qualified and trained scientist. Monitoring conducted outside these months, was at some locations conducted by trained/certified local stakeholders/community volunteers. Sites were monitored for seagrass cover and species composition. Additional information was collected on canopy height, algae cover and epiphyte cover and macrofaunal abundance. An assessment of reproductive health was also conducted via seedbank monitoring (predominately *Halodule uninervis*). 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 (September/October 2008) and late Monsoon (March/April 2009) monitoring periods. Training and equipment (GPS) were provided to personnel involved in the edge mapping.

Field protocols followed Seagrass-Watch standard methodology (McKenzie *et al*. 2001). Edges were recorded as Tracks or a series of waypoints in the field using a portable Global Positioning System receiver. Accuracy in the field was dependent on the portable GPS receiver (3-5m, 95% typical) and how well the edge of the meadow was defined. Generally accuracy was within that of the GPS (i.e. -5m).

Mapping was conducted by trained and experienced FQ (DEEDI) staff using ESRI® ArcMap™ 9.3 (ArcGIS™ Desktop 9.3). Boundaries of meadows were determined based on the positions of survey Tracks and/or Waypoints and the presence of seagrass. Using the GIS, meadow boundaries were assigned a "quality" value based on the type and range of mapping information available for each site and determined by the distance between waypoints and GPS position fixing error. These meadow boundary "errors" were used to estimate the likely range of area for each meadow mapped (McKenzie *et al.* 2001).

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

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

Table 2. *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 (2008)								late Monsoon Season (2009)							
					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 Reef Rescue MMP for plant tissue and reproductive health. Habitat type is classified as Reef=reef intertidal, Coast=coastal intertidal, Estuary=Estuarine intertidal following the classification of Carruthers et al. (2002).*

Zostera capricroni = Zostera muelleri subsp. *capricorni*

** 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	*H. ovalis*	*H. uninervis*	*Z. capricorni*
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 2008 and late Monsoon 2009 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).

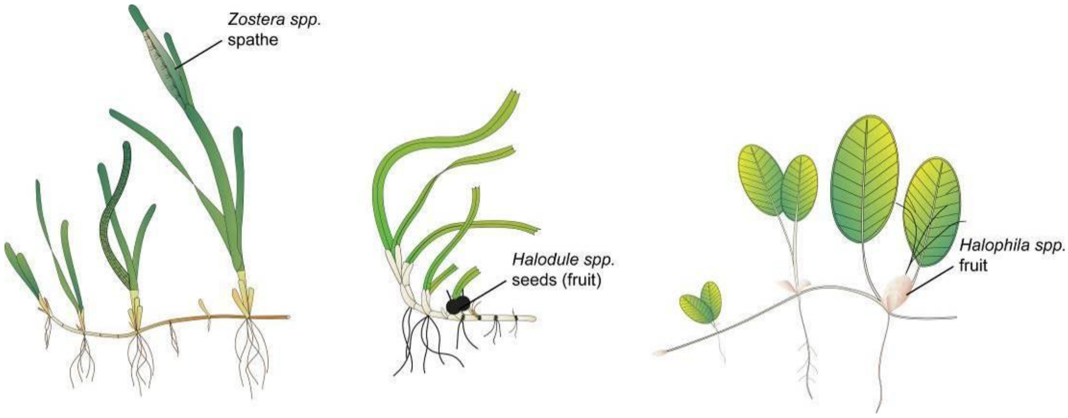


Figure 2. *Form and size of reproductive structure of the three seagrasses collected – Halophila ovalis, Halodule uninervis and Zostera muelleri* ssp. *capricorni.*

[Analysis and presentation of reproductive health (excluding seed banks) was conducted by James Cook University. The report on reproductive health results was not available at time of production of this report]

Seagrass tissue nutrients

In late Dry season (October) 2008, tissue nutrient (*Halodule uninervis*, *Halophila ovalis* and *Zostera capricorni*) samples were collected from the monitoring sites, as indicated in Table 3.

Three haphazardly placed 0.25m^2 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 resulted in the inclusion of sub-sampling, which 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 Chemcentre in Western Australia (a NATA certified laboratory). %C was determined by atomic absorption, also at QHSS. Elemental ratios (C:N:P) were calculated on a mole:mole basis using atomic weights (i.e., C=12, N=14, P=31).

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

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

Where data was sufficient, differences in each individual tissue ratio within each of the key species at each location were investigated using one-way ANOVA. Where appropriate, data was transformed using a log function.

Sediment nutrients

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 (NH_4^+) 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.

Collecting sediment samples for rhizosphere nutrient analysis

To extract adsorbed phosphate (PO_4^{3-}), the Olsen/ Colwell/Bicarbonate method was used. This technique is not affected by pH, and potentially strips all adsorbed PO_4^{3-} from the sediments. Although this has the potential to overestimate the PO_4^{3-} 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 (µmolkg^{-1}) to equivalent units (µmolL^{-1} sediment) to enable the molar ratios of the total sediment nutrient pool to be calculated.

Equation 1:

p_s = (Dry sample wt - Syringe weight)/(Volume - ((Wet sample wt - Dry sample wt)/dw)))

where dw = specific gravity of water = 1.025

Equation 2:

Φ = (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

Data was expressed as individual nutrient concentrations as well as the ratio of N:P (ammonium to phosphate). It was not possible to conduct statistical analyses between years as conglomeration of samples for laboratory analysis reduced sample replication.

Rhizosphere sediment herbicides

Sediment (approximately 250ml) for herbicide analysis was collected at each monitoring site identified in Table 2. Along each of the three transects monitored per site, approximately 20ml of sediment were collected every 5m to a depth approximately equal to the depth of the rhizome layer. Three homogenised samples (one per each transect) were collected per site. Detailed procedures are outlined in the *Water Quality and Ecosystem Monitoring Programs - Reef Water Quality Protection Plan: Methods and Quality Assurance/Quality Control Procedures.* Frozen samples were then sent for analysis. Extraction, clean-up and analysis of the sediments for herbicides were conducted according to NATA approved methods developed by QHSS.

Within seagrass canopy temperature

Autonomous iBTag™ submersible temperature loggers were deployed at all sites identified in Table 1. The loggers recorded temperature (degrees Celsius) within the seagrass canopy every 90 minutes. The large capacity of these loggers allows the collection of 256 days of readings at 90 minute intervals. iBCod 22L submersible temperature loggers were attached to the permanent marker at each Seagrass-Watch site above the sediment-water interface.

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

Seagrass canopy light

Submersible Odyssey™ photosynthetic irradiance autonomous loggers were attached to permanent station markers at inshore and an offshore seagrass sites in both the Cairns and Townsville regions (Table 2). Measurements were recorded by the logger every 30 minutes. Where possible, automatic wiper brushes cleaned the optical surface of the sensor every 15 minutes to prevent marine organisms fouling.

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

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

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. Symbols/icons have been used in the conceptual diagrams to illustrate major controls, processes and threats/impacts (Figure 2).

Figure 3. *Key to symbols used for conceptual diagrams detailing impacts to seagrasses.*

3. Results

Cape York

2008/2009 Summary

Cape York Peninsula is an area of exceptional conservation value and has cultural value of great significance to both Indigenous and non-Indigenous communities. The majority of the land is relatively undeveloped, therefore water entering the lagoon is perceived to be of a high quality. Only one location at an intertidal fringing reef seagrass habitat was monitored in this region. Physical disturbance from waves and swell and associated sediment movement primarily control seagrass growing in these habitats.

- The sampling sites are dominated by *Halodule uninervis* and *Halophila ovalis* communities, with varying amounts of *Cymodocea* and *Thalassia*.
- Seagrass cover although seasonal, has remained stable and appears to have recovered from previous declines.
- Seagrass species composition has varied since 2003, but stabilised over past 12 months.
- Seagrass tissue C:N and C:P ratios within previous levels (using *Cymodocea*), however N:P was significantly lower in 2008. Ratios suggest the habitat to be low light availability, nutrient rich and plants possibly replete or N limited in 2008.
- Seagrass spatial extent declined slightly and remains lower than 2005 baseline
- Epiphyte fouling of seagrass remains relatively low.
- Seagrass sediment phosphate has increased. Seagrass sediment ammonium reduced but within the range of previous recorded levels.
- No herbicides detected in sediments.
- Within canopy temperatures similar to previous years and the maximum recorded was 37.1ºC.
- Mean maximum daily air temperature was 0.5°C hotter and mean annual rainfall was16% lower than the 80 year average.

Background

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

Cape York Peninsula is an area of exceptional conservation value and has cultural value of great significance to both Indigenous and non-Indigenous communities. (http://www.nrm.gov.au/state/qld/cape-york/publications/report-card/index.html). The majority of the land is relatively undeveloped, therefore water entering the lagoon is perceived to be of a high quality. Mining, agriculture, shipping tourism and commercial and recreational fishing are the major economic activities. All have potential to expand in this region and with this expansion the possible increase in pollutants.

Of the seagrass habitats types identified for the GBR (Figure 1), Reef Rescue MMP monitoring of intertidal seagrass meadows within this 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 4). 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.

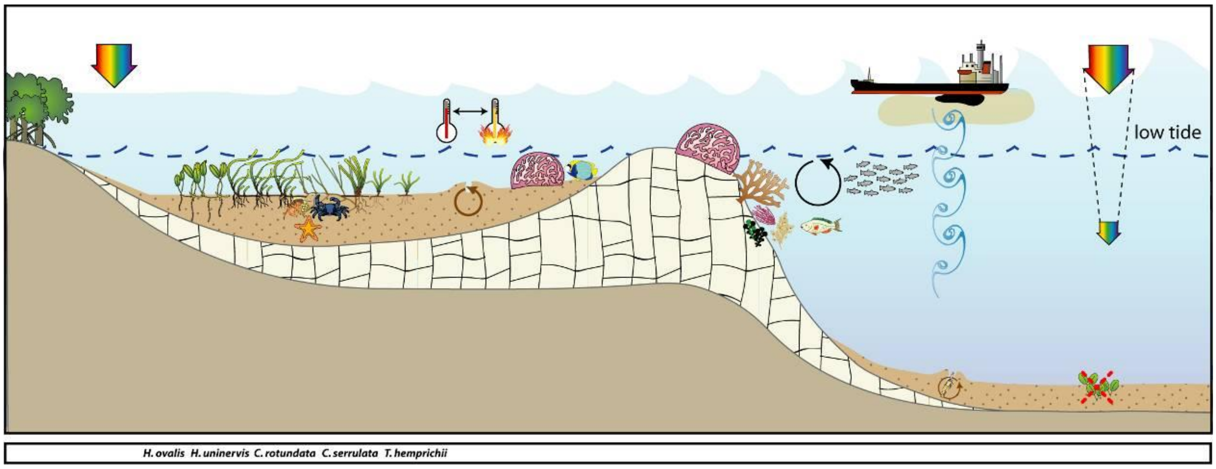


Figure 4. *Conceptual diagram of reef-platform habitat in the Cape York region – major control is pulsed physical disturbance, salinity and temperature extremes: general habitat and seagrass meadow processes (See Figure 2 for icon explanation).*

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

Seagrass cover and composition

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 5). Seagrass cover was higher in late Monsoon 2009 than 2008, however not significantly. Abundance in the late Dry season remained stable over the past 12 moths. Overall, the meadow appears to have generally recovered from the declines reported in the previous monitoring period, and has stabilised within long-term abundances (Figure 5).

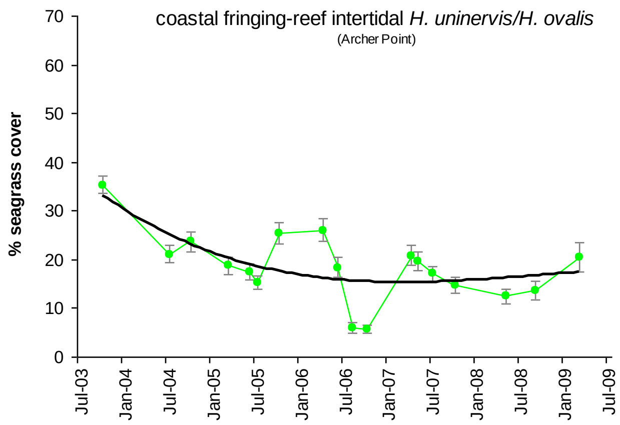
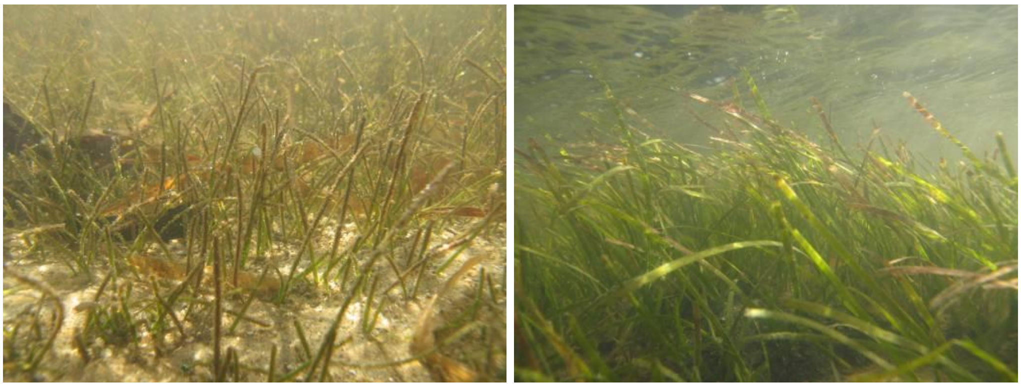


Figure 5. *Seagrass abundance (% cover, ± Standard Error) at Archer Point, inshore intertidal fringing-reef habitat (sites pooled).*

Sites at Archer Point are dominated by *Halodule uninervis* (Figure 6). Although sites were only 50m apart, AP2 had slightly more *Cymodocea* and *Thalassia* present. Species composition at AP1 has varied since sampling began in 2003. The composition of *Halophila ovalis* was originally low, but increased in 2006, coinciding with significant losses in abundance. This result is not surprising, as following disturbance or loss, *H. ovalis* is commonly the first species to recolonise. Since 2006, the composition of *H. ovalis* has decreased and *H. uninervis* increased. During 2008 the amount of *C. rotundata* also increased slightly, indicating the meadow may be stabilising. At AP2 the species composition has been more variable, however also during 2008, there were increasing in *H. uninervis* and *C. rotundata*.



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

Quadrat at 5m on transect 3 at AP1 on 05 May 2008 (left) and 27 March 2009 (right)

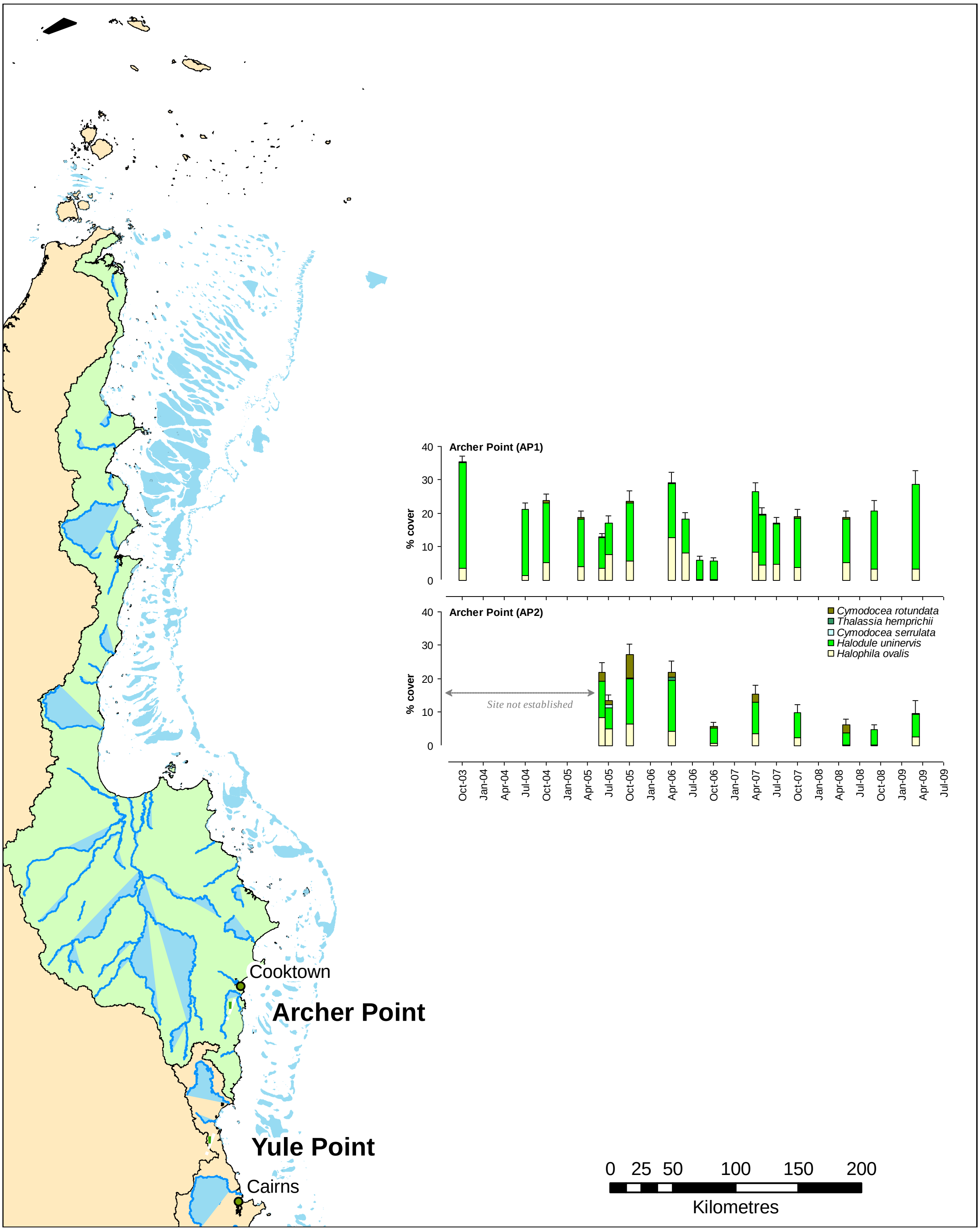


Figure 6. *Mean percentage cover for each seagrass species at Archer Point monitoring sites (+Standard Error). NB: if no sampling conducted then x-axis is clear.*

Since monitoring was established at AP1 in 2003, seagrass cover has generally followed a seasonal trend with higher abundance in late Dry to late Monsoon period (Figure 7). The seasonal trend at AP2 is similar, with the exception of the lower abundance in late Monsoon 2009.

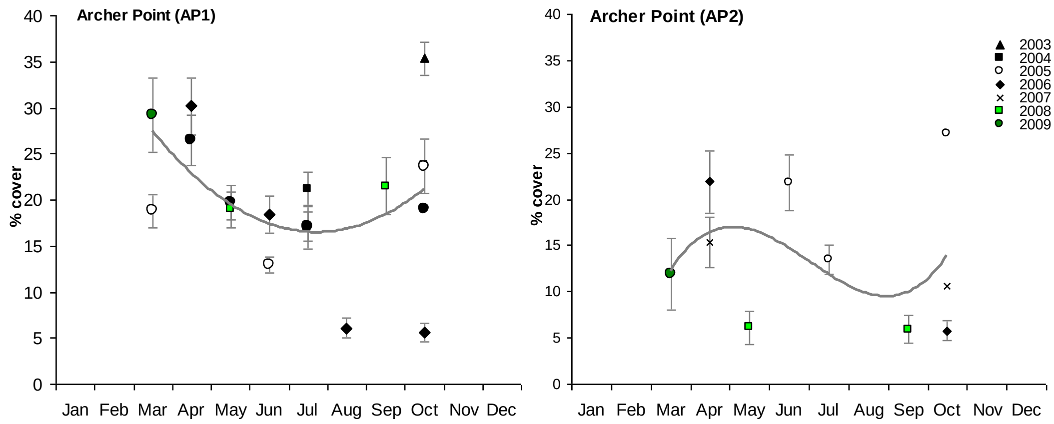


Figure 7. *Mean percentage seagrass cover (all species pooled) (± Standard Error) for inshore fringing-reef long-term monitoring sites in Cape York at time of year. NB: Polynomial trendline for all years pooled.*

Seagrass tissue nutrients

Seagrass species in Archer Pt in late Dry season 2008 all had low molar C:N ratios, where values of 20 or less indicated light availability may be low (Figure 8). Although C:N values in 2008 were lower than 2007, they were still within the range of previously observed levels and not significantly different from previous years ($p > 0.05$).

C:P ratios were lower in 2008 relative to all previous years, particularly for both *Halophla ovalis* and *Cymodocea rotundata* (insufficient *Halodule uninervis* samples were collected in 2008 for analysis). All values were below 500, indicating the presence of a relatively large P pool, suggesting the habitat to be nutrient rich (Figure 8).

N:P ratios for all species were the lowest since the commencement of Reef Rescue MMP, with levels within *Halodule uninervis* significantly lower in 2008 than in 2005 and 2006 ($F_{3,25} = 3.89$, $p < 0.05$). N:P ratios for all species were below 30. *H. uninervis* N:P ratios were between 25-30, indicating that plants were replete, and *C. rotundata* and *H. ovalis* ratios below 25 indicating that plants were N limited (Figure 8).

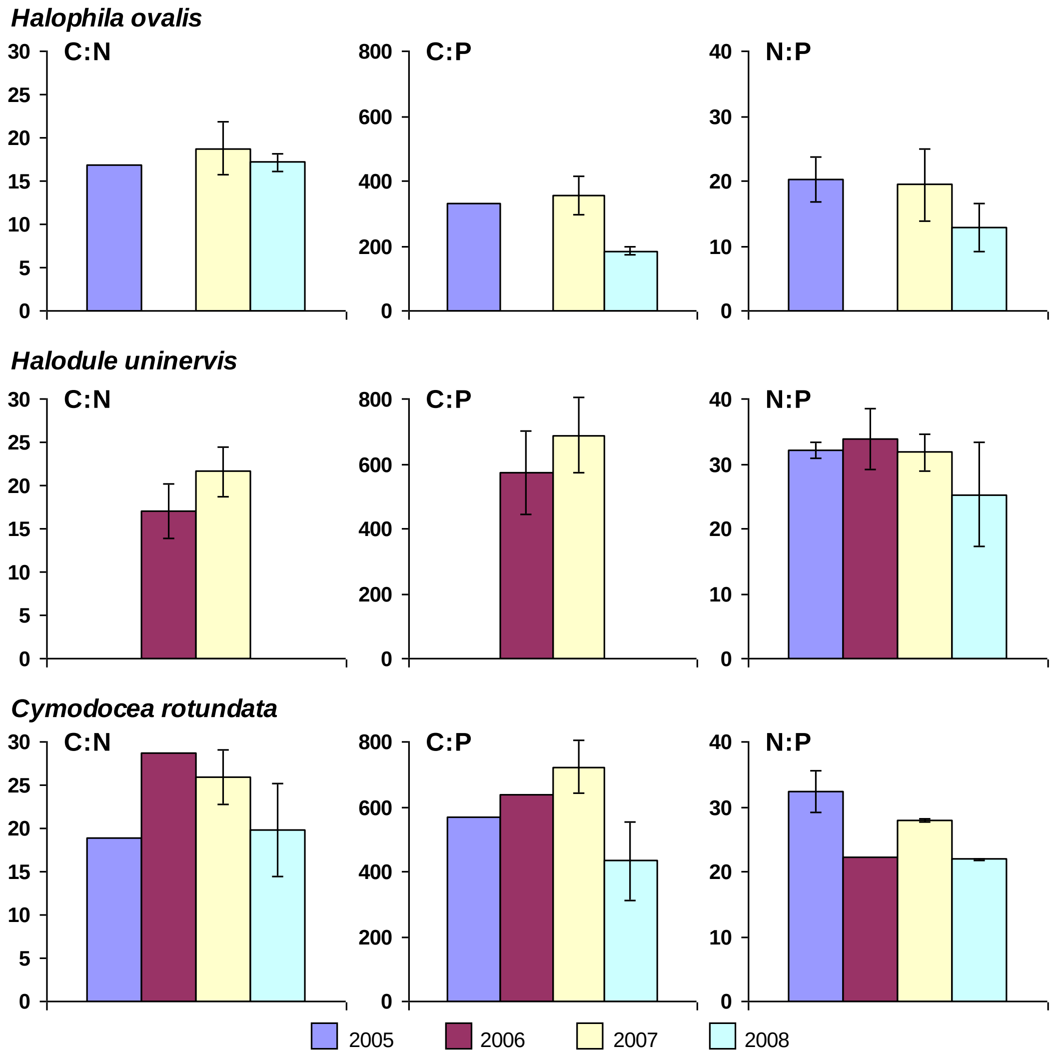


Figure 8. *Plant Tissue Ratios C:N, C:P and N:P for Halophila ovalis, Halodule uninervis and Cymodocea rotundata in Cape York at Archer Point (mean and SD displayed).*

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 has remained stable at AP2, but has declined seaward at AP1, decreasing the overall area of seagrass present within the mapping boundaries (Figure 9, Table 4).

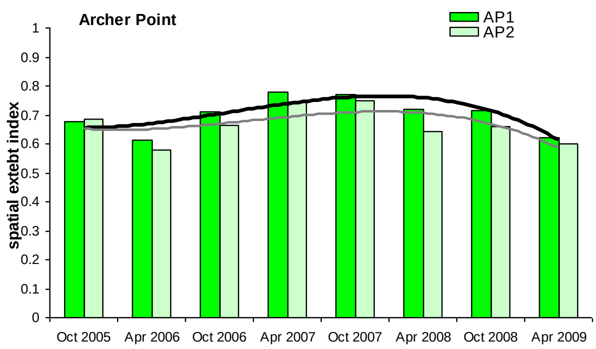


Figure 9. *Extent of area (100m radius of monitoring site) covered by seagrass at each monitoring site.*

Table 4. *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	October 2008	April 2009
AP1	3.667	3.330 *(-9.2%, decrease seaward)*	3.843 *(4.8%, increase shoreward)*	4.212 *(14.9%, increase shoreward)*	4.173 *(13.8%, decrease seaward)*	3.905 *(6.5%, decrease seaward)*	3.88 *(5.7%, decrease seaward)*	3.36 *(-8.3%, decrease seaward)*
AP2	3.710	3.139 *(-15.4, decrease seaward)*	3.5865 *(-3.3, increase shoreward)*	4.0367 *(8.8%, decrease seaward)*	4.053 *(9.28%, decrease seaward)*	3.489 *(-5.98%, decrease seaward)*	3.57 *(-3.73%, increase shoreward)*	3.26 *(-12.14%, decrease seaward)*

Epiphytes and macro-algae

Epiphyte cover on seagrass leaf blades at Archer Point are generally variable (Figure 10). Overall, the abundance of epiphytes appears to have declined since monitoring began in 2003 (Figure 10). Epiphyte abundances remained low over the past monitoring period.

Percentage cover of macro-algae is also variable. Although abundance increased in 2006 and 2007, they have since declined significantly. Overall, macro-algae appear to be declining in abundance at Archer Point (Figure 10).

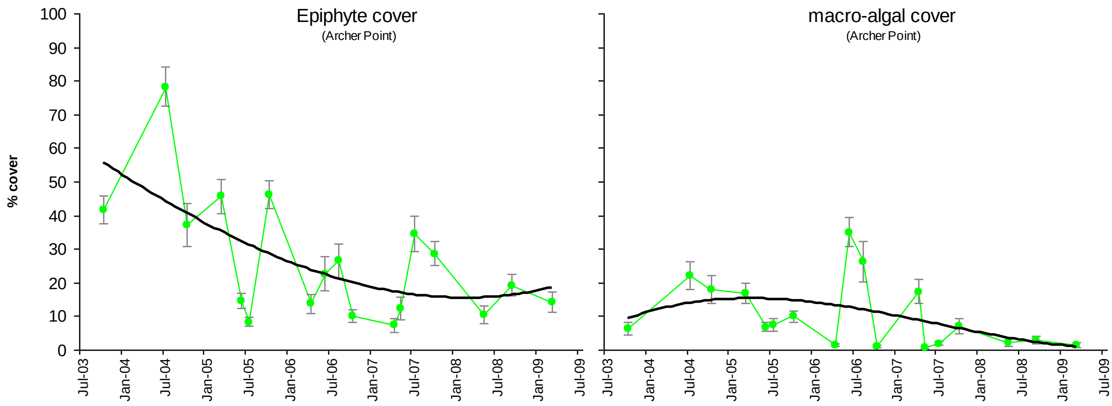


Figure 10. *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at Archer Point (sites pooled). NB: Polynomial trendline for all years pooled.*

Sediment nutrients

Seagrass sediments at Archer Pt in late Dry 2008 contained highly variable concentrations of Phosphate (PO_4^{3-}) within the rhizosphere; the mean value of which was higher than levels previously recorded at this site (Figure 11). Sediment ammonium (NH_4^+) was reduced in 2008 but within the range of previous recorded levels. The highly elevated sediment Phosphate levels result in a very low N:P ratio.

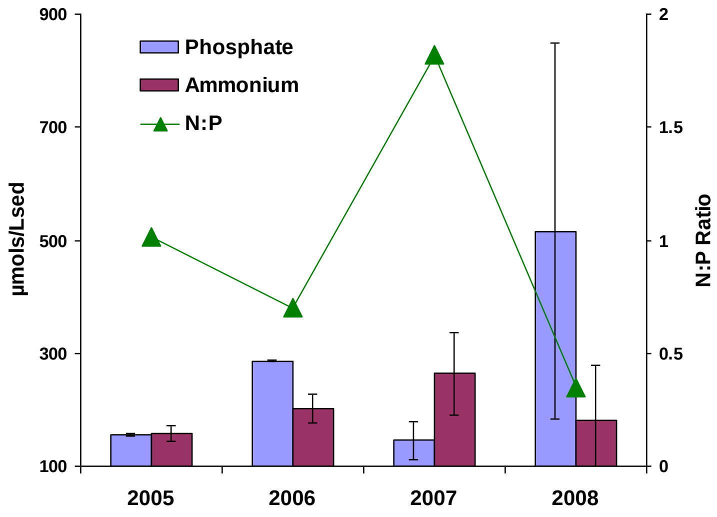


Figure 11. *Adsorbed nutrient levels within seagrass sediments of Cape York (Ammonium (NH_4), Phosphate, and the ratio of PO_4^{3-} to NH_4) at Archer Pt October 2005 to October 2008.*

Sediment herbicides

No herbicides were found above detectable levels in the sediments of the seagrass meadows at either monitoring site (**Table 5**).

Table 5. *Concentration of herbicides (µg kg^{-1}) in sediments of Archer Point seagrass monitoring sites in post Monsoon 2009. ND=not detectable, <0.1 µg kg^{-1}*

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

Autonomous temperature loggers were deployed at both sites during the monitoring period. However loggers deployed over the Aug-Nov 2008 period failed and no measures could be retrieved. High temperatures were recorded from November 2008 to March 2009, however no temperatures exceeded 40°C (Figure 12), with the highest maximum recorded 37.1° C in December 2008 and February 2009 at AP2 (Figure 13). Temperatures over the monitoring period were similar to previous years.

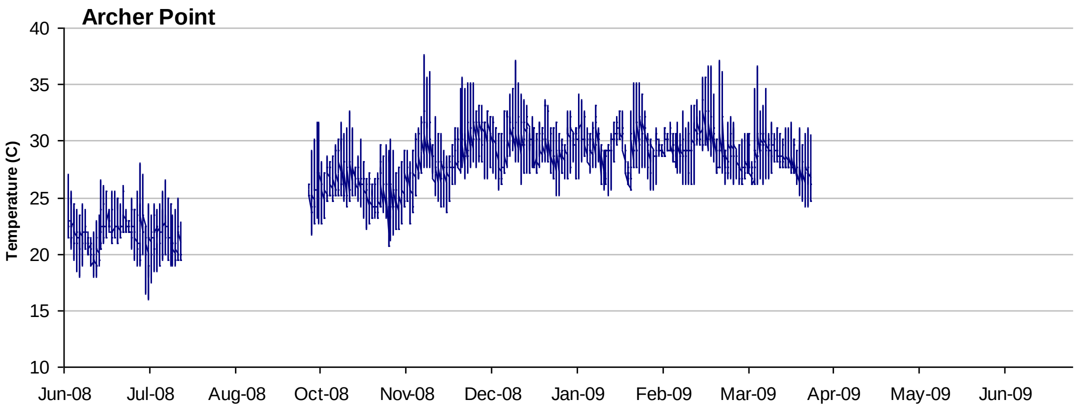


Figure 12. *Within seagrass canopy temperature (°C) at Archer Point intertidal meadow over the 2008/2009 monitoring period.*

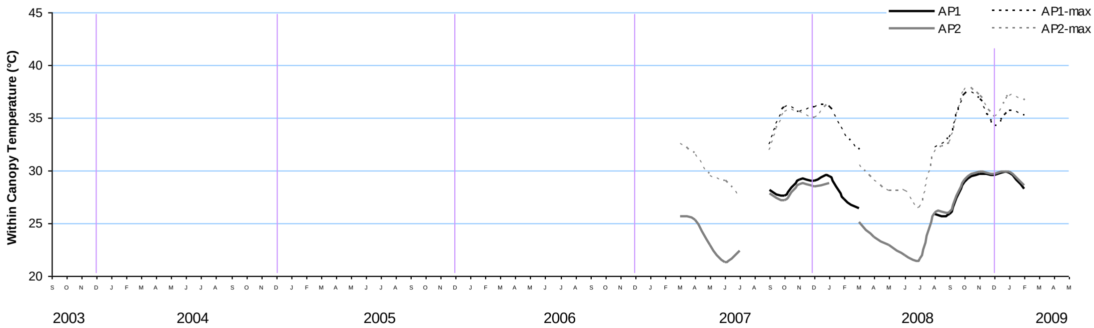


Figure 13. *Monthly mean and maximum within seagrass canopy temperatures (°C) at Archer Point intertidal meadow, Cape York region.*

Regional Climate

The monthly average maximum temperatures recorded in Cooktown during 2008 and 2009 were generally higher than their equivalent months in 2006 and 2007, while the yearly average maximum temperature in 2008 was 29.4°C; 0.5°C hotter than the 80 year average (BOM 2009). Mean annual rainfall in Cooktown in 2008 was 1518mm, this was 16% below the 100 year average of 1814 mm, however this rainfall was higher than had been received in 2005 and 2007. Cloud cover in Cooktown during 2008 was similar to levels in 2007; this was following high cloud cover in 2006.

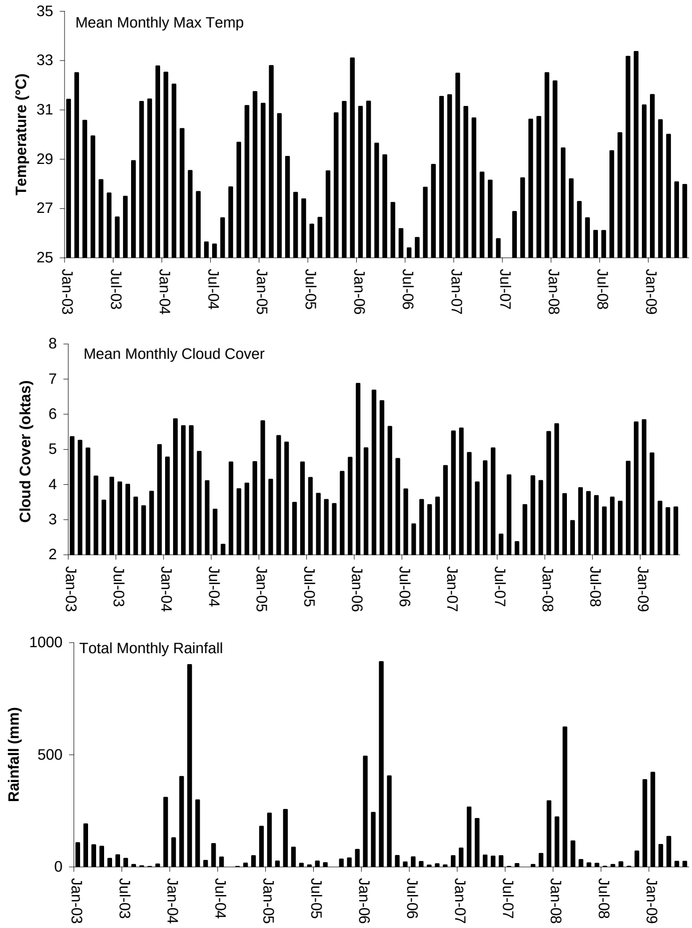


Figure 14. *Mean monthly daily maximum temperature (°C) and cloud cover (quarts) recorded at Cooktown airport (BOM station 031209) (source www.bom.gov.au). Cooktown Airport used as a surrogate for the climate at Archer Point.*

Wet Tropics

2008/2009 Summary

The region includes two significant World Heritage Areas, however increased land use practices (agriculture and coastal development) and declining water quality have been identified as significant in the region.

Seagrass monitoring was conducted on coastal and reef platform habitats. A dominant influence on these habitats is disturbance from wave action, sediment movement, elevated temperatures as well as seasonal terrigenous runoff. Nutrient concentrations are also generally low in reef habitats due to the nature of the coral sand sediments.

- Seagrass species composition is relatively stable and dominated by *Halodule uninervis* and *Halophila ovalis* meadows at coastal locations and *Cymodocea rotundata* and *Thalassia hemprichii* at offshore island locations.
- Seagrass cover although seasonal, has generally increased or stabilised over the past 12 months and naturally lower at coastal locations compared to reef.
- Seagrass tissues in reef environments had higher C:N ratios than those in coastal, indicating a potentially higher light environment in reef habitats. Decreasing C:N ratios at Green Island since 2006 indicate decreasing light availability at this location.
- Tissue C:P ratios indicate high levels of nutrients at both coastal locations and Dunk Island. Ratios have progressively increased at Yule Point since 2005.
- N:P ratios generally increasing over time at coastal and reef habitats indicating increased nitrogen availability.
- Overall results suggest poor water quality at coastal locations with low light availability and elevated N (potentially eutrophic).
- Seagrass spatial extent was stable at reef locations and variable at coastal locations due to the dynamic nature of sandbanks.
- Epiphyte fouling of seagrass increasing at most locations, macro algae negligible.
- Reef locations had higher sediment Phosphate and ammonium relative to coast. Sediment nutrients higher at Green Is and Dunk Is than in previous years, but in coastal meadows, levels were mostly unchanged.
- No herbicides were detected in sediments.
- Within canopy temperatures were slightly warmer at coastal than reef locations. The maximum canopy temperature was 39°C. Temperature of 08/09 monitoring period similar to previous years.
- Within seagrass canopy light environment varied as a function of season, with higher light present within winter relative to summer (windspeed, daylight hours and tidal height). The coastal light environment was 39% lower than offshore.
- Mean maximum daily air temperature was 0.2°C hotter and mean annual rainfall was 11% higher than the 100 year average.

Background

The Wet Tropics NRM includes the wet tropics catchment region and covers 22,000 km^2 (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: coastal and reef.

Reef Rescue monitoring occurs at two coastal seagrass habitat locations: Yule Point, in the north and Lugger Bay to the south. The seagrass meadows at Yule Point and Lugger Bay are located on naturally dynamic intertidal sand banks, protected by fringing reefs. These meadows are dominated by *Halodule uninervis* with some *Halophila ovalis* and are often exposed to regular periods of disturbance from wave action and consequent sediment movement. The sediments in these locations are relatively unstable restricting seagrass growth and distribution. A dominant influence of to these coastal meadows is terrigenous runoff from seasonal rains (Figure 15). The Barron, Tully and Hull Rivers are a major source of pulsed sediment and nutrient input to these monitored meadows.

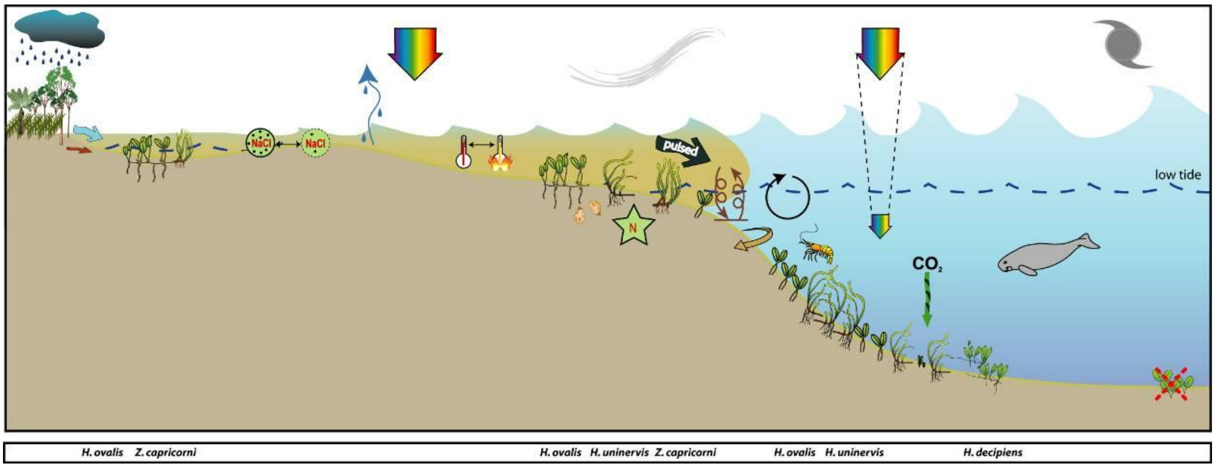


Figure 15. *Conceptual diagram of coastal habitat (<15m) in the Far North Queensland region – major control is pulsed terrigenous runoff, salinity and temperature extremes: general habitat, seagrass meadow processes and threats/impacts (See Figure 2 for icon explanation).*

Monitoring of reef habitats occurs at two locations: Green Island, and Dunk Island. The Dunk Island sites were only established in early 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 16). Reef seagrass habitats in the region are often adjacent to areas of high tourism use and boating activity with propeller and anchor scarring impacts. Globally, nutrient concentrations are generally low in reef habitats due to the coarse nature of the coral sand sediments. In these types of carbonate sediments the primary limiting nutrient for seagrass growth is generally phosphate (Short *et al.* 1990; Fourqurean *et al*. 1992; Erftemeijer and Middelburg 1993). This is due to the sequestering of phosphate by calcium carbonate sediments. In this region seagrass meadows inhabiting the near shore inner reefs and fringing reefs of coastal islands inhabit a mixture of terrigenous and carbonate sediments, such as Green Island. Seagrasses at this location have been shown to be nitrogen limited (Udy *et al.* 1999).

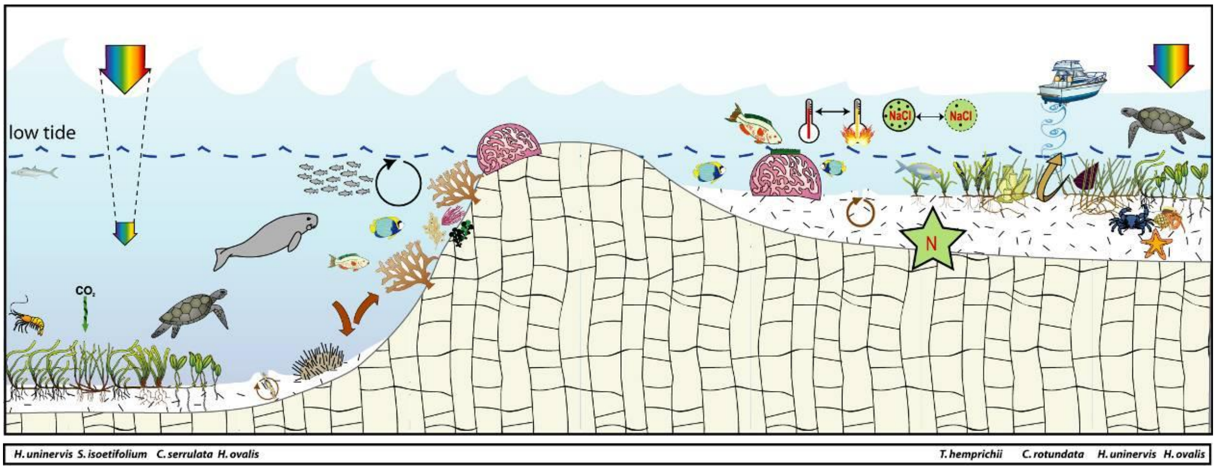


Figure 16. *Conceptual diagram of reef habitat (<15m) in the Wet Tropics region – major control is nutrient limitation, temperature extremes, light and grazing: general habitat, seagrass meadow processes and threats/impacts (See Figure 2 for icon explanation).*

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* (Figure 17).

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 Reef Rescue MMP until April 2007, when isolated plants were found inshore, within the 100m radius of the monitoring site. The meadow has continued to expand and is now mixed with the shoreward *H. uninervis* dominated meadow. During 2008, the proportion of *Halophila ovalis* at YP1 increased until the Monsoon 2009, when it declined to long-term average (Figure 17).

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 late Dry 2008, the seagrass had recovered to 2005 abundances. No significant changes in species composition were observed at Lugger Bay (Figure 17).

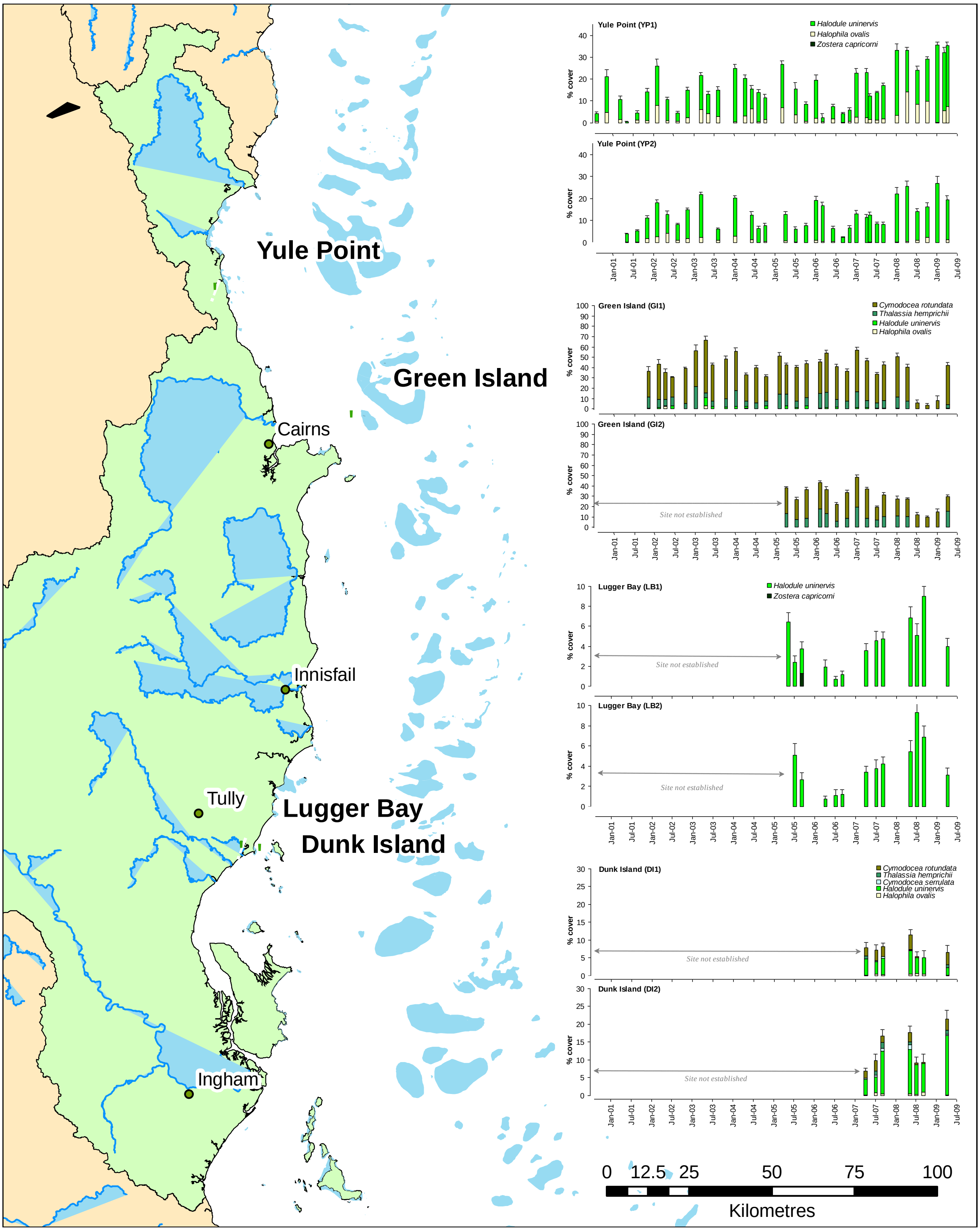


Figure 17. *Mean percentage cover for each seagrass species at Wet Tropics Seagrass-Watch long-term monitoring sites (+ Standard Error). NB: if no sampling conducted then x-axis is clear.*

Seagrass cover from the start of monitoring at Yule Point in 2000, had changed little from year to year until 2008 (Figure 18). Abundances in 2008 and 2009 were some of the highest recorded. Abundances at Lugger Bay increased during 2008, recovering to 2005 levels. However in late Monsoon 2009, abundances decreased and were significantly lower than late Monsoon 2008 (Figure 18).

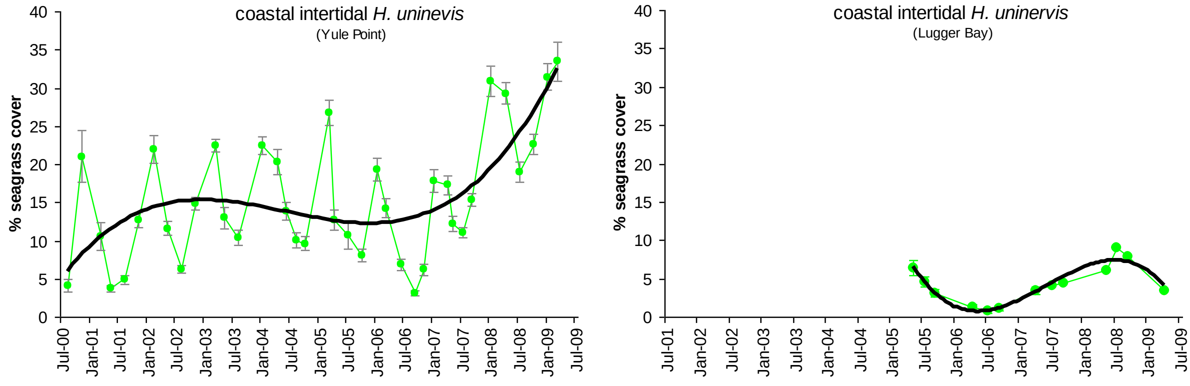
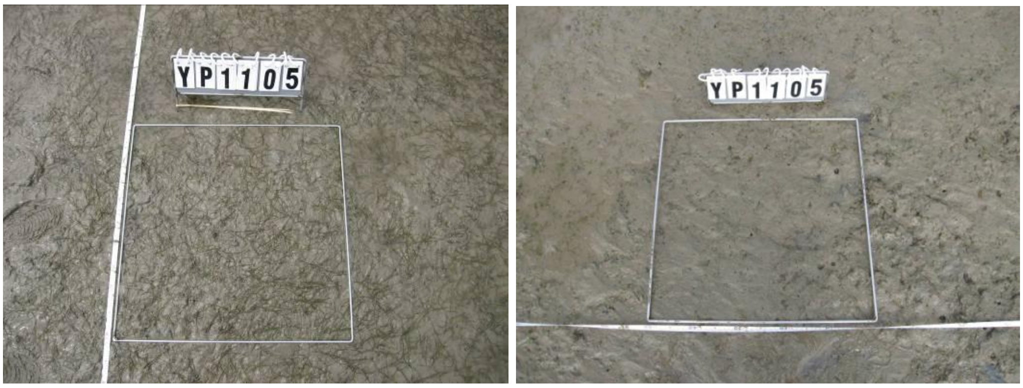


Figure 18. *Changes in seagrass abundance (% cover) of coastal intertidal Halodule uninervis meadows monitored in the Wet Tropics region from 2000 to 2009.*



Quadrat at 5m on transect 1 at Yule Point site YP1, on 18 April 2008 (left) and 22 July 2009 (right)

Seagrass cover over the past 12 months at Yule Point appeared to follow a seasonal trend with higher abundance over the period from late Dry to Monsoon (Figure 19).

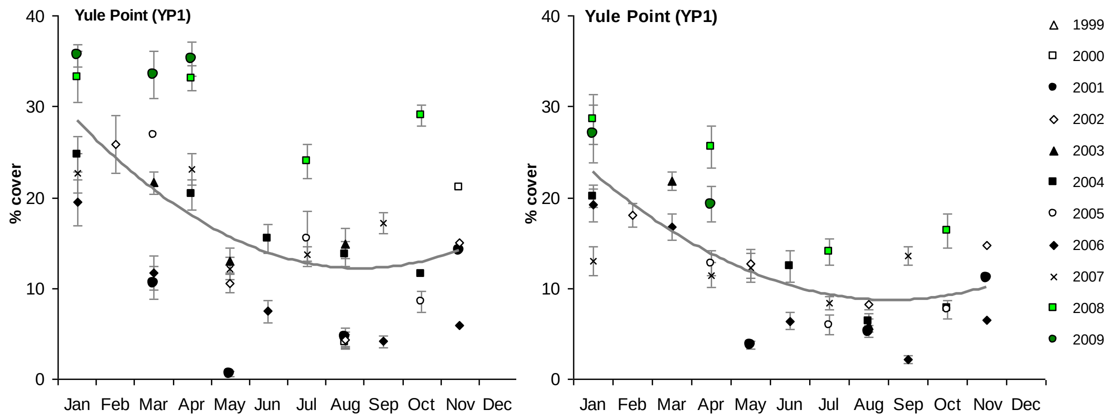


Figure 19. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Yule Point long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

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

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 20).

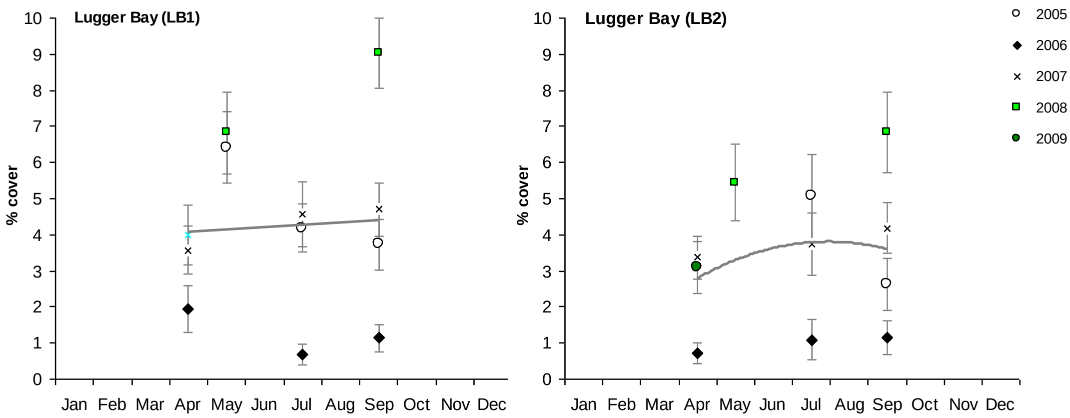
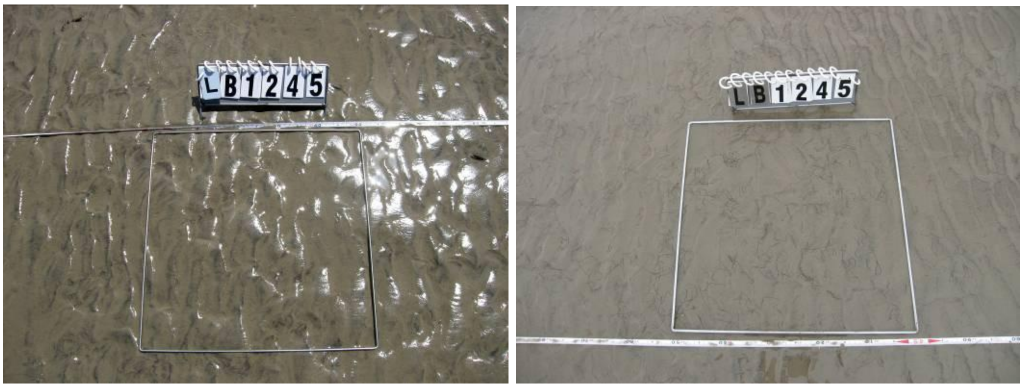


Figure 20. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Lugger Bay long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*



Quadrat at 45m on transect 2 at Lugger Bay site LB1, on 05 September 2006 (left) and 21 July 2009 (right)

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 17). 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 17, Figure 21 and Figure 22).

Seagrass meadows on the reef platform at Green Island.

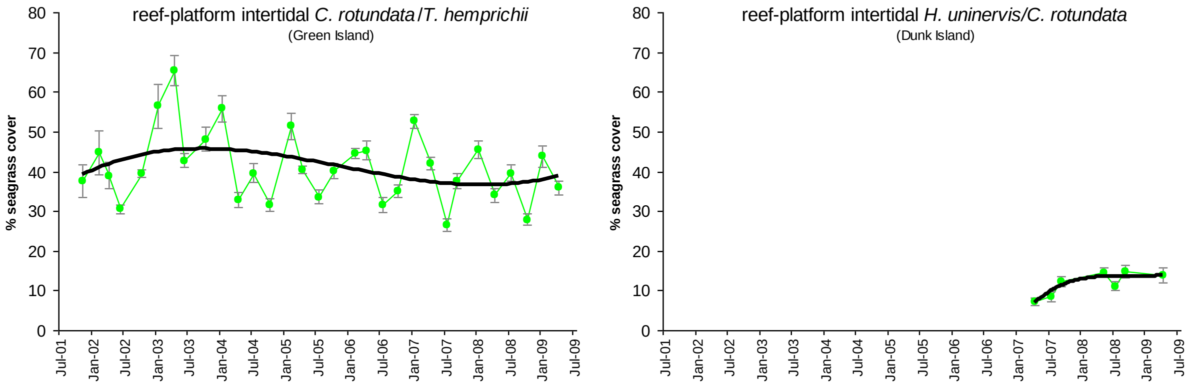


Figure 21. *Mean percentage seagrass cover (all sites pooled) at Green Island long-term monitoring sites (± Standard Error).*

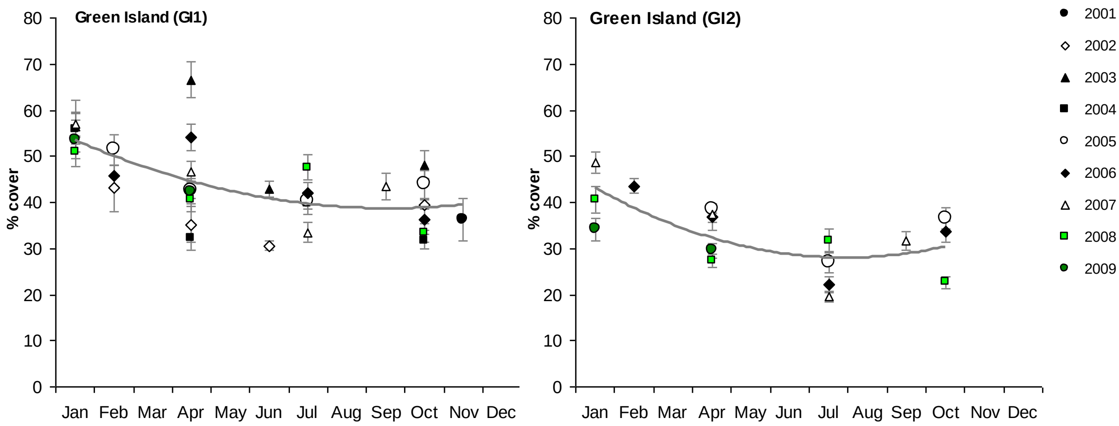


Figure 22. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Green Island long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

Quadrat at 5m on transect 3 at Green Island site LB1, on 19 April 2008 (left) and 23 April 2009 (right)

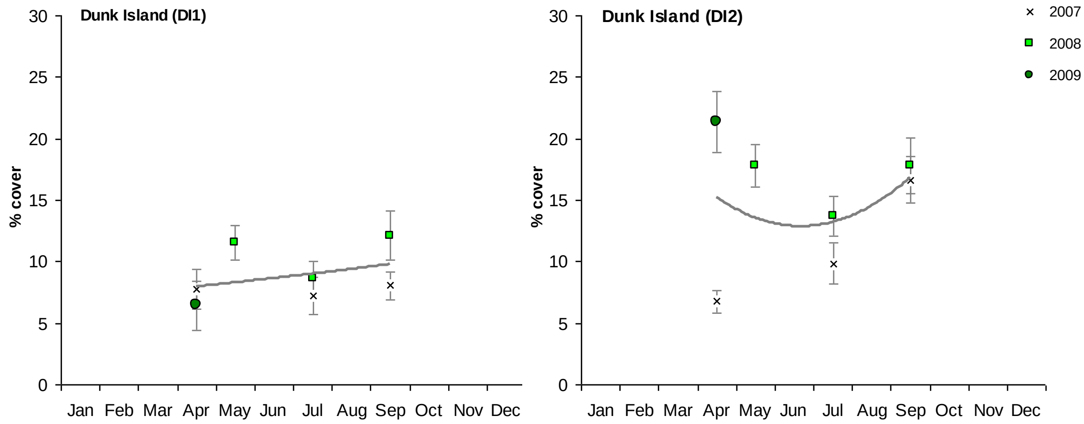


Figure 23. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Dunk Island long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

Seagrass tissue nutrients

Within the Wet Tropics region, seagrasses in reef environments (Dunk Island and Green Island) mostly had higher C:N ratios than those in coastal environments (Yule Pt and Lugger Bay) (Figure 24). This indicates a potentially higher light environment in reef habitats. Levels of the C:N ratio below 20 may be considered as indicative of environments where light may be limiting to growth. *Halodule uninervis* and *Halophila ovalis* at both Yule Pt and Dunk Is were below this level. Similarly, *H. uninervis* at Lugger Bay was well below this level. At Green Island, C:N ratios were at or below 20 for all four species (Figure 24). Since 2006, C:N values for *H. ovalis* at Green Is have declined, as have levels in *Cymodocea rotundata*, indicating reduced light availability over time. But within *Thalassia hemprichii* at Green Island the C:N ratios have remained unchanged between years ($p > 0.05$) (Figure 24). At Yule Pt, C:N ratios have remained broadly similar between years (Figure 24), indicating no change in light availability.

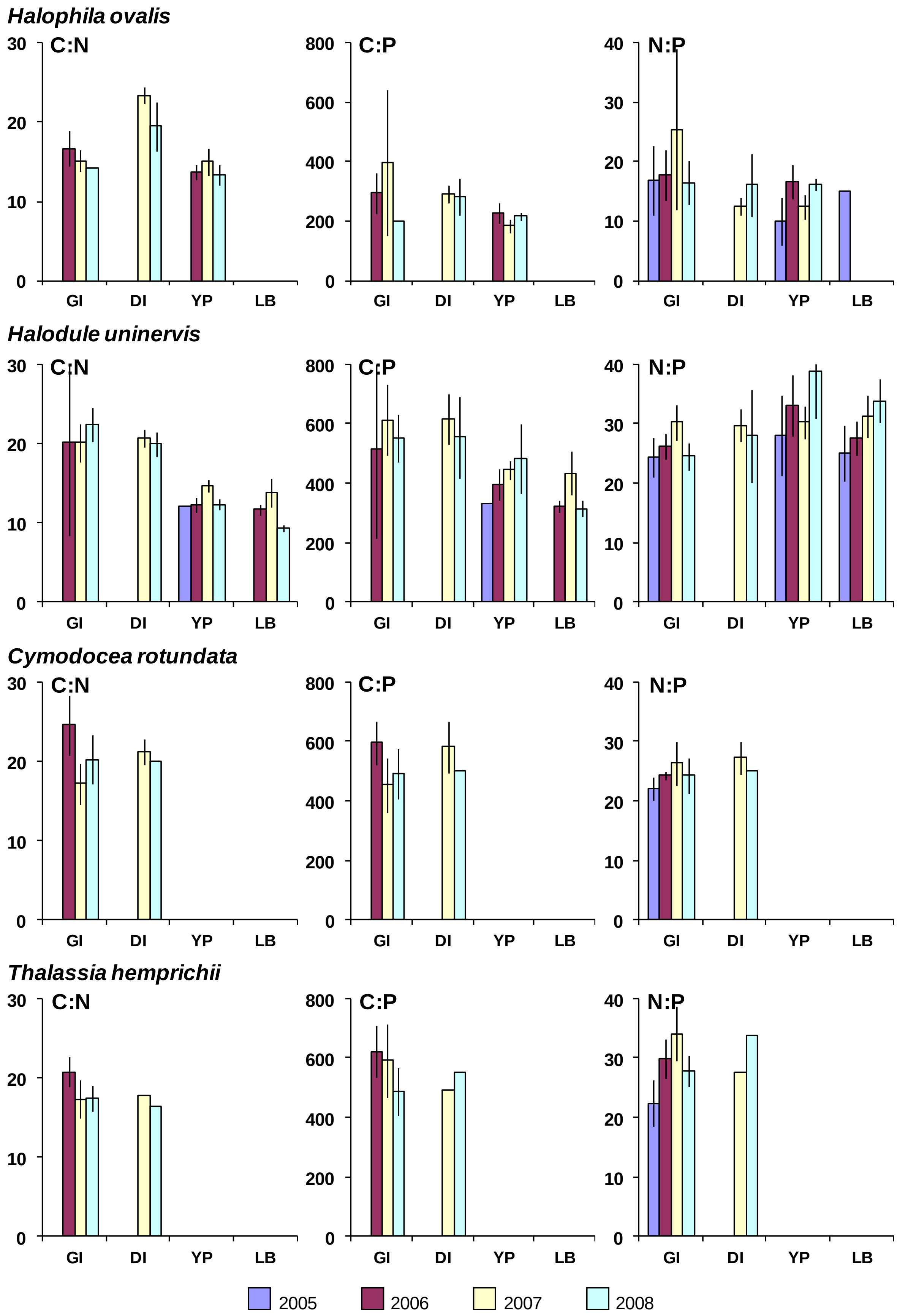


Figure 24. *Plant tissue ratios C:N, C:P and N:P for each of the seagrass species examined in the Wet Tropics at Green Island (GI), Dunk Island (DI), Yule Pt (YP), and Lugger Bay (LB) (mean and SD displayed).*

The late Dry 2008 C:P ratio of *H. ovalis* was well below 500 at Dunk Island, Green Island, and Yule Pt; indicating these sites were nutrient rich (Figure 24). Values below 500 were also recorded for *H. uninervis* in 2008 at Lugger Bay, again indicating high levels of nutrients. In contrast, levels of the C:P ratio were approximately 500 in *C. rotundata* and *T. hemprichii* in both the reef environments (Figure 24). At Yule Pt, *H. uninervis* C:P ratios were approximately 500 in 2008 indicating a reduced P pool. These levels have consistently increased between 2005 and 2008 (Figure 24), but these were not significant inter-annual changes ($p > 0.05$). In 2007 and 2008, the levels of the C:P ratio in *H. uninervis* were above 500 at Dunk Is and Green Is, indicating a small P pool.

The N:P ratio of *H. ovalis* within the Wet Tropics was consistently below 25, with values of ~15 recorded at Green Is and Dunk Is in 2008 (Figure 24). This indicates environments where N is limiting. The N:P ratios of *H. ovalis* show little between year variability at Green Is, Dunk Is, and Lugger Bay but at Yule Pt show a significant ($F_{3,16}=5.38$, $p< 0.05$) trend of increase, indicating seagrass becoming more replete and slightly P limiting.

The N:P ratios of *H. uninervis* at Lugger Bay ($F_{3,27}=3.86$, $p < 0.05$) and Yule Pt ($F_{3,27}=7.43$, $p < 0.05$) both show a consistent significant increase yearly (Figure 24). At Green Island, there were also significant between year differences in N:P of *H. uninervis* ($F_{3,26}=4.37$, $p < 0.05$) and *T. hemprichii* ($F_{3,26}=13.7$, $p < 0.001$). However these differences were not in a consistent direction and levels in 2008 were within the variability of previous years. Levels in 2008 of N:P at Green Island within *H. uninervis*, *C. rotundata* and *T. hemprichii* in 2008 were approximately replete.

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 6). 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. In 2009, some erosion had occurred on the seaward edges of the YP1 meadow, decreasing the overall distribution. The drainage channel still persist through part of YP2, however the meadow has continued to increase across other sections. (Figure 25).

There were no detectable differences in the edge mapping data of the seagrass meadows at Green Island between 2008 and 2009 (Figure 25).

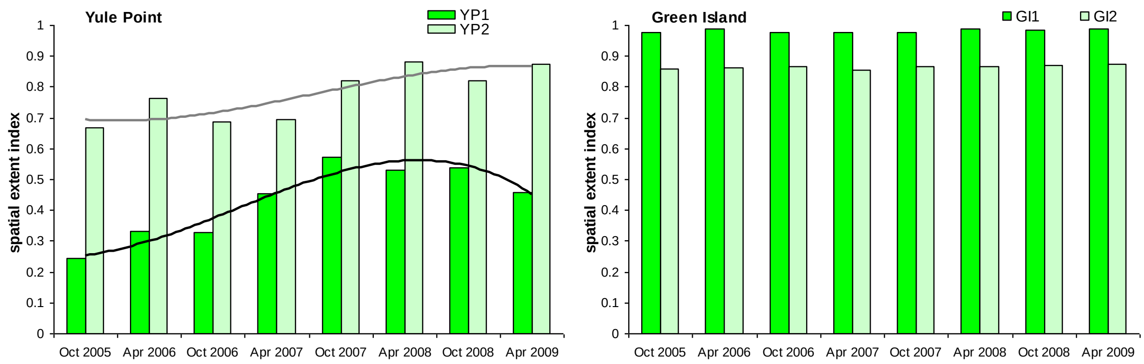


Figure 25. *Extent of area (100m radius of monitoring site) covered by seagrass at each coastal and offshore monitoring site at Cairns locations.*

At Lugger Bay, the distribution of the seagrass meadow continued to recover in 2008 from the significant losses in 2006 (Table 6). The slight decrease in April 2009 may be a consequence of seasonal, however the overall distribution is still greater than late Monsoon 2008 (Figure 26). The fringing reef meadow at Dunk Island expanded in the late Dry 2007 and has remained stable over 2008 and into 2009 (Table 6, Figure 26).

Table 6. *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	October 2008	April 2009
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)*	2.910 *(119.4%, decrease shoreward)*	2.463 *(85.7%, 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)*	4.432 *(23.2%, decrease overall)*	4.712 *(31.0%, 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)*	5.298 *(0.8%, no change)*	5.316 *(1.1% negligible)*
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)*	4.682 *(1.1%, negligible)*	4.703 *(1.5%, 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)*	1.607 *(-4.1% increase overall)*	1.218 *(-27.3% 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 *(-19.9% decrease seaward)*	1.945 *(8.0% increase shoreward)*	1.655 *(-8.1% decrease seaward)*
DI1	*NA*	*NA*	*NA*	**3.278**	3.479 *(6.1% increase overall)*	3.36 *(2.5% decrease shoreward)*	3.393 *(3.5% increase overall)*	3.34 *(1.9% decrease shoreward)*
DI2	*NA*	*NA*	*NA*	**3.972**	4.19 *(5.5% increase overall)*	4.425 *11.4% increase overall)*	4.332 *(9.1% increase overall)*	4.420 *(11.3% increase overall)*

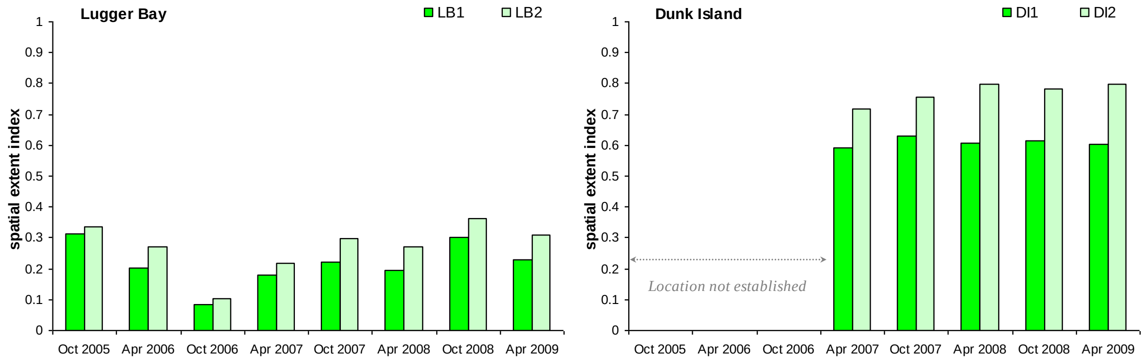


Figure 26. *Percentage of area (100m radius of monitoring site) covered by seagrass at each coastal and offshore monitoring site at Mission Beach locations.*

Epiphytes and macro-algae

Epiphyte cover on seagrass leaf blades at coastal sites was highly variable (Figure 27) and appears correlated with seagrass abundance. Epiphyte cover has continued to increase at Yule Point over the past 12 months however appears to have remained low at Lugger Bay (Figure 27). Percentage cover of macro-algae at coastal sites is also variable, however at Yule Point abundance has declined over the last four years (Figure 27).

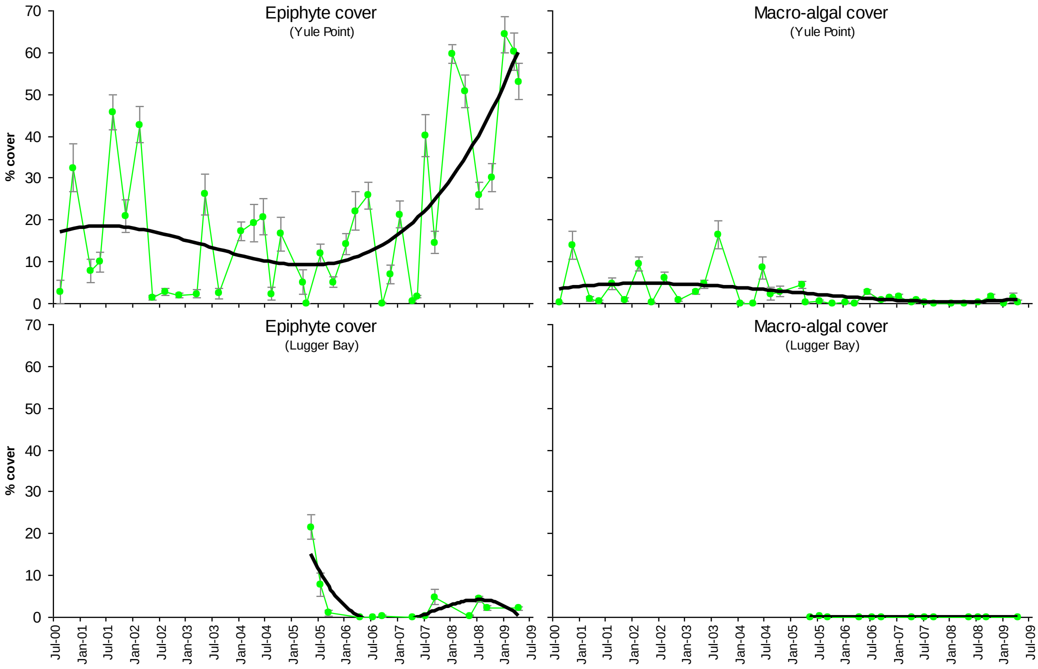
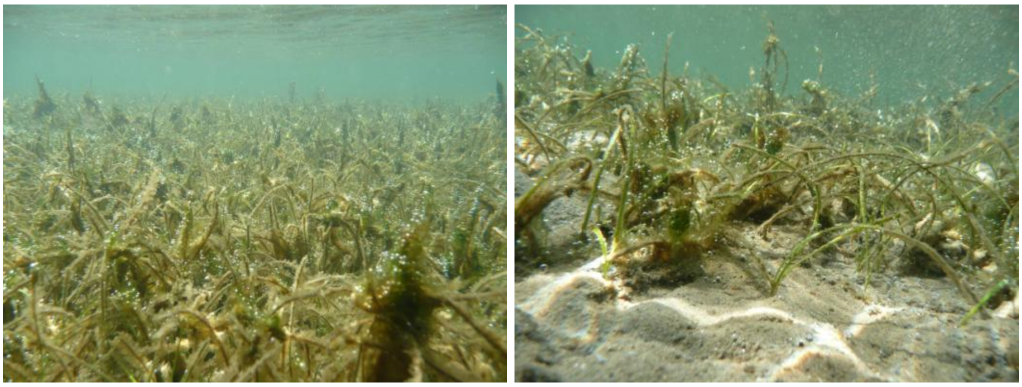


Figure 27. *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at coastal intertidal seagrass monitoring locations (sites pooled) in the Wet Tropics region. NB: Polynomial trendline for all years pooled.*



Epiphytes covering Halodule uninervis leaf blades at Yule Point.

Epiphyte cover at reef sites is highly variable and although not significant, it appears to be increasing (Figure 28). Macro-algae at both reef locations were predominately composed of *Halimeda* spp. and abundance is relatively stable, with mean covers less than 10% (Figure 28).

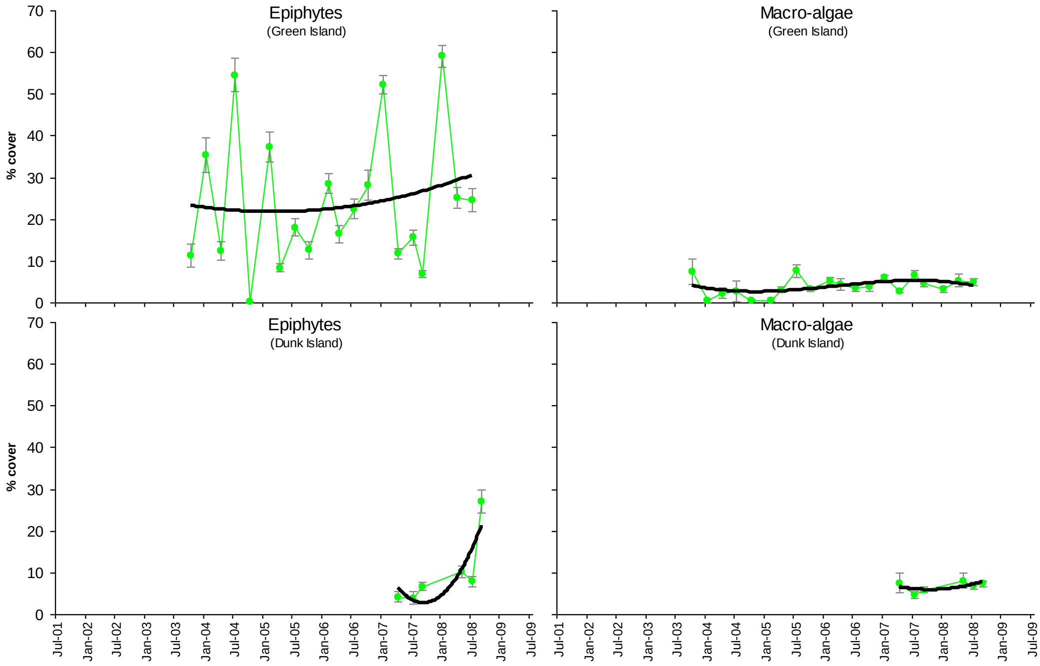
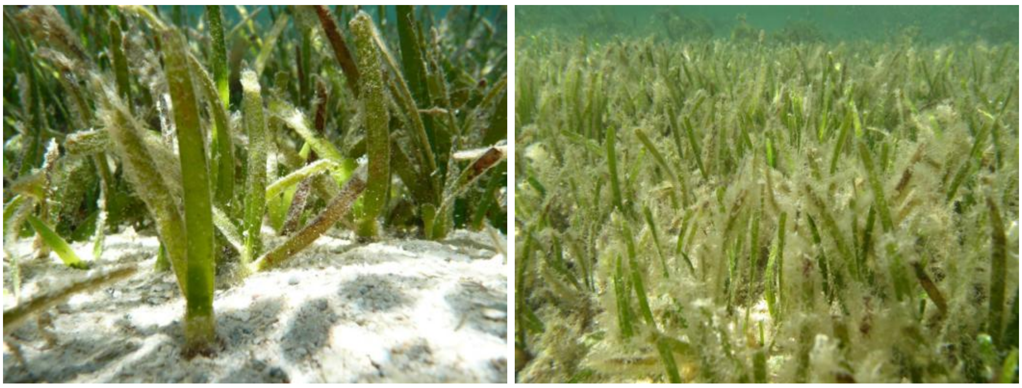


Figure 28. *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at reef intertidal seagrass monitoring locations (sites pooled) in the Wet Tropics region. NB: Polynomial trendline for all years pooled.*



Epiphytes covering Cymodocea rotundata leaf blades at Green Island.

Sediment nutrients

The concentration of adsorbed Phosphate on sediments of the reef meadows at Green Is and Dunk Is during 2008 was approximately double that of the coastal environments of Lugger Bay and Yule Pt. Levels of ammonium at Green Is were also double that recorded in coastal meadows, while levels at Dunk Is were also elevated. Overall, the levels of Phosphate and ammonium were higher in 2008 at Green Is and Dunk Is than in previous years, but in coastal meadows, levels were mostly unchanged.

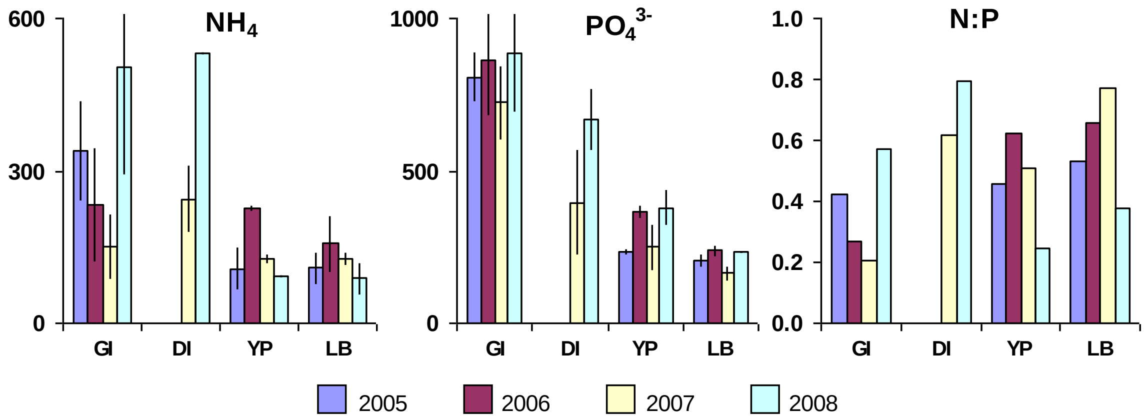


Figure 29. *Adsorbed nutrient levels within seagrass sediments of the Wet Tropics (ammonium (NH_4), phosphate, and the ratio of PO_4^{3-} to NH_4) at Green Island (GI), Yule Pt (YP), Dunk Island (DI), and Lugger Bay (LB) October 2005 to October 2008. Mean and SD displayed.*

Sediment herbicides

No herbicides were found above detectable levels in the sediments of the seagrass meadows at any of the monitoring sites in post-Monsoon 2009 (Table 7).

Table 7. *Concentration of herbicides ($\mu g\ kg^{-1}$) in sediments of seagrass monitoring sites in post Monsoon 2009. ND=not detectable, <0.1 $\mu g\ kg^{-1}$*

Site	Flumeturon	Diuron	Simazine	Atrazine	Desethyl Atrz.	Desisopropyl Atrz.	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 30). Intermittent logger failure was experienced at Dunk Island. No extreme temperatures (>40°C) were recorded at any of the monitoring locations over the sampling period (Figure 30). Over the last 12 months maximum mean temperatures were recorded in November 2008 and April 2009 during the low spring tides.

Temperatures in 08/09 at most sites, except Green Island, were similar to previous years. Wiithin canopy temperature in 2008/2009 (27.13±0.09°C) was significantly warmer at Green Island than the long-term (2003-2009) average (26.6±0.1°C), however Dunk Island was similar.

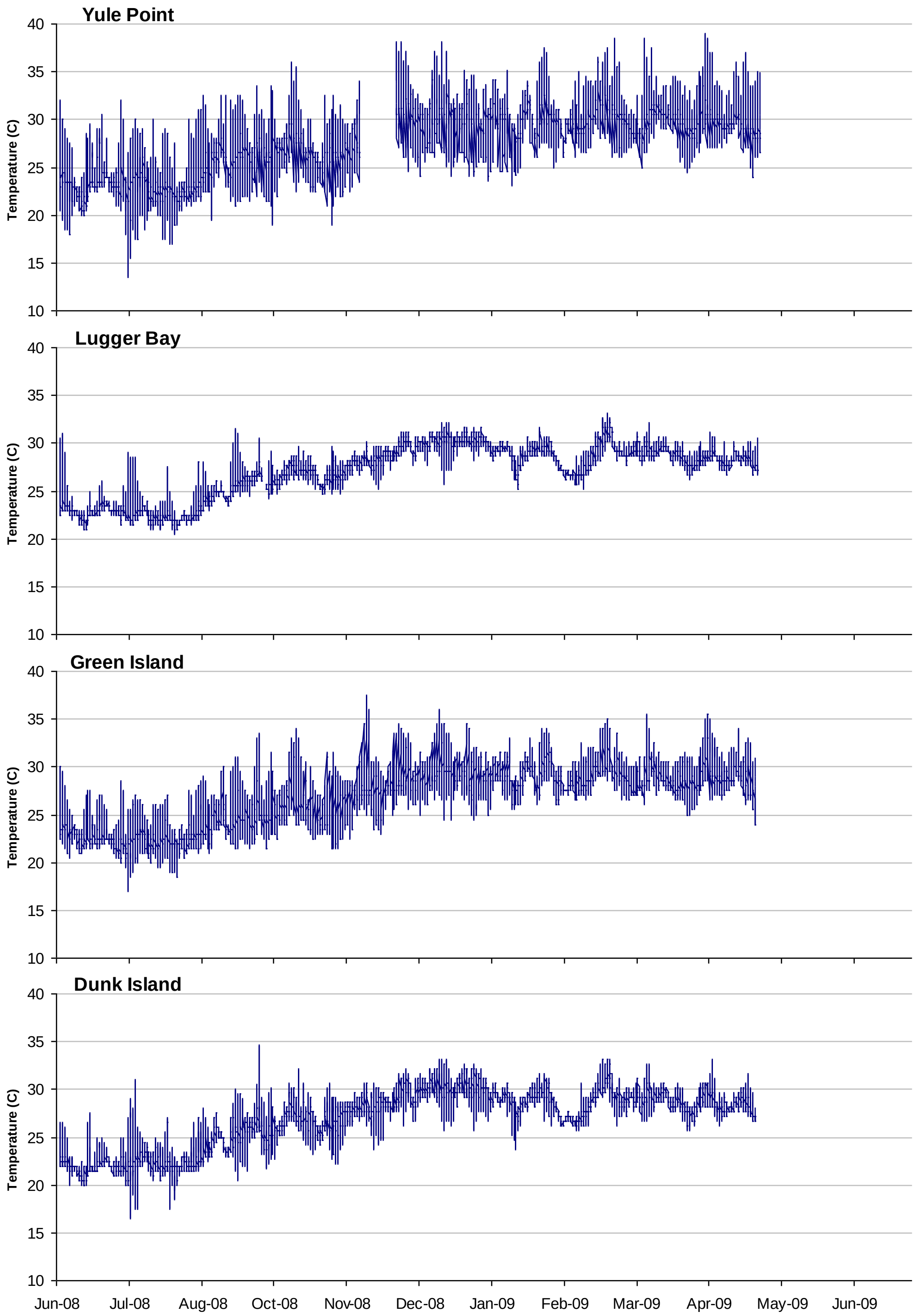


Figure 30. *Within seagrass canopy temperature (°C) at coastal (Yule Point and Lugger Bay) and offshore reef (Green Island and Dunk Island) intertidal meadows within the Wet Tropics region over the 2008/2009 monitoring period.*

Mean within canopy temperatures were generally within the 22 – 31°C range. Mean temperatures were the highest in December 2008 across all sites. Temperatures at the coastal and reef-platform locations generally follow a similar pattern, however coastal sites experienced lowest mean temperatures in August 2008, whereas reef sites experienced lowest mean temperatures a month earlier in July 2008 (Figure 31). Within canopy temperatures at

Dunk Island varied the greatest; experiencing both the lowest and highest mean temperatures across the region

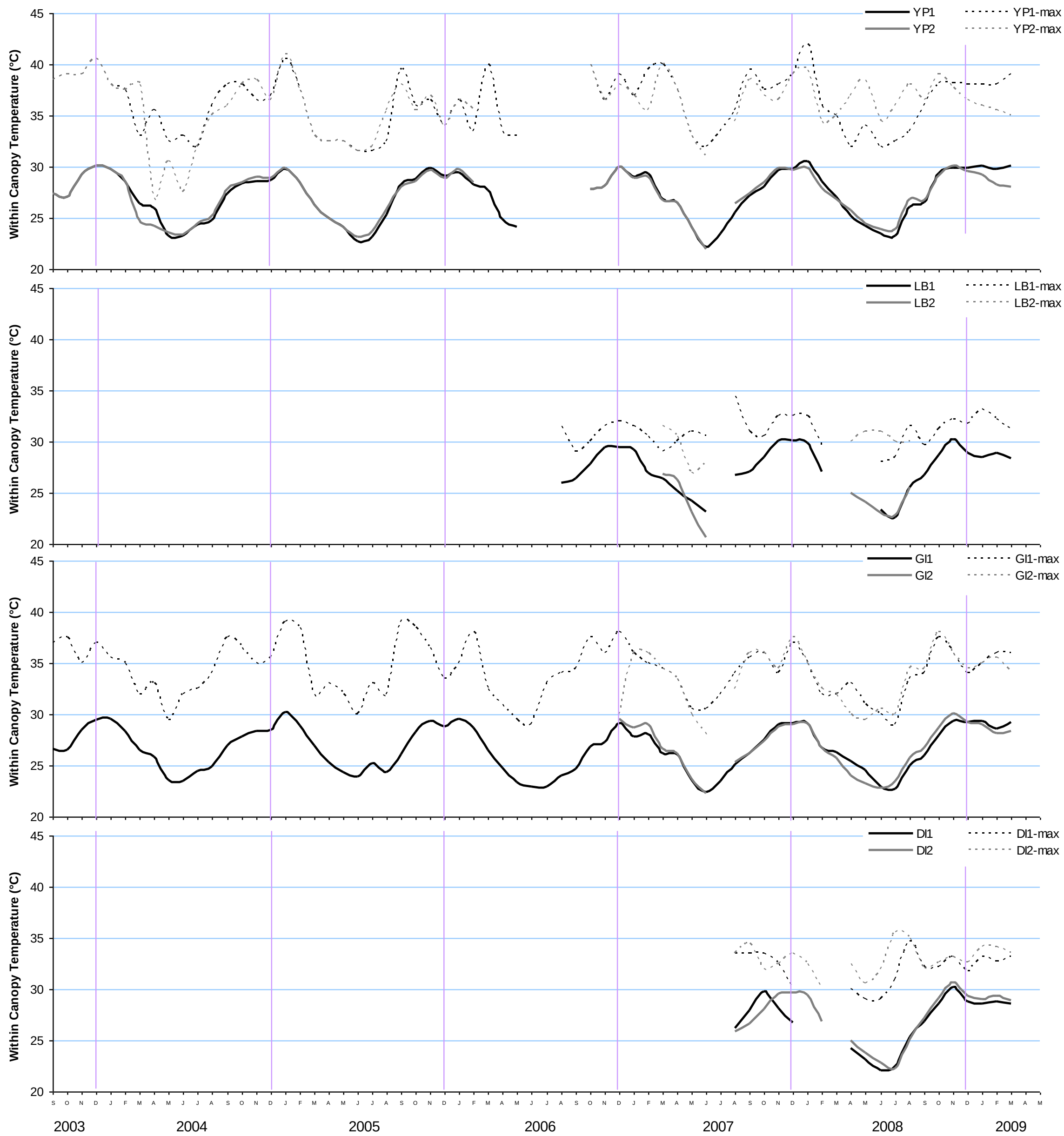


Figure 31. *Monthly mean and maximum within seagrass canopy temperatures (°C) at coastal (Yule Point and Lugger Bay) and fringing-reef (Green Island and Dunk Island) intertidal meadows within the Wet Tropics region.*

Within meadow canopy light availability

A light logger was deployed at two sites within the Wet Tropics, at Green Island and at Yule Point (Figure 32). These have been collecting measurements every half hour continuously since December 2007. Loggers have been collecting data at both locations without the use of a wiper unit, therefore some biological fouling of the light sensors have occurred. By placing a non-fouled logger at Yule Pt three days before retrieval of the existing logger a comparison was made. Fouling has been determined to result in the recording of 54% less daily total light (Figure 32).This results suggest that loggers in the Wet Tropics require wipers in order to reduce fouling.

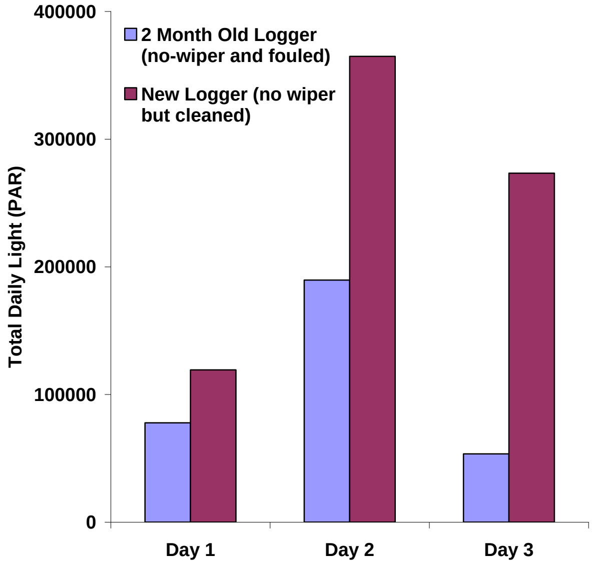


Figure 32. *Total daily light (PAR) recorded at Yule Pt (Wet Tropics) on a logger stationed in the field for two months (biologically fouled) in comparison to a new (clean) logger. Fouled logger resulted in a 54% loss of recorded total daily light.*

The light environment within the seagrass canopy varied as a function of season, higher light was mostly present within the summer months relative to the winter (Figure 33). Highest light generally occurred within January at both sites. The coastal site at Yule Point mostly had a lower light environment (mean monthly total daily light) than the offshore reef seagrass meadow at Green Island, this was on average 39% less.

Preliminary analysis (using linear regression rather than multiple) of the factors driving the seagrass canopy light environment at Yule Point and Green Island indicate that climate is a key factor. These factors changed as function of month and site (Figure 34). At Green Island there was less observed effect of climate than at Yule Point. Increasing wind at Green Island explained >50% of the variance of the light environment in January and July. In August the major factor influencing the Green Island light environment was reducing mean daily daytime tidal height explaining >60% of the variance of the increasing light. Rainfall and sunshine were not found to explain the variance of the daily total light at Green Island (Figure 34).

At Yule Pt tidal height and sunshine hours were the major driving factors of the daily light environment (Figure 34), with decreasing tidal height and increasing sunshine hours having positive effects on light. These factors were mostly important in explaining the variance in the winter months. Wind also had a negative influence on Yule Pt seagrass during March (Figure 34).

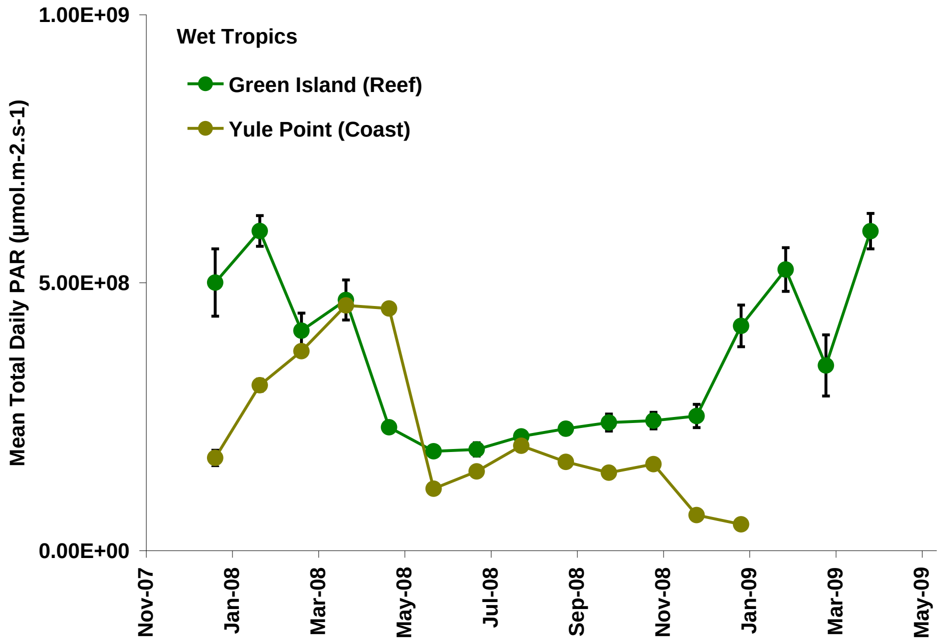


Figure 33. *Mean (±SE) monthly total daily light availability within intertidal seagrasses at two sites within the Wet Tropics NRM region. Dataset is incomplete for Yule Point from Jan to April 09 due to failed battery.*

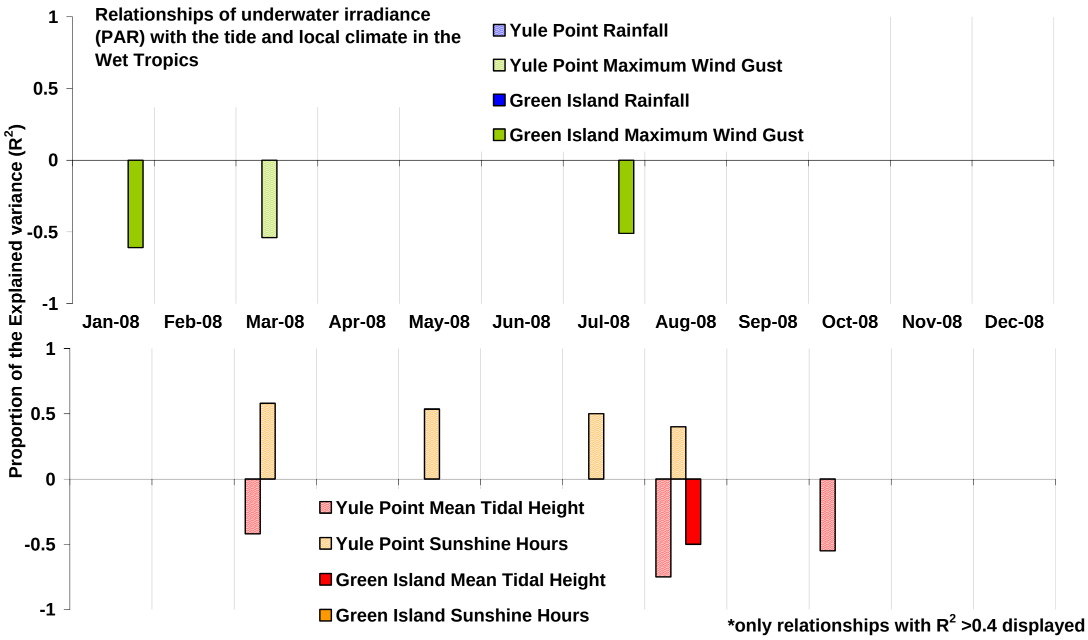


Figure 34. *The proportion of the explained variance (r^2) calculated by linear regression of the intertidal underwater seagrass light environment (total daily PAR) attributed to the total monthly rainfall, speed of the daily maximum wind gust, number of daily sunshine hours, and the mean daily daytime tidal height each month at two sites within the Wet Tropics NRM region.*

Regional Climate

Cairns – Yule Point and Green Island

The mean maximum daily temperature recorded in Cairns during 2008 was 29.4°C; 0.4°C hotter than the 60 year average. This reflects higher temperatures during the earlier period of the year that were higher than their equivalent 2007 values. Mean annual rainfall in 2008 was 2215mm; 10% higher than the 60 year average of 2010mm. January and February levels of rainfall were higher than most of the previous six years. Cloud cover in Cairns during 2008 was mostly high relative to other years, except for the month of September that had on average only 2 quarters of cloud cover.

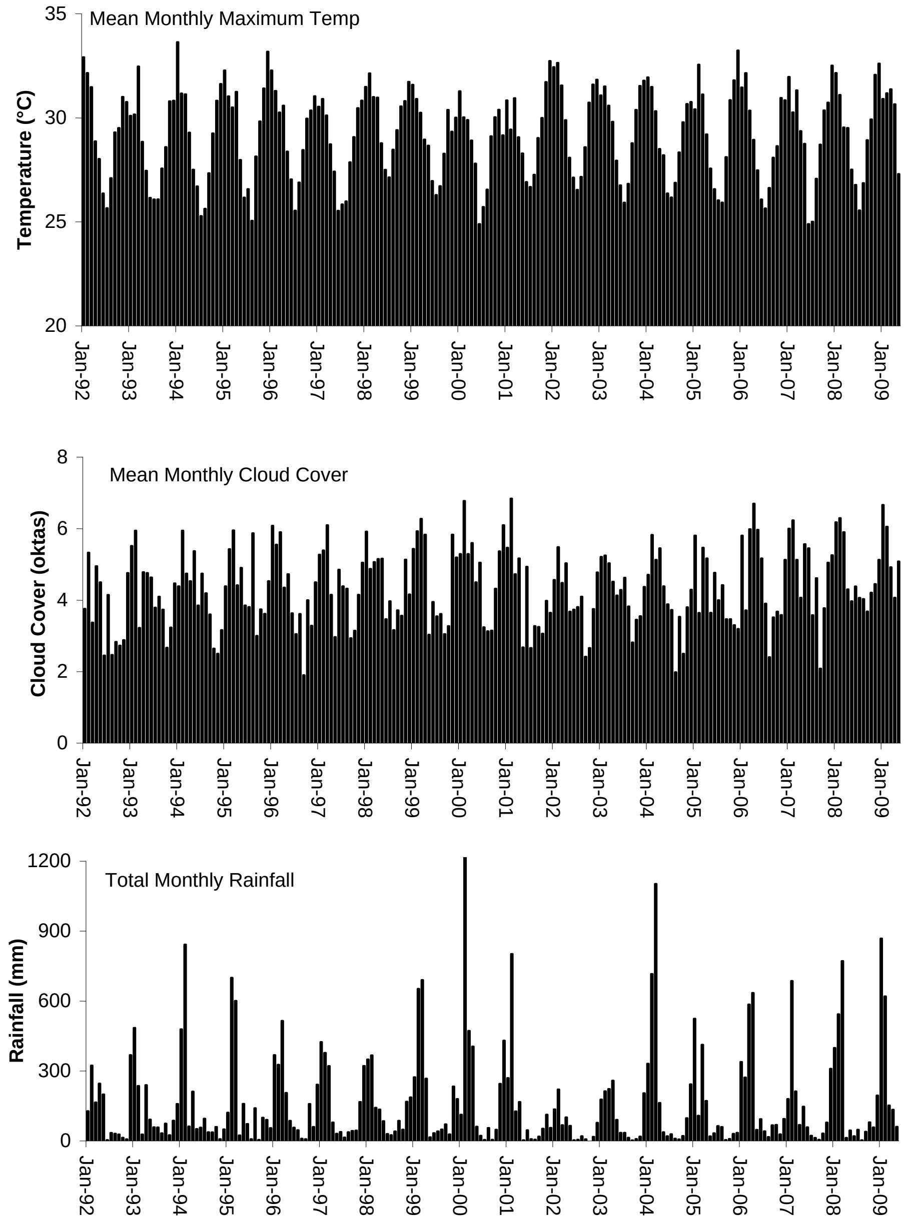


Figure 35. *Mean monthly daily maximum temperature (°C), mean monthly daily cloud cover (quarts) and total monthly rainfall (mm) recorded at Cairns airport (BOM station 031011) (Source* www.bom.gov.au*). Cairns Airport used as a surrogate for the climate at Yule Point and Green Island.*

Innisfail – Lugger Bay and Dunk Island

The mean maximum daily temperature recorded in Innisfail during 2008 was 28.1°C; 0.2°C hotter than the 100 year average. This reflects temperatures that were similar to many of the previous years of monitoring. Mean annual rainfall in 2008 was 3165mm; 11% higher than the 100 year average of 3568mm. This reflects consistently high rainfall during January, February and March. Cloud cover in Innisfail during 2008 was mostly high relative to other recent years, with no months showing low cloud cover.

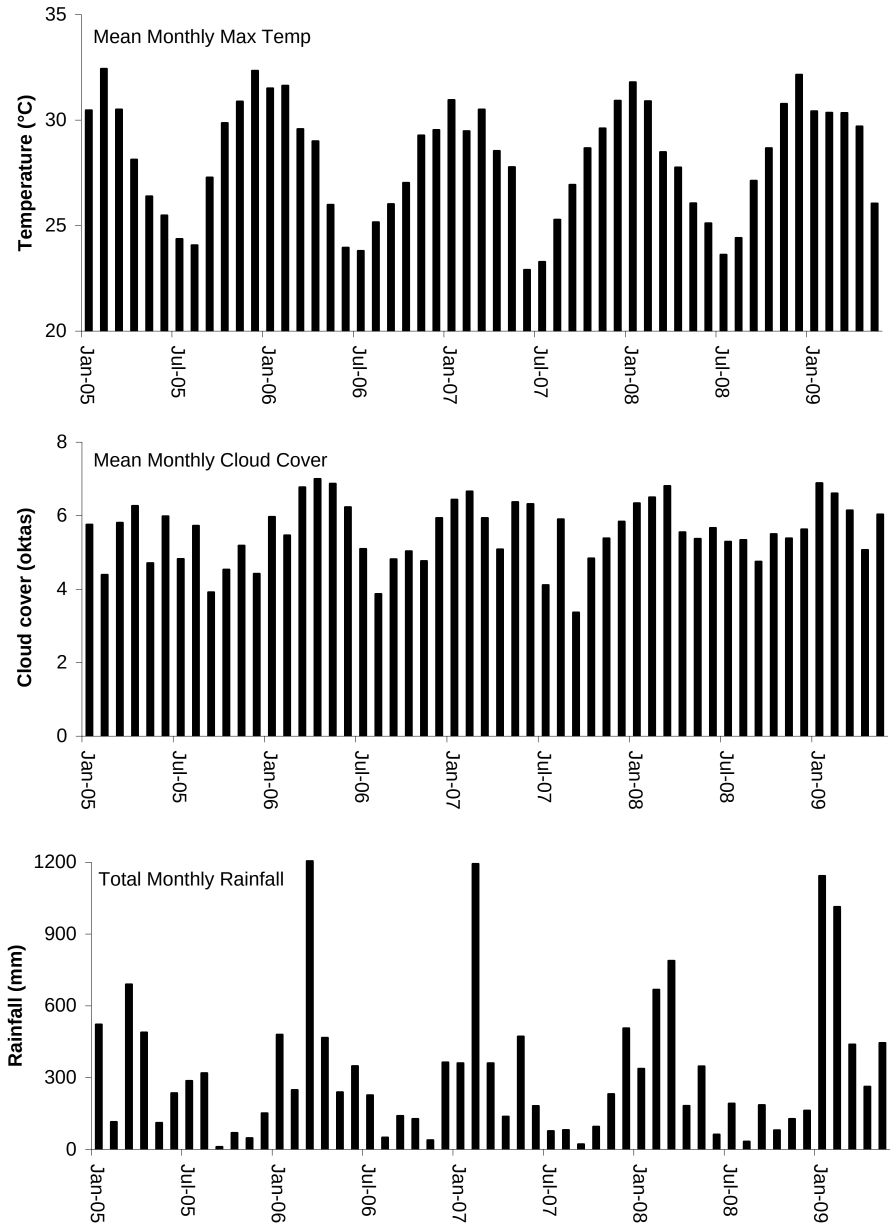


Figure 36. *Mean monthly daily maximum temperature (°C), mean monthly daily cloud cover (quarts) and total monthly rainfall (mm) recorded at Innisfail (BOM station 032025) (Source www.bom.gov.au). Innisfail used as a surrogate for the climate at Lugger Bay and Dunk Island.*

Burdekin Dry Tropics

2008/2009 Summary

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

- Although seagrass species composition has fluctuated, it remains dominated by *Halodule uninervis* and *Halophila ovalis* at coastal meadows and *Cymodocea rotundata* and *Halodule uninervis* at offshore island meadows.
- Seagrass abundance overall declined at coastal locations and was variable at reef locations.
- Seagrass tissues in both coastal and reef habitats had low C:N ratios, indicating a potentially low light environment. Decreasing C:N ratios at coastal sites since 2006 indicate decreasing light availability at this location.
- Tissue C:P ratios indicate both coastal and reef locations are nutrient rich.
- Tissue N:P ratios indicates that all species at reef sites were replete or N limited. Seagrass at coastal sites were P limited with an increasing but non-significant trend since 2006.
- Overall results suggest poor water quality at coastal sites with low light availability and elevated N (potentially eutrophic).
- Seagrass spatial extent has declined at most sites due to the dynamic nature of sandbanks.
- Epiphyte fouling of seagrass highly variable at reef habitats and increased at coastal sites.
- Levels of ammonium and Phosphate in coastal sediments were the lowest and highest recorded to date, respectively. Since 2005, both Phosphate and Ammonium concentrations had generally declined in reef sediments.
- No herbicides were detected in sediments.
- Maximum canopy temperature was 41°C (Magnetic Island). 2008/2009 monitoring period was 1°C hotter on average than the previous 2 years and the long term average.
- Within seagrass canopy light environment varied as a function of season, with higher light present within winter relative to summer (daylight hours and tidal height). The coastal light environment was 79% lower than offshore.
- Mean maximum daily air temperature was 0.1°C hotter and mean annual rainfall was 27% higher than the 70 year average.

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 (Schletinga and Heydon 2005).

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

The coastal sites are located on naturally dynamic intertidal sand flats and are subject to sand waves and erosion blowouts moving through the meadows. The Bushland Beach and Shelley Beach area is a sediment deposition zone, so the meadow must also cope with incursions of sediment carried by long shore drift. Sediments within this habitat are mud and sand that have been delivered to the coast during the episodic peak flows of the creeks and rivers (notably the Burdekin) in this area. While episodic riverine delivery of freshwater nutrients and sediment is a medium time scale factor in structuring these coastal seagrass meadows, it is the wind induced turbidity of the costal zone that is likely to be a major short term driver (Figure 37). In these shallow coastal areas waves generated by the prevailing SE trade winds are greater than the depth of water, maintaining elevated levels of suspended sediments, limiting the amount of light availability for photosynthesis during the trade season. Intertidal seagrasses can survive this by photosynthesizing during periods of exposure, but must also be able to cope with desiccation. Another significant feature in this region is the influence of ground water. The meadows are frequented by dugongs and turtles as witnessed by feeding trails and scars.

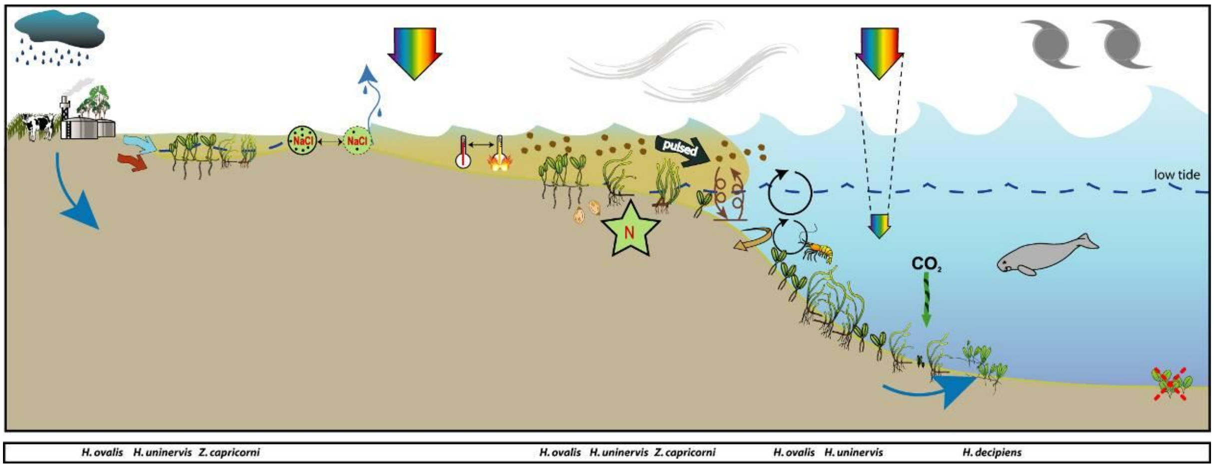


Figure 37. *Conceptual diagram of coastal habitat in the Burdekin Dry Tropics region - major control is wind and temperature extremes, general habitat, seagrass meadow processes and threats/impacts (See Figure 2 for icon explanation).*

The Reef habitats are mainly represented by fringing reefs on the many continental islands within this area. Most fringing reefs have seagrass meadows growing on their intertidal flats. Nutrient supply to these meadows is by terrestrial inputs via riverine discharge, re-suspension of sediments and groundwater supply (Figure 38). The meadows are typically composed of zones of seagrasses: *Cymodocea serrulata and Thalassia hemprichii* often occupy the lower intertidal/subtidal area, blending with *Halodule uninervis* (wide leaved) in the middle intertidal region. *Halophila ovalis* and *Halodule uninervis* (narrow leaved) inhabit the upper intertidal zone. Phosphate is often the nutrient most limiting to reefal seagrasses (Short e*t al.* 1990; Fourqurean *et al.* 1992). Experimental studies on reef top seagrasses in this region however, have shown seagrasses to be nitrogen limited primarily with secondary phosphate limitation, once the plants have started to increase in biomass (Mellors 2003). In these fringing reef top environments fine sediments are easily resuspended by tidal and wind generated currents making light availability a driver of meadow structure.

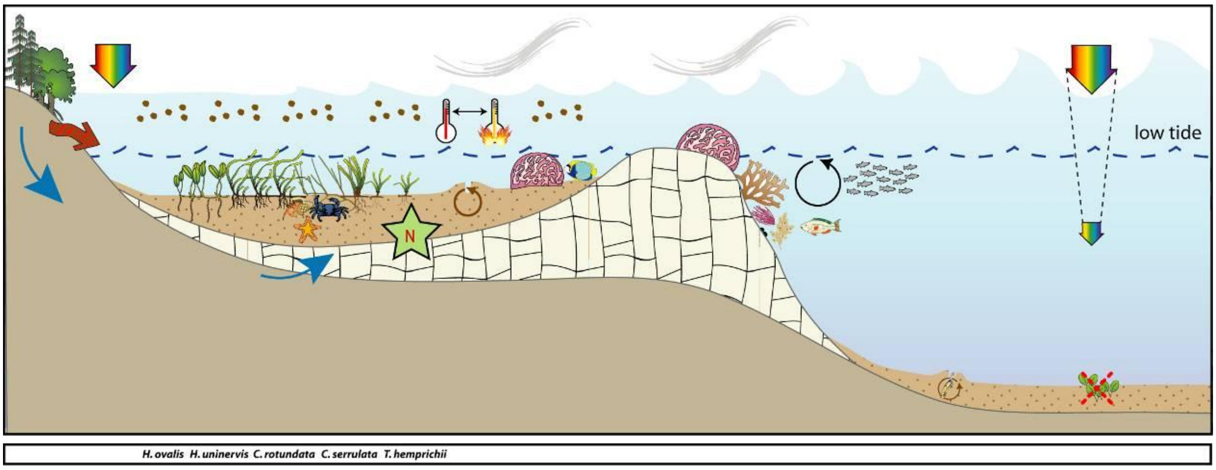


Figure 38. *Conceptual diagram of fringing reef habitat in the Burdekin Dry Tropics region - major control is nutrient supply (groundwater), light and shelter: general habitat and seagrass meadow processes (See Figure 2 for icon explanation)*

Seagrass cover and composition

Both Bushland Beach and Shelley Beach were dominated by *Halodule uninervis* with varying amounts of *Halophila ovalis*. The composition of *H. ovalis* increased at both sites during 2008, however this decrased in the late Monsoon 2009 to long term average levels (Figure 40).

Seagrass cover has fluctuated both within and between years at Bushland Beach (Figure 39). Seagrass cover increased dramatically at Bushland Beach (BB1) during late Dry-Monsoon 2008/2009, however severely declined in the late-Monsoon (Figure 39). The cover in late-Monsoon 2009 was significantly lower that for the same time in 2008. Seagrass cover continued to decline at Shelley Beach (SB1) in 2008, however the increase in January 2009 was followed by losses in the late Monsoon. The cover in late-Monsoon 2009 was not significantly different than for the same time in 2008. Although variable, coastal seagrass meadows in Townsville have continued to decline in abundance since late 2006 (Figure 39).

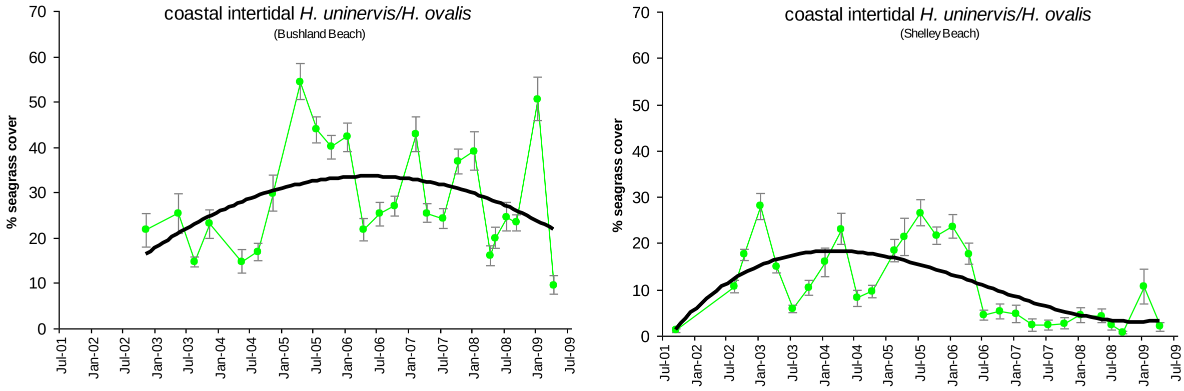


Figure 39. *Change in seagrass abundance (percentage cover) at coastal intertidal meadows in the Burdekin Dry Tropics region.*

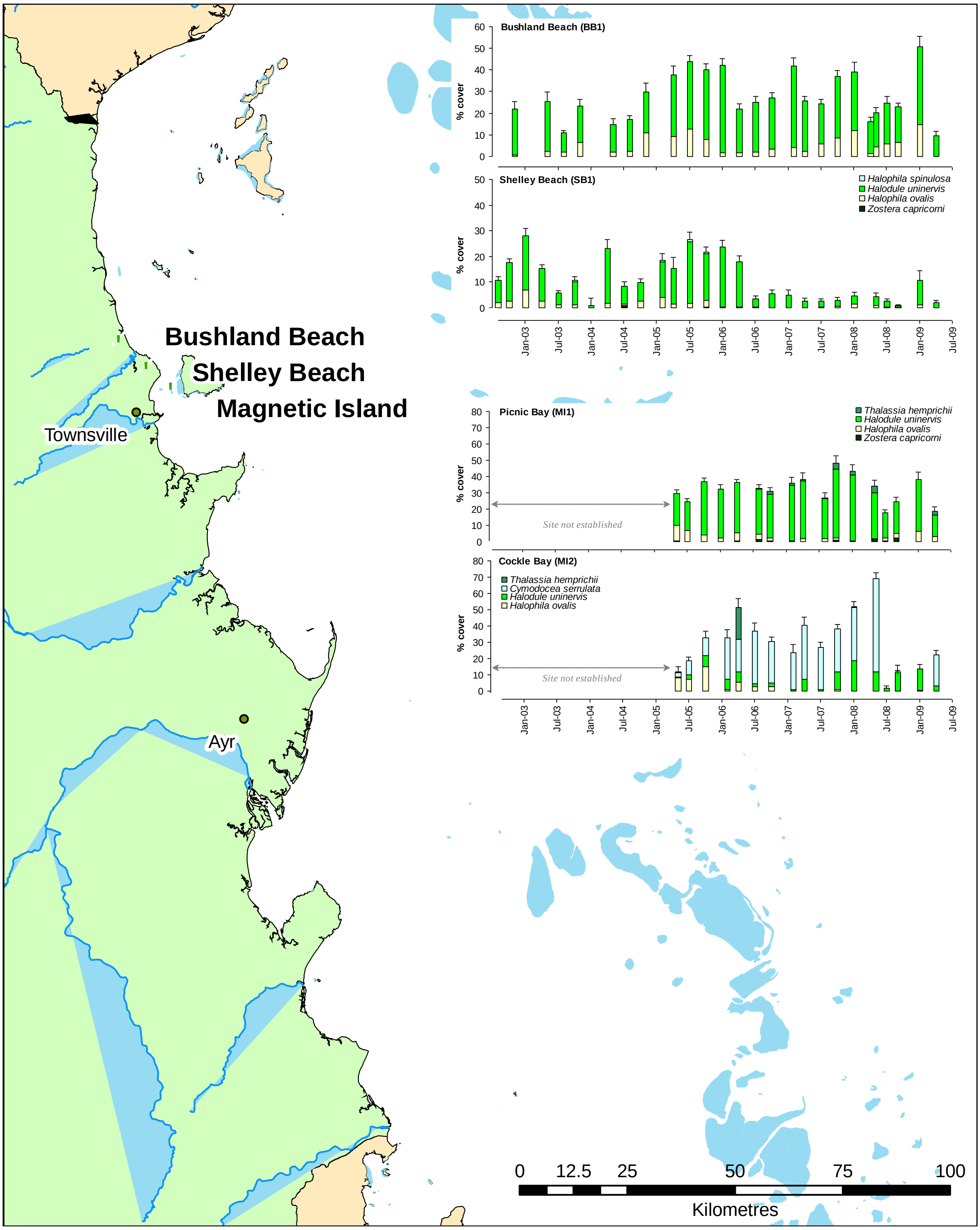


Figure 40. *Mean percentage cover for each seagrass species at sites in the Burdekin Dry Tropics region (+ Standard Error). NB: if no sampling conducted then x-axis is clear.*

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 41).

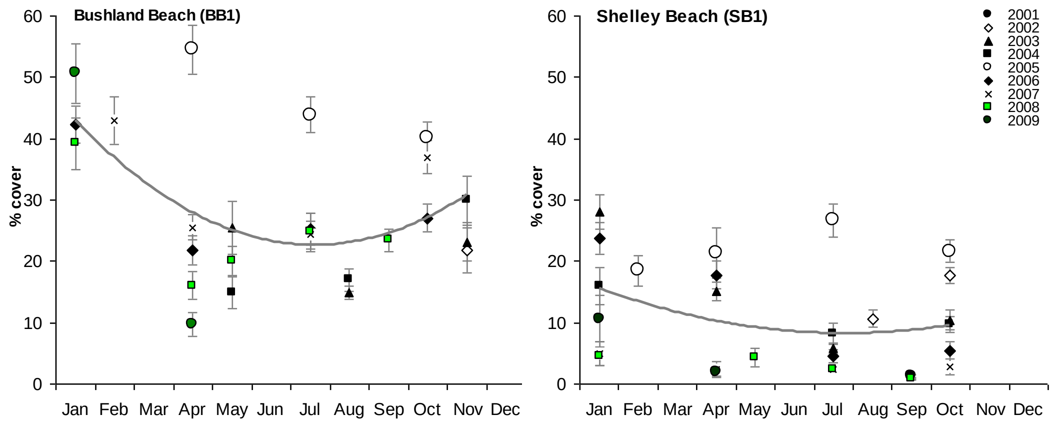


Figure 41. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Townsville coastal long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

Offshore reef habitats are monitored on the fringing reef 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 40). Over the last monitoring period, seagrass cover at both sites appears to have declined (Figure 42). Although seagrass abundances in late Dry 2008 are similar to 2009, abundances in late Monsoon 2009 are significantly lower than previously reported in 2008 (Figure 42).

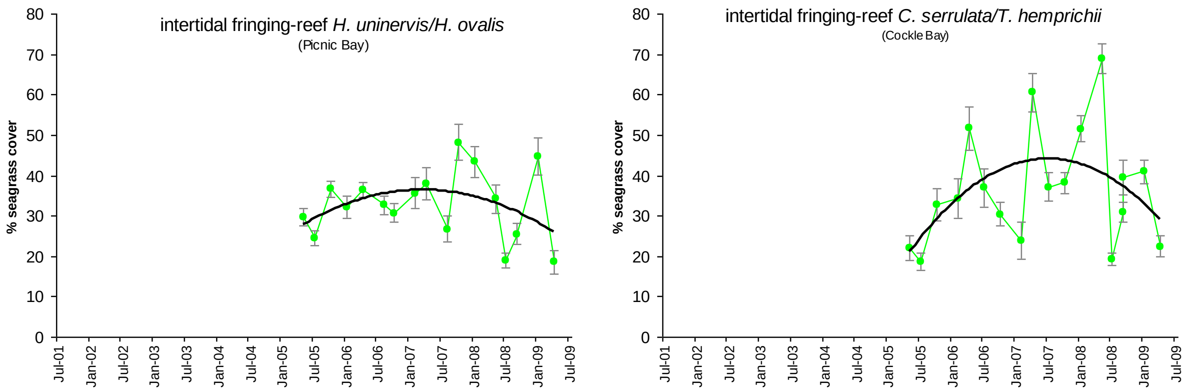


Figure 42. *Change in seagrass abundance (percentage cover) at intertidal meadows on fringing reef platforms in the Burdekin Dry Tropics region.*

Quadrat at 25m on transect 3 at Picnic Bay (MI1), on 24 September 2008 (left) and 26 April 2009 (right)

Seagrass abundance at Cockle Bay appears to follow a seasonal pattern, which is clearer at Picnic Bay (Figure 43).

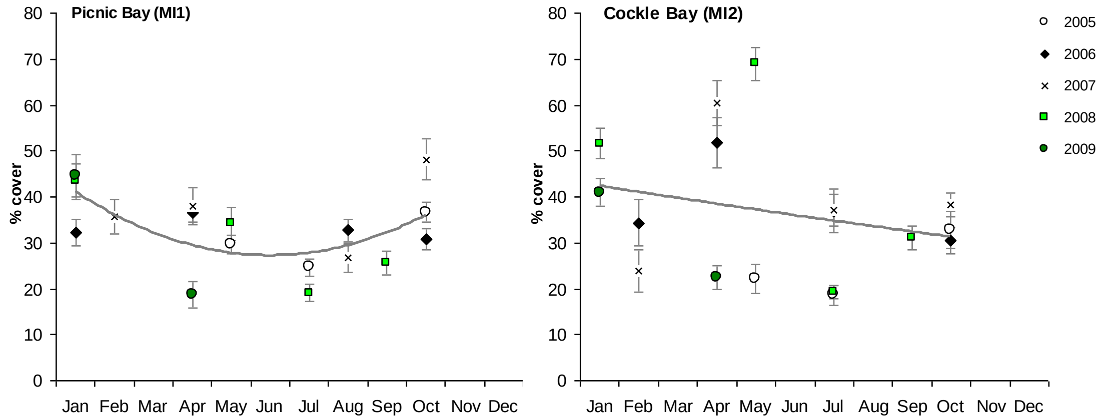


Figure 43. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Magnetic Island long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

Seagrass tissue nutrients

Seagrass leaf tissue C:N ratios for both coastal (Bushland and Shelley Beaches) and offshore reef (Cockle and Picnic Bays, Magnetic Island) locations were below 20 (except for *Halodule uninervis* in 2007 and *Cymodocea serrulata* in 2008) (Figure 44), indicating reduced light environments. At the reef sites on Magnetic Island, the C:N ratios of *Halophila ovalis* and *H. uninervis* have been subject to high within year variability, with no significant changes between years ($p > 0.05$). At the coastal Townsville sites, *H. uninervis* showed a pattern of declining C:N since 2006, indicating declining light availability, but this change was not significant ($p > 0.05$). At Magnetic Island, *C. serrulata* had a lower C:N ratio in 2008 relative to 2006.

The nutrient status of the habitat at both the coastal (Townsville) and offshore reef (Magnetic Island) sites (defined by the C:P tissue ratio) indicates that these locations are both nutrient rich (except *Halodule uninervis* in 2007) (Figure 44), containing a large P pool. The between year trend for *H. uninervis* at both sites, and *Thalassia hemprichii* at Magnetic Island is of an increasing P pool, these inter-annual changes were however not significant for *H. uninervis* ($p > 0.05$).

The N:P ratio indicates that all species at Magnetic Island in 2008 were N limited (N:P < 30) (Figure 44). Both *Halophila ovalis* and *Halodule uninervis* at Magnetic Island show a consistent but non-significant pattern of increasing N limitation ($p > 0.05$). At the Townsville sites *H. uninervis*, is marginally P limited (N:P > 30) in 2008, while other species lack data or have consistently high variability. This P limitation within *H. uninervis* is an increasing but non-significant trend since 2006.

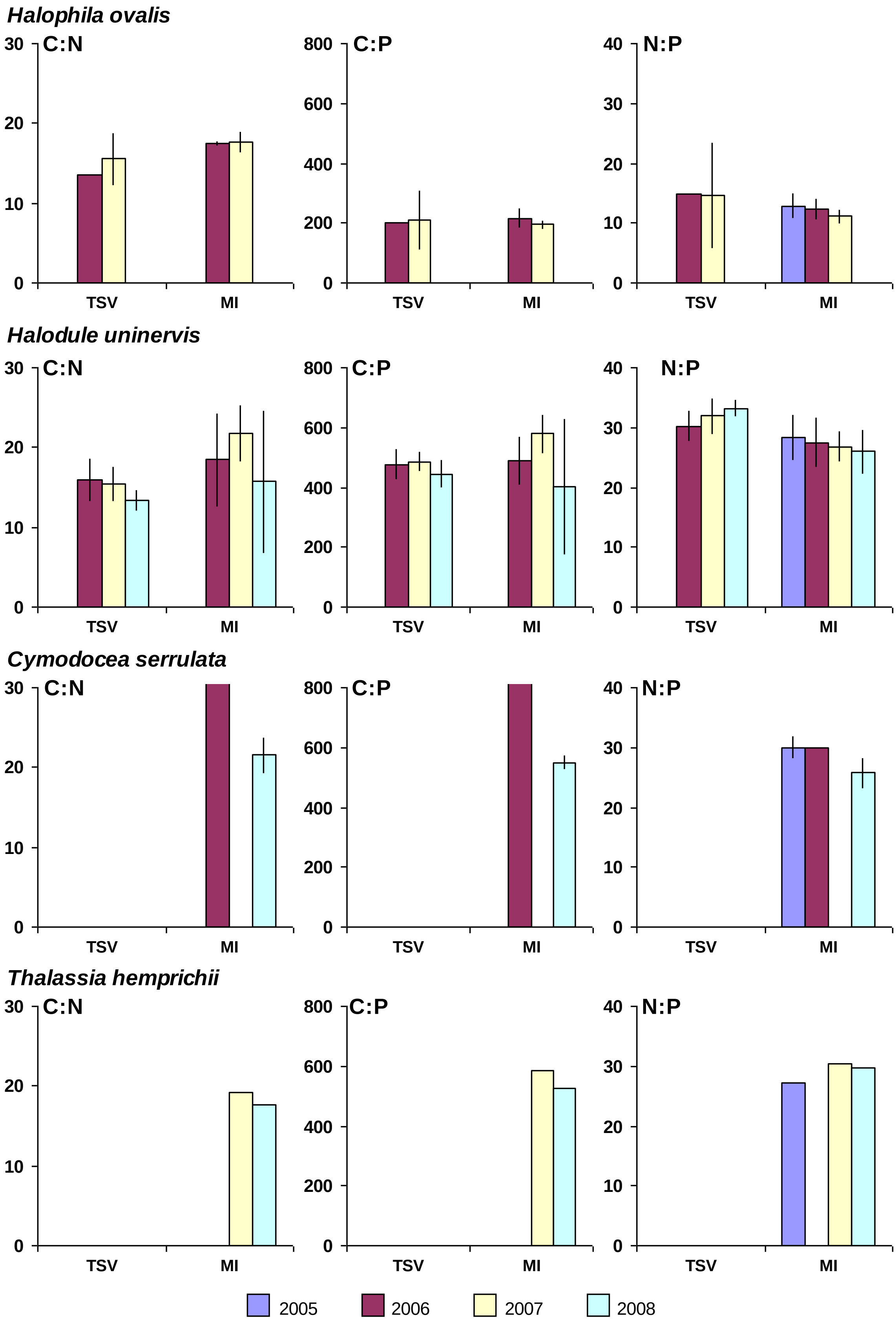


Figure 44. *Plant Tissue Ratios C:N, C:P and N:P for Halophila ovalis, Halodule uninervis and Zostera capricorni in the Dry Tropics at Townsville (BB), and Magnetic Island (MI), (mean and SD displayed).*

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 8). The edges of some meadows changed within the mapping area, but were outside the 50m x 50m monitoring sites.

The most dramatic changes over the past 2-3 years has occurred in the meadow at Shelley Beach (SBI) (Figure 45). In October 2006 the Shelley Beach meadow was significantly fragmented due to "blowouts". This resulted in relatively few of the sampling quadrats falling with 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" which has continued over the last sampling period. In late Monsoon 2009, the Shelley Beach meadow was less than 35% of its baseline extent (Table 8).

Table 8. *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	October 2008	April 2009
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)*	2.76 *(-5.9%, increase shoreward)*	2.677 *(-8.7%, 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)*	4.32 *(5.3%, increase shoreward)*	5.179 *(26.2%, 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)*	5.264 *(-0.9%, increase shoreward)*	2.275 *(57.2%, 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)*	1.648 *(-61.7%, decrease overall)*	1.178 *(-72.6%, decrease overall)*

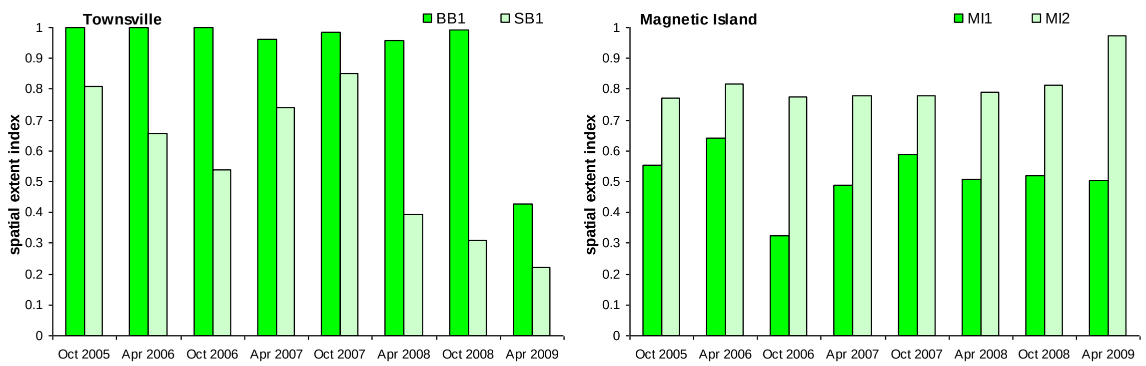


Figure 45. *Extent of area (within 100m radius of monitoring site) covered by seagrass at each coastal and offshore monitoring site at Townsville and Magnetic Island locations.*

Epiphytes and Macro-algae

Epiphyte cover on seagrass leaf blades at coastal sites was highly variable (Figure 46) and appears correlated with seagrass abundance. Epiphyte cover, although higher than the previous monitoring period, has continued to decline from the peaks reported in 2005 (Figure 46). Percentage cover of macro-algae at coastal sites is also variable, but has similarly remained low over the past couple of years (Figure 46).

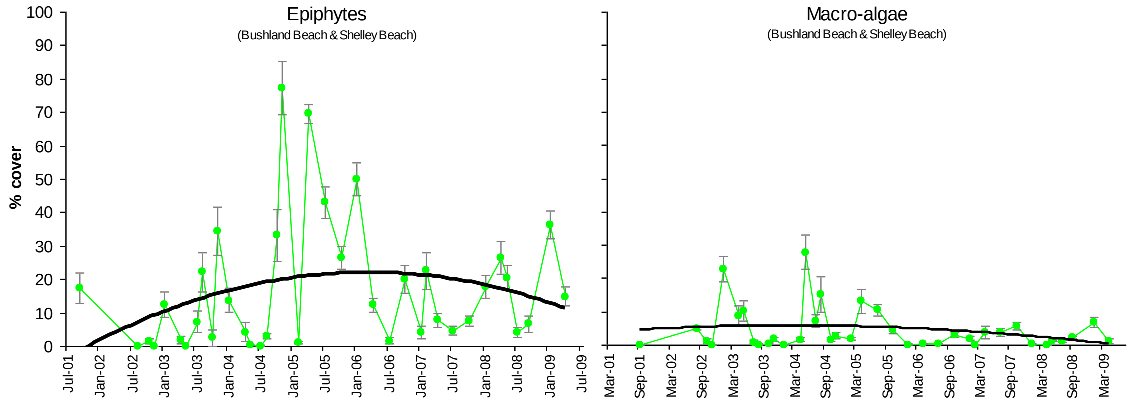


Figure 46. *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at coastal intertidal seagrass monitoring locations (sites pooled). NB: Polynomial trendline for all years pooled.*

Epiphyte cover at reef sites differs greatly between sites (Figure 47). At Picnic Bay (MI1), epiphyte cover is generally <40%, compared to Cockle Bay where it is >50% on average (Figure 47). Epiphyte abundance appears to be increasing at Picnic Bay, whereas at Cockle Bay it appears to be decreasing.

Macro-algae were low at Picnic Bay, but higher and more variable at Cockle Bay (Figure 47). Macro-algae at Cockle Bay was predominately composed of *Halimeda* spp., however in 2008, the composition of *Hydroclathrus* spp. was increasing. There does not appears to be any clear long-term trend in abundance (Figure 47).

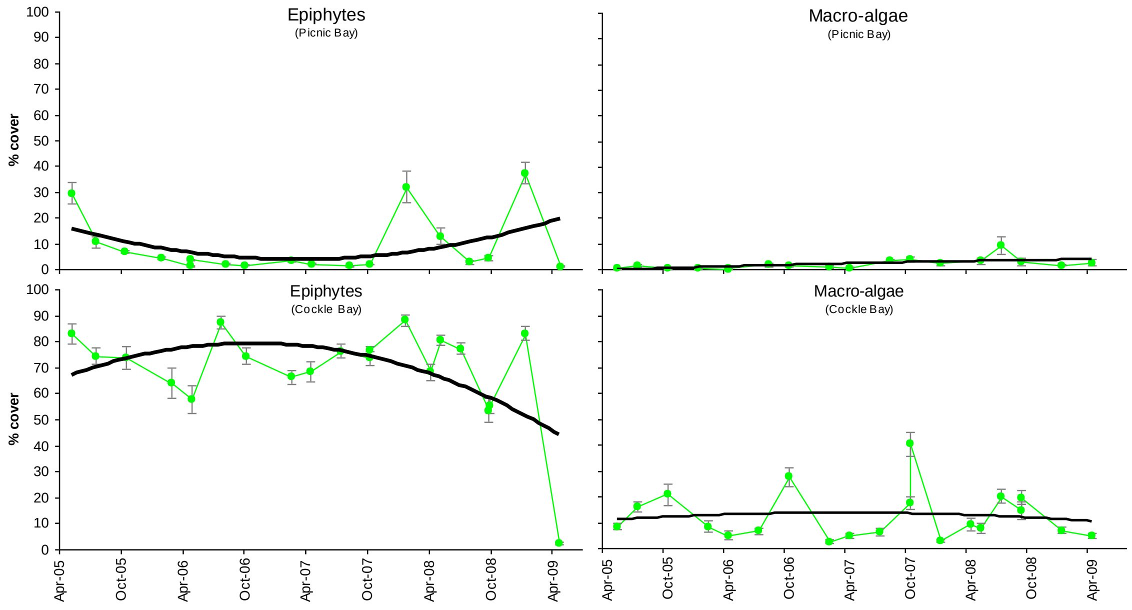


Figure 47. . *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at intertidal reef seagrass monitoring locations. NB: Polynomial trendline for all years pooled.*

Sediment nutrients

Phosphate and ammonium concentrations within the seagrass sediment rhizosphere of the Dry Tropics region have shown high inter-annual variability. Concentrations varied between the offshore reef environments of Magnetic Island and Townsville but this was not a consistent directional trend (Figure 48). Since 2005, sediments at Magnetic Island had generally declined in both Phosphate and Ammonium concentrations. Within Townsville coastal sites during 2008, the seagrass sediments had increased in Phosphate levels but decreased in Ammonium levels relative to all previous years. Levels of Ammonium at both Townsville and Magnetic Island sites in 2008 are the lowest recorded during the program to date, while Phosphate levels at Townsville sites were the highest recorded to date.

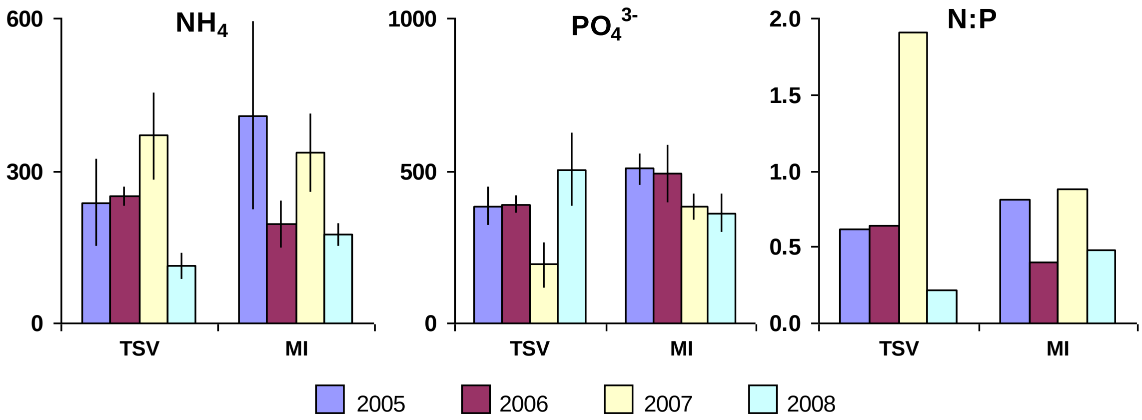


Figure 48. *Adsorbed nutrient levels within seagrass sediments of the Dry Tropics (ammonium (NH_4), phosphate (PO_4^{3-}), and the ratio of PO_4^{3-} to NH_4) at Townsville (TSV), and Magnetic Island (MI), October 2005 to October 2008. Mean and SD displayed.*

The ratio of N:P within seagrass sediments has varied highly between years; in 2008 levels were low relative to previous conditions, indicating P limitation at both Magnetic Island and Townsville sites.

Sediment herbicides

No herbicides were found above detectable levels in the sediments of the seagrass meadows at any of the monitoring sites in post-Monsoon 2009 (Table 9).

Table 9. *Concentration of herbicides ($\mu g\ kg^{-1}$) in sediments of seagrass monitoring sites in post Monsoon 2009. ND=not detectable, <0.1 $\mu g\ kg^{-1}$*

Site	Flumeturon	Diuron	Simazine	Atrazine	Desethyl Atrz.	Desisopropyl Atrz.	Hexazinone	Tebuthiuron	Ametryn	Prometryn	Bromacil	Terbutryn	Metolachlor
MI1	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*
MI2	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*
BB1	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*
SB1	*ND*	*ND*	*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 over the monitoring period (Figure 49). No extreme temperatures (>40°C) were recorded over the last 12 months. Maximum temperatures peaked several times throughout the year at all locations, generally during the time of low spring tide of the Dry season through to December 2008 (Figure 49). The maximum temperature recorded was 38.5 C at Picnic Bay (Magnetic Island) in November and December 2008. Mean temperatures were mostly within the 21 – 32°C range, with highest mean temperatures in December 2008 (Figure 50).

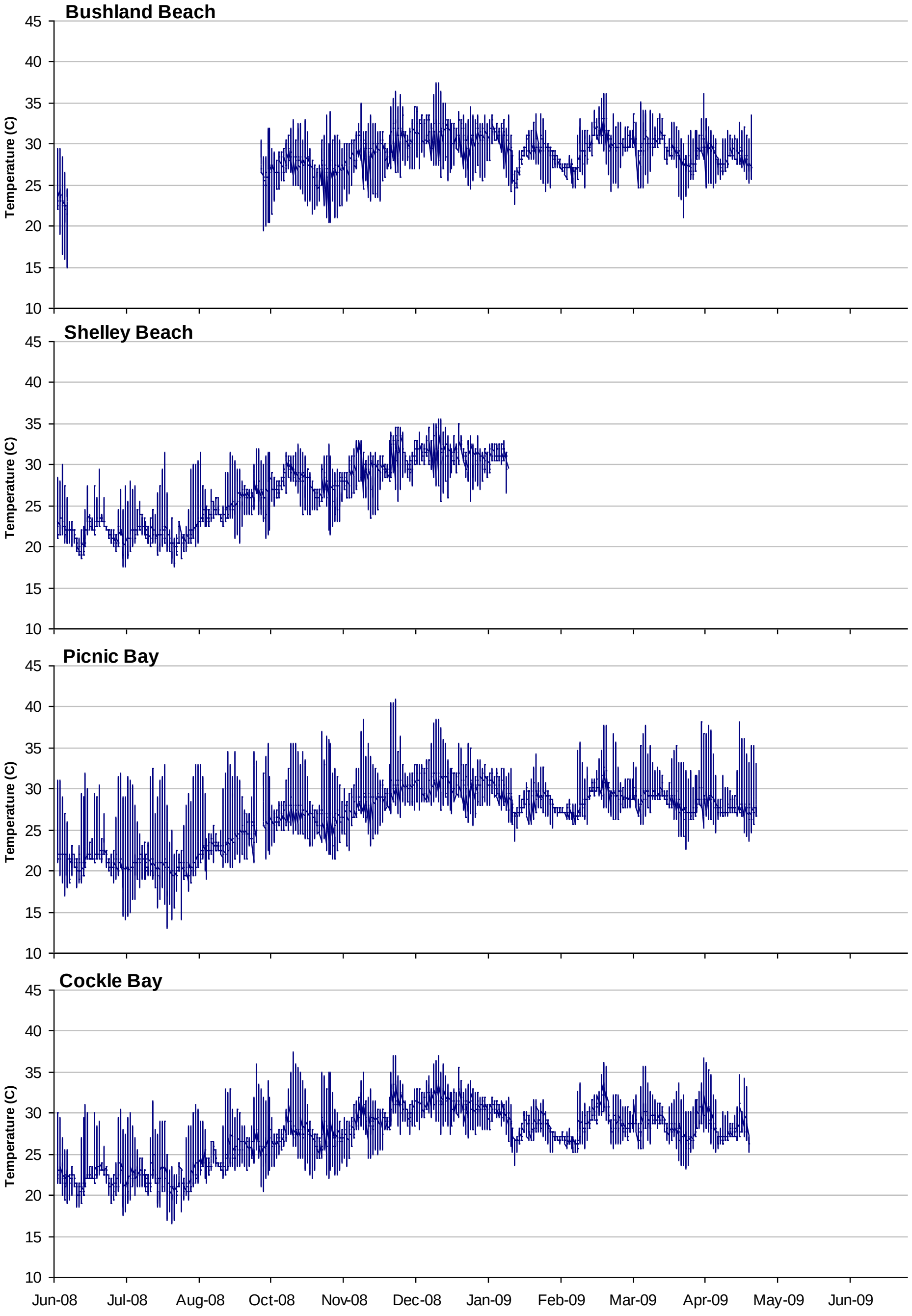


Figure 49. *Within seagrass canopy temperature (°C) at coastal (Bushland Beach and Shelley Beach) and offshore fringing-reef (Picnic Bay and Cockle Bay, Magnetic Island) intertidal meadows within the Burdekin Dry Tropics region over the 2008/2009 monitoring period.*

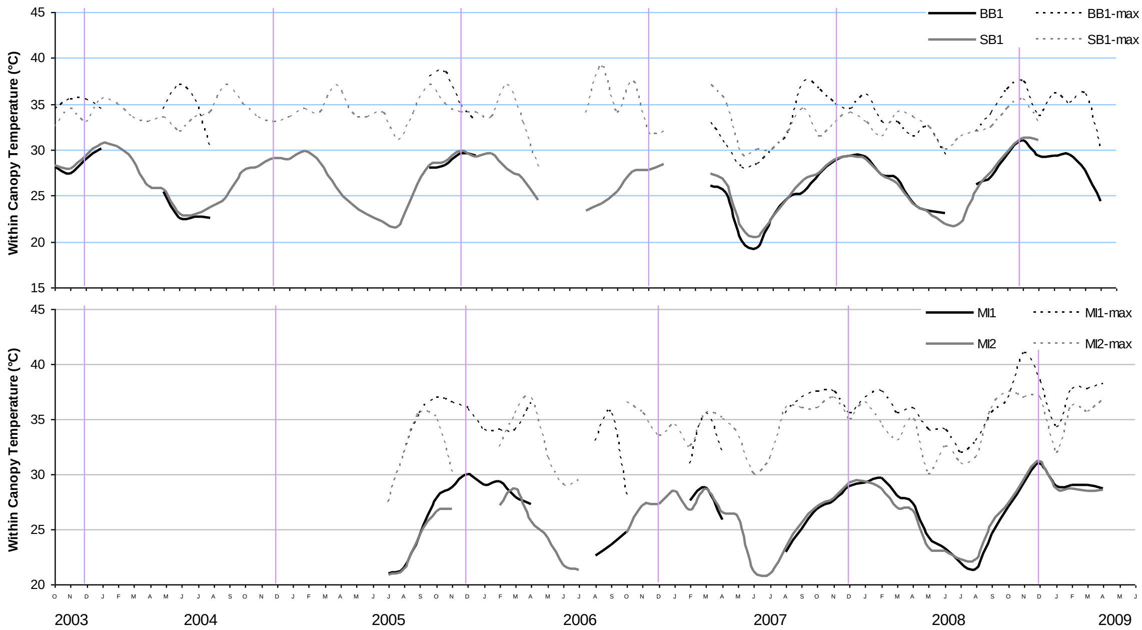


Figure 50. *Monthy mean and maximum within seagrass canopy temperature (°C) at intertidal meadows in coastal (Bushland Beach and Shelly Beach) and offshore fringing-reef (Picnic Bay and Cockle Bay, Magnetic Island) habitats within the Burdekin Dry Tropics region.*

Within meadow canopy light availability

A light logger was deployed at two sites within the Dry Tropics region: Magnetic Island (Cockle Bay) and Bushland Beach (Figure 51). These loggers have collected measurements every half hour continuously since March 2007. Loggers have been collecting data at both locations with the use of a wiper unit. In addition, experiments examining the effect of wipers in preventing biological fouling and reduction in light measurements were conducted at both locations during early 2008. These were conducted utilising a paired logger placed at each site without a wiper unit. Fouling (i.e. without a wiper unit) was determined to result in the recording of 61% less light at magnetic Island. At Bushland Beach daily total light was on average 16% less in the unit without a wiper, however high standard errors crossing indicate that this difference is not significant (Figure 51). This suggests that wipers may not always be required at Bushland Beach due to low fouling levels.

Autonomous submersible Odyssey™ photosynthetic irradiance loggers with (left) and without (right) a wiper unit at Cockle Bay

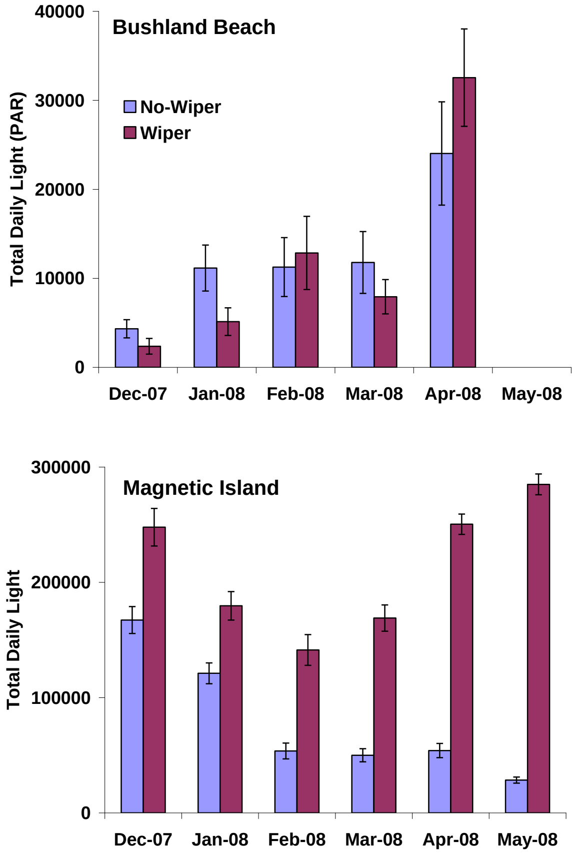


Figure 51. *Mean (±SE) monthly total daily light (PAR) recorded at two sites (Bushland Beach and Magnetic Island) within the Burdekin using Odyssey light sensors with and without Wipers. Fouled loggers without a wiper resulted in a 61% loss of recorded mean monthly total daily light.*

The light environment within the seagrass canopy varied as a function of season, with higher light generally present within the winter relative to the summer at both Bushland Beach and Magnetic Island (Figure 52). The coastal site at Bushland Beach mostly had a lower light environment (mean monthly total daily light) than the offshore reef seagrass meadow at Magnetic Island, this was on average 79% less.

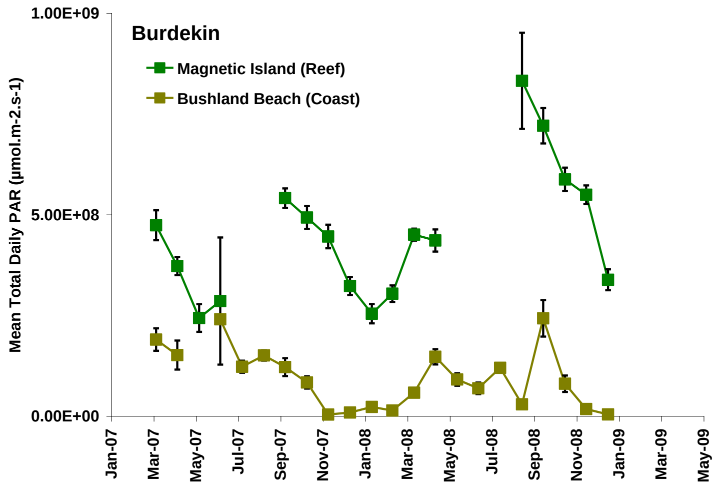


Figure 52. *Mean (±SE) monthly total daily light availability within intertidal seagrasses at two sites within the Burdekin NRM region. Dataset is incomplete at Magnetic Island during winter 2007 and 2008, and at both sites from Jan to April 09 due to logger failures.*

Preliminary analysis (using linear regression rather than multiple) of the factors driving the seagrass canopy light environment at Bushland Beach and Magnetic Island indicate that climate is a key factor. Individual climate factors changed as function of month and site (Figure 53). At Magnetic Island rainfall had a negative impact on the light environment in December and January, explaining >40% of the variance. The light environment was mostly influenced by a positive effect of the number of sunshine hours during the summer period, explaining between 50 and 80% of the variance in the total daytime light. Increasing tidal height had a positive impact in April 08, explaining 62% of the variance, whilst it had a negative impact on light in October 08.

At Bushland Beach decreasing tidal height commonly had a positive effect on light availability explaining up to 80% of the variance, this was mostly during the winter months. Wind also negatively effected the light environment at Bushland Beach in June 08 and May 07.

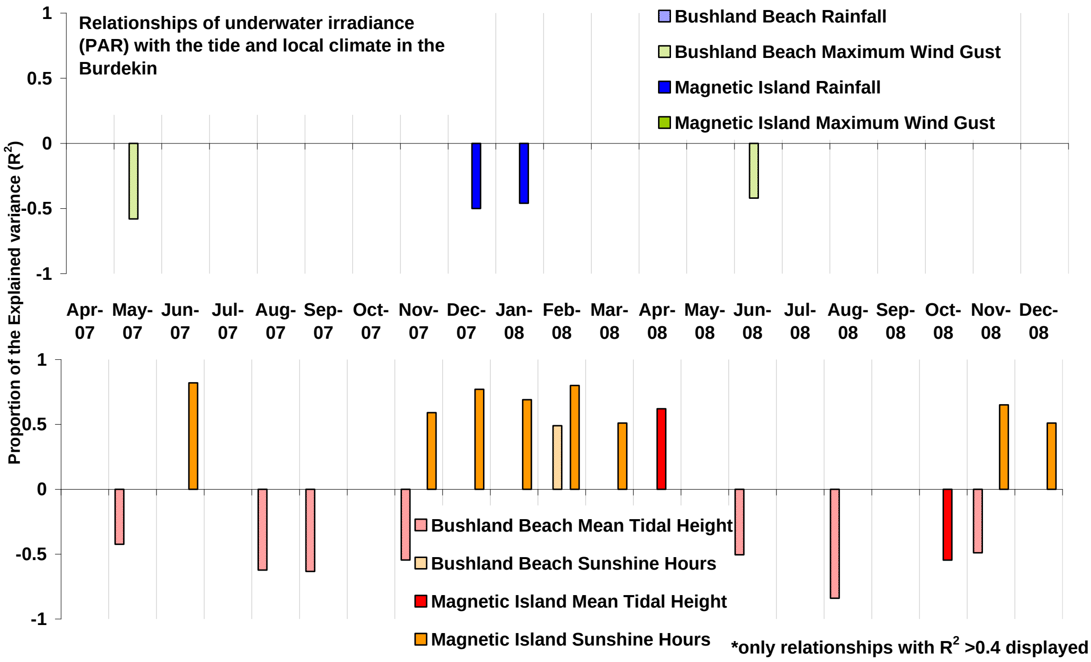


Figure 53. *The proportion of the explained variance (r^2) and its slope (+ or -) calculated by linear regression of the intertidal underwater seagrass light environment (total daily PAR) attributed to the total monthly rainfall, speed of the daily maximum wind gust, number of daily sunshine hours, and the mean daily daytime tidal height each month at two sites within the Burdekin NRM region.*

Regional Climate

Townsville – Townsville and Magnetic Island

The mean maximum daily temperature recorded in Townsville during 2008 was 28.9°C, this was 0.1°C hotter than the 70 year average. This reflects temperatures that were similar to many of the previous years of the monitoring programme, but were lower than the high temperatures of 2005 and 2006. Mean annual rainfall in 2008 was 1442mm; this was 27% higher than the 70 year average of 1134mm and reflects consistently high rainfall during January and February. No cloud cover data is available for Townsville.

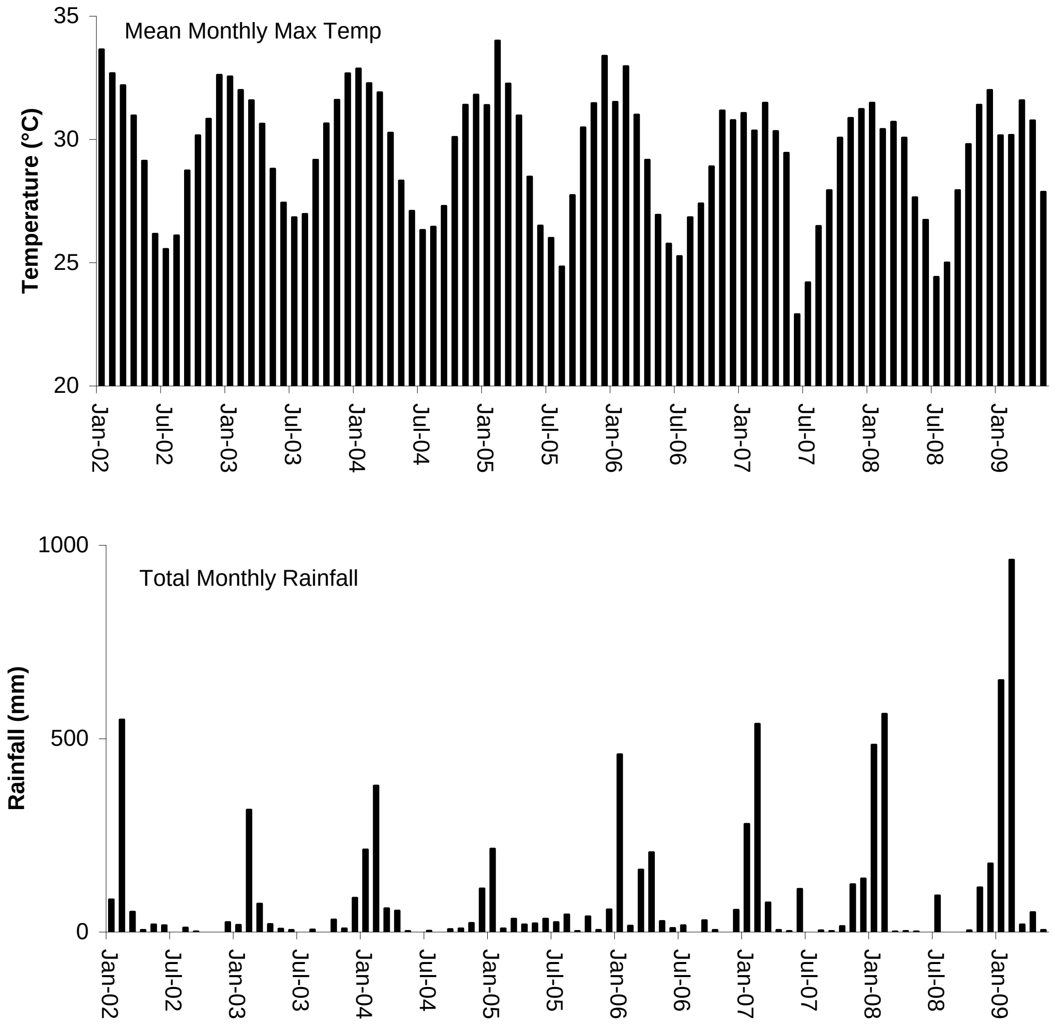


Figure 54. *Mean monthly daily maximum temperature (°C), and total monthly rainfall (mm) recorded at Townsville Airport (BOM station 032040) (Source www.bom.gov.au). Townsville Airport used as a surrogate for the climate at Townsville coastal beaches and Magnetic Island.*

Mackay Whitsunday

2008/2009 Summary

Intertidal seagrass meadows are found on the large sand/mud banks of sheltered estuaries and coastal fringes; they are also present on top of the offshore fringing reefs. Key environmental drivers include exposure, desiccation and variable flood runoff during the wet season.

- Intertidal reef and coastal monitoring meadows dominated *by Halodule uninervis*, and estuarine meadows dominated by *Zostera capricorni*.
- Coastal and estuarine seagrass abundance is variable over time, but continued to decline at the reef site (since 2007).
- Estuarine and reef seagrasses remained highly variable in meadow area but increased within the coastal habitat.
- Resilience of the estuarine seagrass meadows was limited, as no seeds were recorded in 2009 (large decline from previous years). Seed banks in Pioneer Bay remained variable.
- Epiphytes mostly variable and of low abundance. Macro-algae mostly stable.
- Seagrass tissue nutrient ratios indicate seagrasses replete or marginally N limited. Ratios remain highly variable between years at all sites.
- Tissue ratios of C:N indicate all sites were low light environments.
- Low C:P tissue ratios indicates all habitat types were nutrient rich.
- Sediment P levels at the reef and coastal sites (but not the estuarine sites) were among the highest recorded at any site within the MMP. P remained variable at all sites, but N had decreased.
- No herbicides were detected in sediments during 2009, but elevated levels of Diuron had been found in 2006 and 2008.
- No extreme canopy temperatures (>40°C) were recorded over the last 12 months.

Background

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 55).

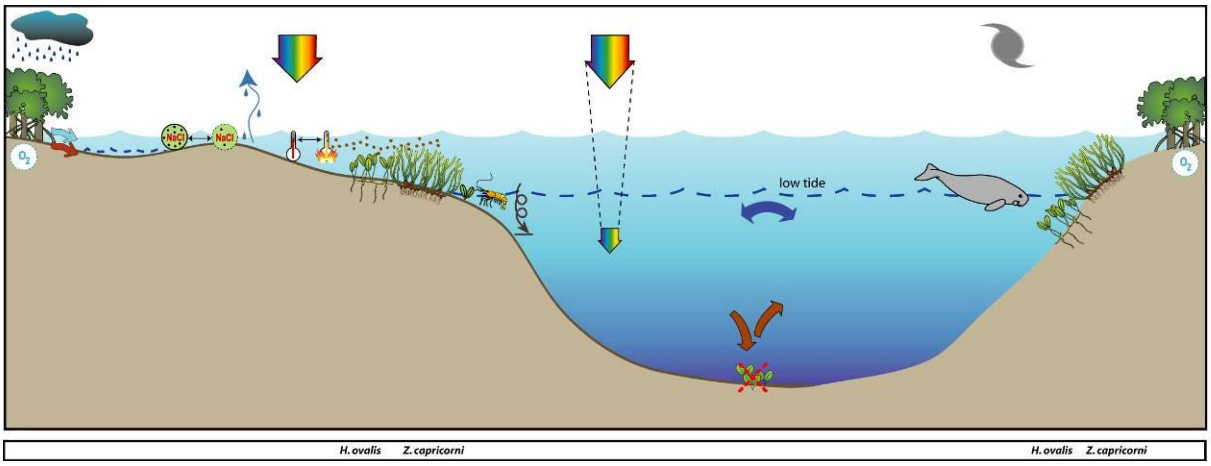


Figure 55. *Conceptual diagram of estuary habitat in the Mackay Whitsunday region: general habitat and seagrass meadow processes (See Figure 2 for icon explanation).*

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

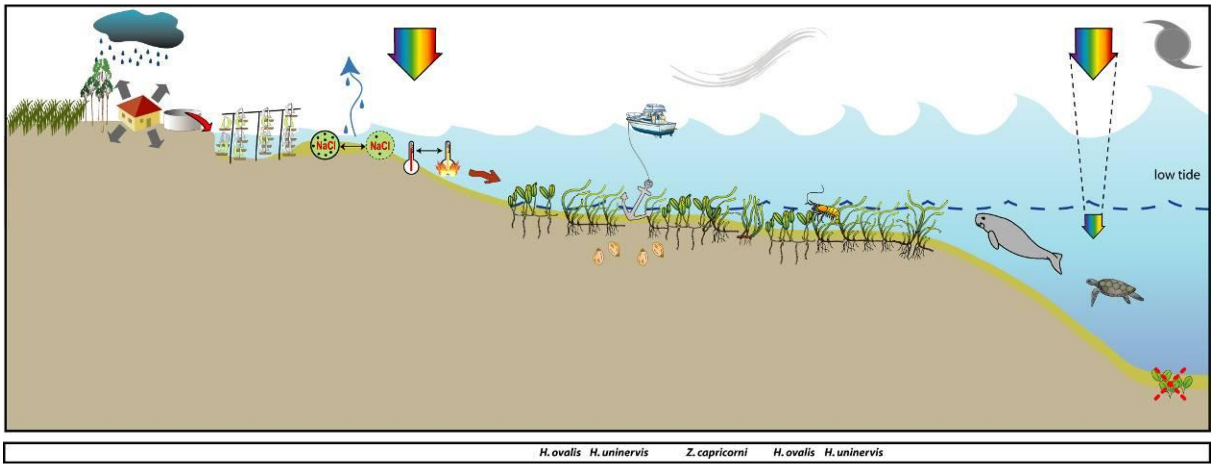


Figure 56. *Conceptual diagram of coastal habitat in the Mackay Whitsunday region – major control is shelter and temperature extremes: general habitat, seagrass meadow processes and threats/impacts (See Figure 2 for icon explanation)*

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

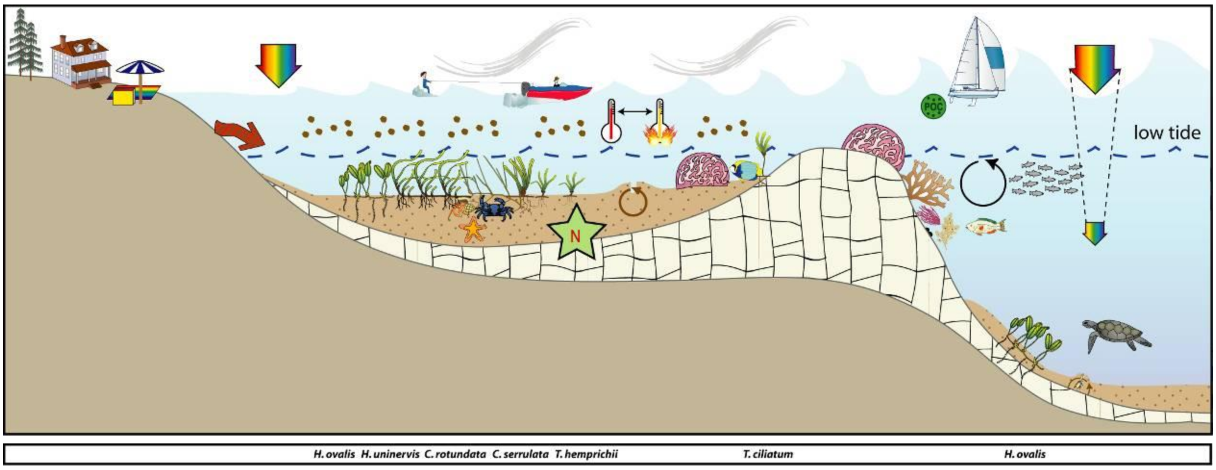


Figure 57. *Conceptual diagram of reef habitat in the Mackay Whitsunday region - major control is light and temperature extremes: general habitat, seagrass meadow processes and threats/impacts (See Figure 2 for icon explanation).*

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 were dominated by *Halodule uninervis* and *Zostera capricorni* mixed with *Halophila ovalis*. Although sites are dominated by *H. uninervis*, species composition has been gradually changing over the past decade of monitoring (Figure 59). The composition of *Z. capricorni* in the meadow at PI2 has increased, particularly on the shoreward extent. Over the past 2 years, the composition of *Z. capricorni* at PI3 has similarly begun increasing. Fluctuations are also apparent between years indicating disturbance regimes at longer time periods than annually.

Seagrass abundance has fluctuated at the coastal sites between and within years, however there is no apparent overall trend (Figure 58). A seasonal pattern in abundance is clear at PI2, however no pattern is apparent at PI3 (Figure 60).

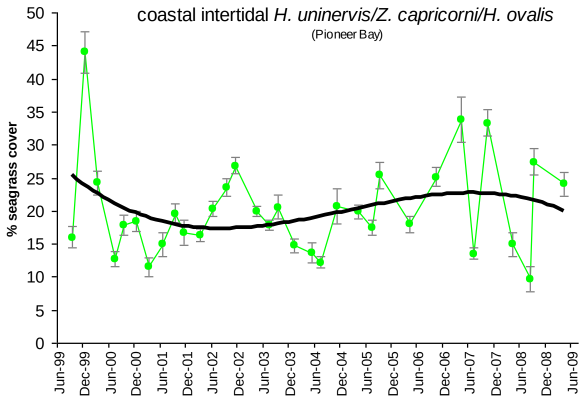


Figure 58. *Change in seagrass abundance (percentage cover) at the coastal intertidal meadows at Pioneer Bay, in the Mackay Whitsunday region.*

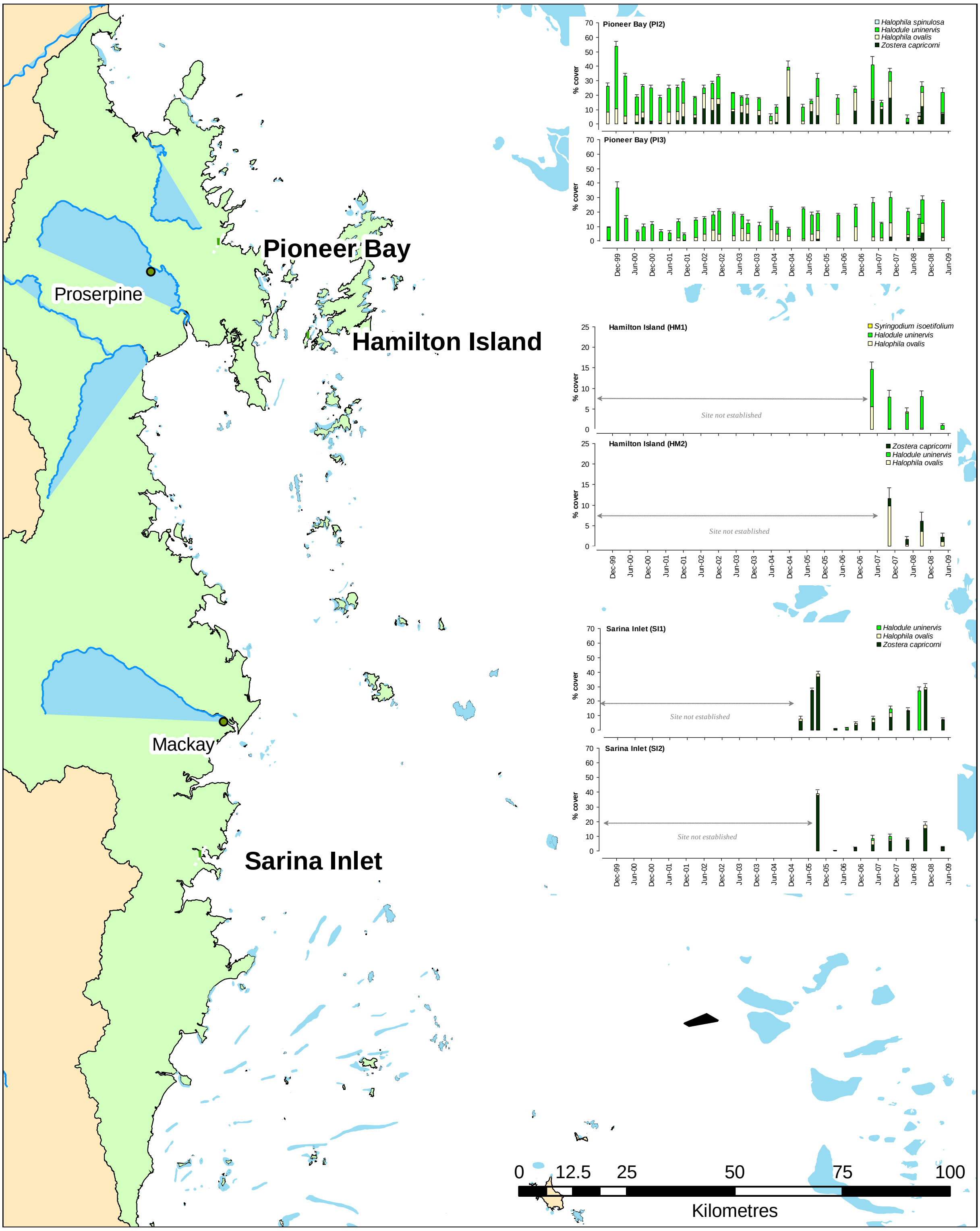


Figure 59. *Mean percentage cover for each seagrass species at Seagrass-Watch long-term monitoring sites in the Mackay Whitsunday region (+ Standard Error). NB: if no sampling conducted then x-axis is clear.*

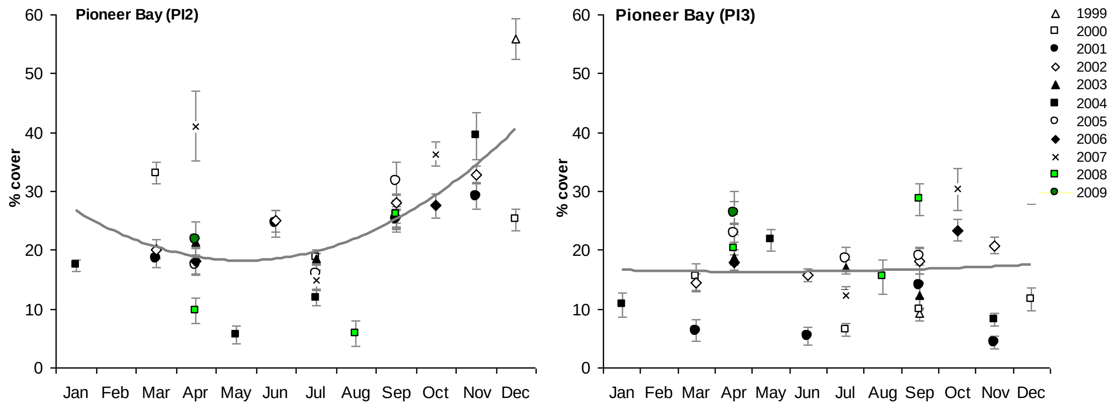


Figure 60. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Pioneer Bay long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

The estuarine monitoring sites are located on an intertidal sand/mud bank in Sarina Inlet south of Mackay. This site is dominated by *Zostera capricorni* with some *Halophila ovalis* (Figure 59). Seagrass cover in late Monsoon 2009 was similar to cover recorded in previous monitoring periods for the same time of year (Figure 61). Seagrass cover in late Dry 2008 was also similar to previous monitoring periods with the exception of 2006 when significant losses were reported (Figure 62). Although there is insufficient data across months within years, the seagrass abundance appears greater in the late Dry than late Monsoon

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

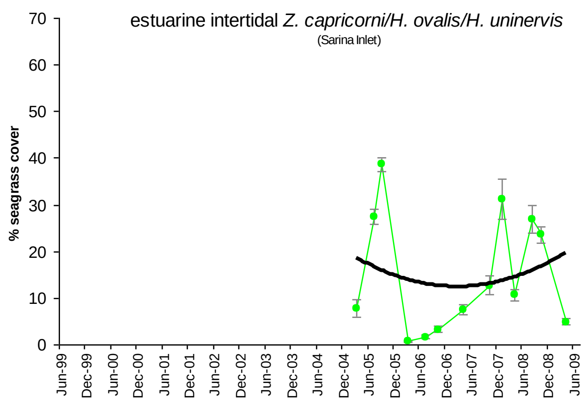
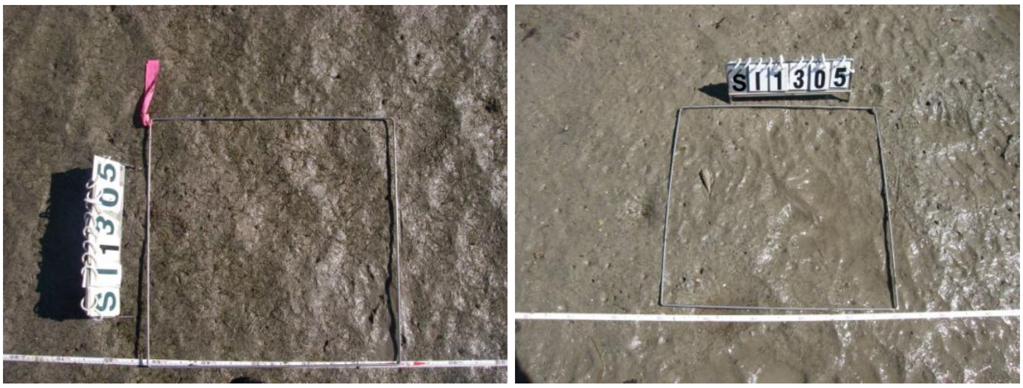


Figure 61. *Change in seagrass abundance (percentage cover) at intertidal meadows located in estuaries in the Mackay Whitsunday region.*



Quadrat at 5m on transect 3 at Sarina Inlet site SI1, on 3 April 2008 (left) and 6 April 2009 (right).

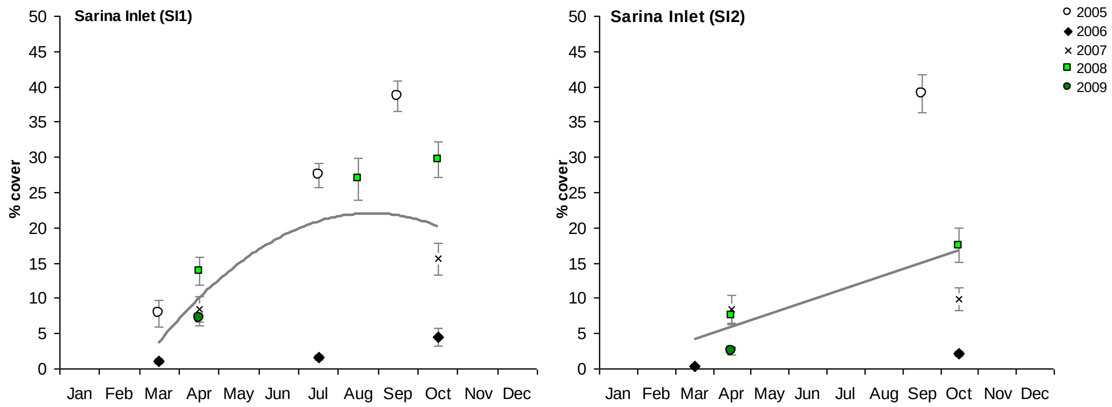


Figure 62. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Sarina Inlet long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

The offshore reef monitoring sites are located on an intertidal fringing reef at Catseye Bay (Hamilton Island). These sites are dominated by *Halodule uninervis* or *Zostera capricorni* with some *Halophila ovalis* (Figure 59). The site at the eastern end of Catseye Bay (HM2) is dominated by *Z. capricorni* and the site at the western end (HM1) is dominated by *H. uninervis*. Although the composition of HO has fluctuated at each site, there have been no longer term changes in species composition. Seagrass cover has continued to decline at Hamilton Island since monitoring began (Figure 63). Due to the paucity of data, it is difficult to determine if seagrass abundance fluctuates seasonally (Figure 64).

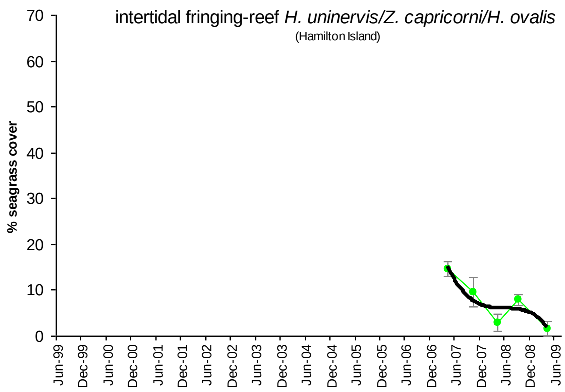
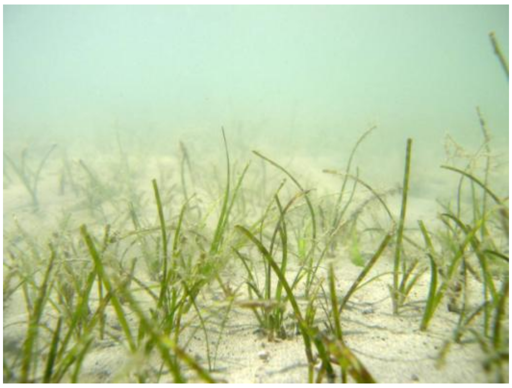


Figure 63. *Change in seagrass abundance (percentage cover) at intertidal meadows located on a fringing reef in the Mackay Whitsunday region.*



Halodule uninervis at Hamilton Island site HM1

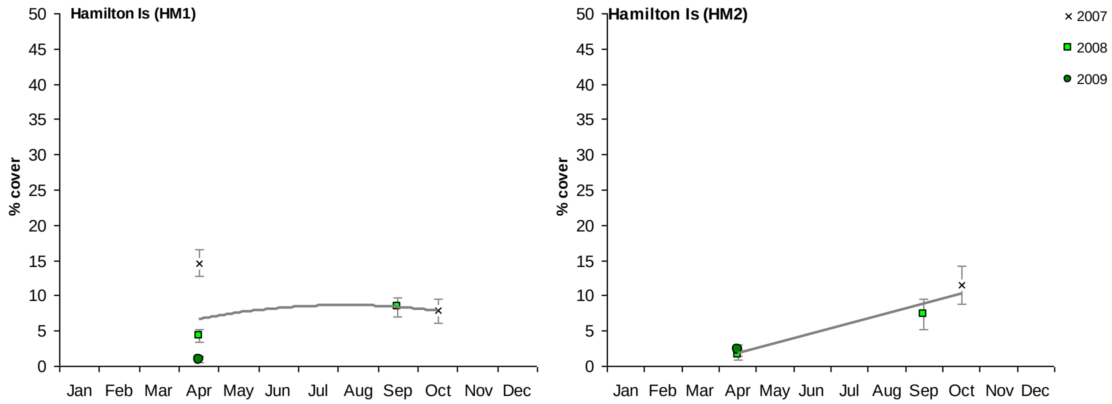


Figure 64. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Hamiton Island long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

Seagrass tissue nutrients

Seagrass tissue C:N ratios in the Mackay region have mostly declined since 2007 (Figure 65), indicating a reduction in light availability. Ratios in 2008 were below 20 (all sites and species) indicating a low light environment. At Pioneer Bay, C:N ratios within all species have consistently declined since 2006, indicating a declining light environment (significant changes of *Halophila ovalis*: $F_{2,16}$=4.8 , p <0.05, *Halodule uninervis*: $F_{2,13}$=4.17 , p <0.05, but not of *Zostera capricorni*). Levels of C:N were at their lowest since measurement commenced in 2006. At Sarina inlet, there has been high inter-annual variability, but this has not been in a consistent direction and levels in 2008 were within the range of previous years (no significant difference between C:N in *Z. capricorni*, *H. ovalis* or *H. uninervis*). At the reef sites on Hamilton Island, seagrass C:N ratios have declined since 2007, but data is absent from previous years.

The C:P ratios of seagrass in the Mackay Whitsundays were mostly lower in 2008 than in previous years (Figure 65). This indicates meadows have increasing P pools (more nutrient rich). C:P ratios in 2008 were all below 500, indicating the seagrass habitat to have a relatively large P pool. C:P ratio within all species at reef sites (Hamilton Island) in 2008 had decreased, indicating a larger P pool. C:P ratios also declined at coastal sites (Pioneer Bay) for *Halodule uninervis* and *Zostera capricorni* (significant declines of *H. uninervis*: $F_{2,16}$=10.0 , p < 0.001), but remained unchanged for *Halophila ovalis* (p > 0.05). At estuarine sites (Sarina Inlet), C:P ratios for *H. ovalis* have consistently declined since 2006, however no such trend was found for *Z. capricorni*, but levels in 2008 were lower than in 2007.

N:P ratios within the Mackay Whitsundays region showed no consistent trend between sites and no significant differences were observed ($p > 0.05$) (Figure 65). In 2008, levels for all species were found to be below 30, indicating N limitation to the plants. At the reef sites (Hamilton Island), the N:P ratio declined in 2008 within both *Halodule uninervis* and *Zostera capricorni*, whereas the N:P ratio of *Halophila ovalis* was higher in 2008 than in previous years. At Sarina Inlet, seagrass N:P ratios were higher in 2008 than in 2007, but remained within the range of previous years. Seagrass N:P ratios in Pioneer Bay varied between species, with declined observed within *Z. capricorni* and *H. uninervis*, but higher levels of N:P observed within *H. ovalis* relative to all previous years.

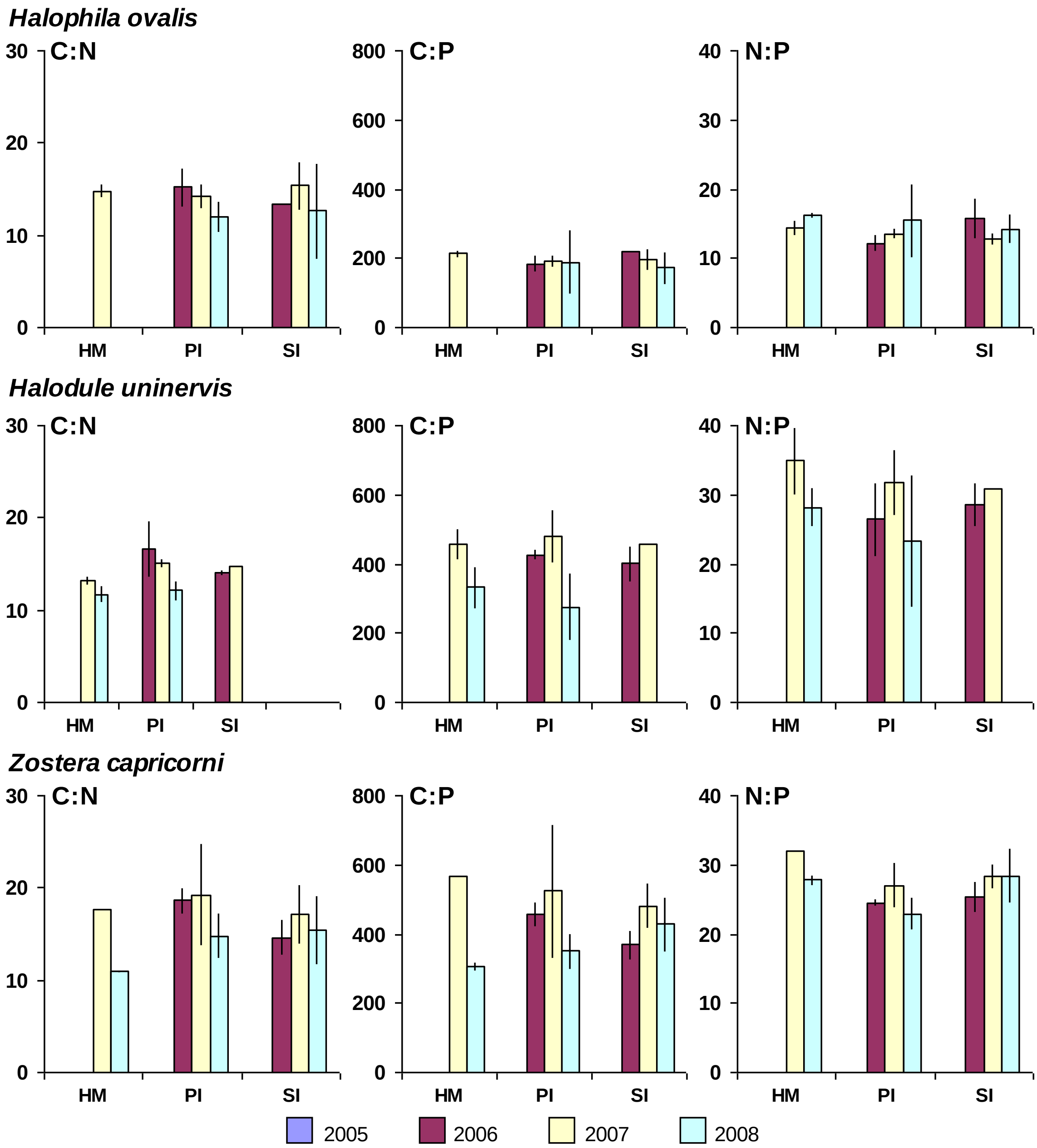


Figure 65. *Plant Tissue Ratios C:N, C:P and N:P for Halophila ovalis, Halodule uninervis and Zostera capricorni in the Mackay Whitsundays region at Hamilton Island (HM), Pioneer Bay (PI), and Sarina Inlet (SI) (Mean and SD displayed).*

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 10).

Over the past 12 months, the meadows at Pioneer Bay have continued to increase in size, particularly at PI2, colonising the shoreward extent. The meadow at Sarina Inlet decreased overall at both sites during the late-Monsoon 2009, and is currently less than half its baseline extent (Table 10, Figure 66). The meadows on Hamilton Island have similarly decreased significantly in overall extent.

Table 10. *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	October 2008	April 2009
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)*	4.094 *(2.3%, increase shoreward)*	4.471 *(6.7%, increase shoreward)*
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)*	4.300 *(2.7%, increase shoreward)*	4.430 *(0.3%, negligible)*
HM1	*NA*	*NA*	*NA*	*NA*	0.810	0.917 *(13.2 %, increase shoreward)*	0.763 *(5.8 %, decrease overall)*	0.687 *(15.2 %, decrease overall)*
HM2	*NA*	*NA*	*NA*	*NA*	0.164	0.05 *(69.2%, decrease overall)*	0.09 *(44.4%, increase overall)*	0.06 *(64.1%, 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)*	3.58 *(12.5%, increase overall)*	1.661 *(59.4%, 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%,decr ease overall)*	3.732 *(5.5%, increase overall)*	1.409 *(60.2%, decrease overall)*

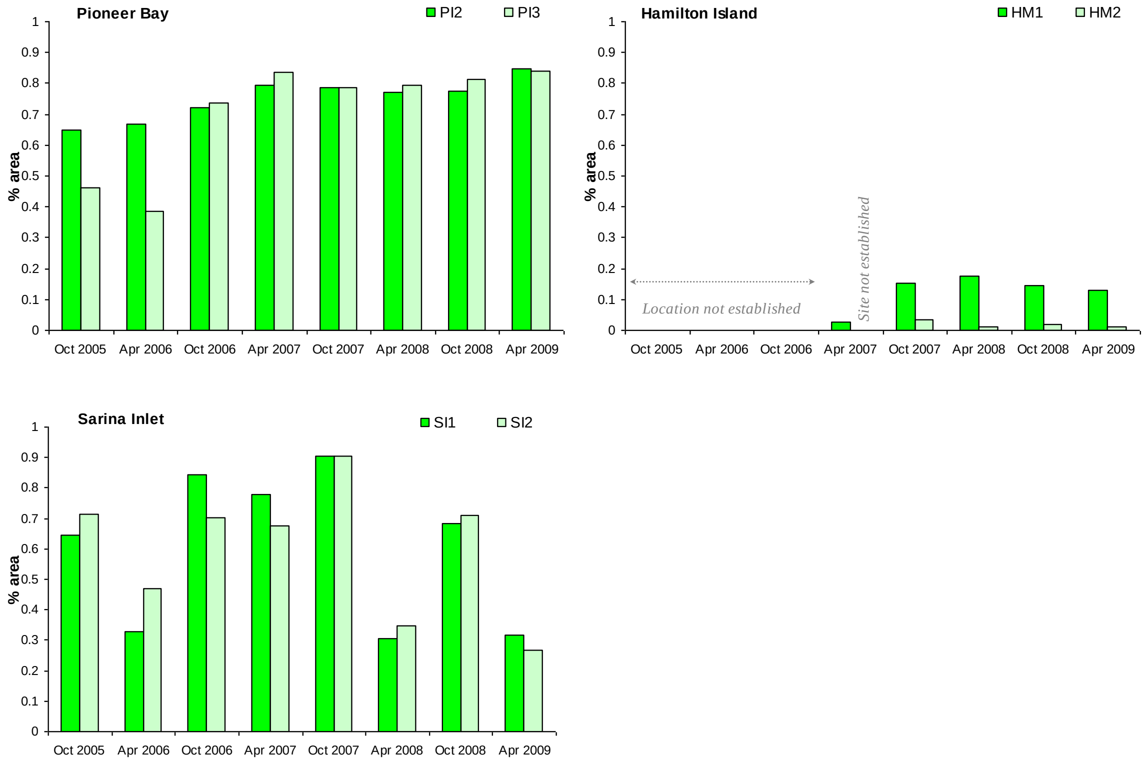


Figure 66. *Extent of area (100m radius of monitoring site) covered by seagrass at each coastal (Pioneer Bay), reef (Hamilton Is) and estuarine (Sarina Inlet) monitoring locations.*

Epiphytes and Macro-algae

Epiphyte cover on seagrass leaf blades was highly variable at both inshore coastal and estuarine sites (Figure 67, Figure 68). Although epiphyte cover appears seasonal, with higher abundance in the Dry season of each year, cover over the last 12 months was similar to the previous monitoring period at the coastal sites, but significantly higher at the estuarine sites (Figure 67, Figure 68). Epiphyte cover declined at the reef habitat sites (Hamilton Island) over the monitoring period (Figure 69)

Percentage cover of macro-algae at coastal sites is also variable and significantly higher than estuarine or reef habitat sites (Figure 67, Figure 68, Figure 69). Over the monitoring period, maco-algae abundance appears to have declined at coastal sites (Figure 67).

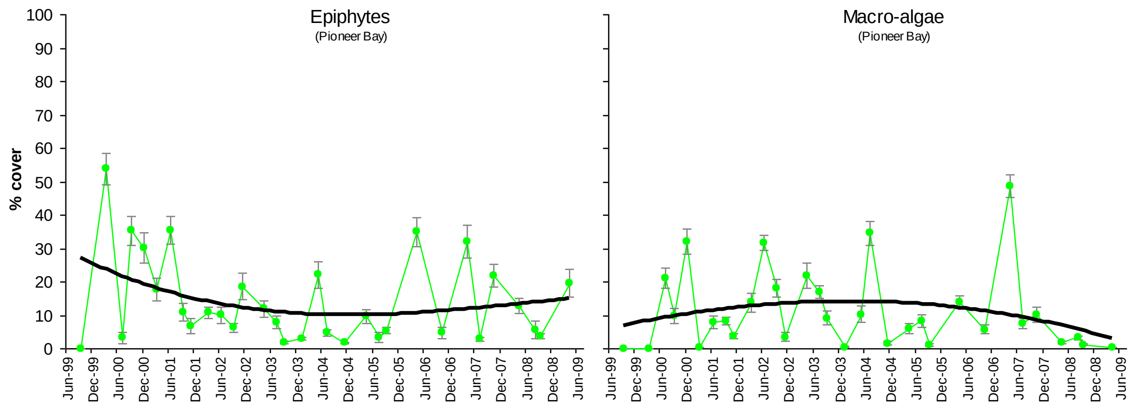


Figure 67. *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at intertidal coastal (Pioneer Bay) seagrass monitoring sites. NB: Polynomial trendline for all years pooled.*

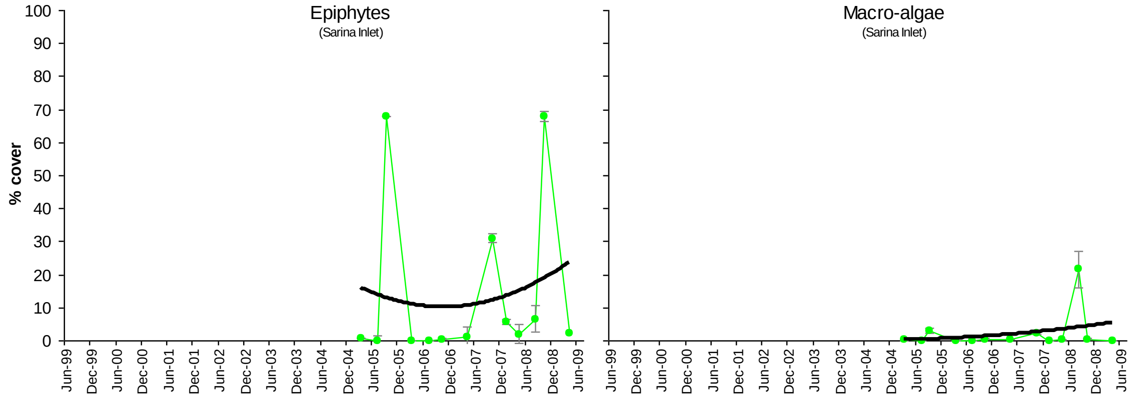


Figure 68. *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at estuarine (Sarina Inlet) seagrass monitoring sites. NB: Polynomial trendline for all years pooled.*

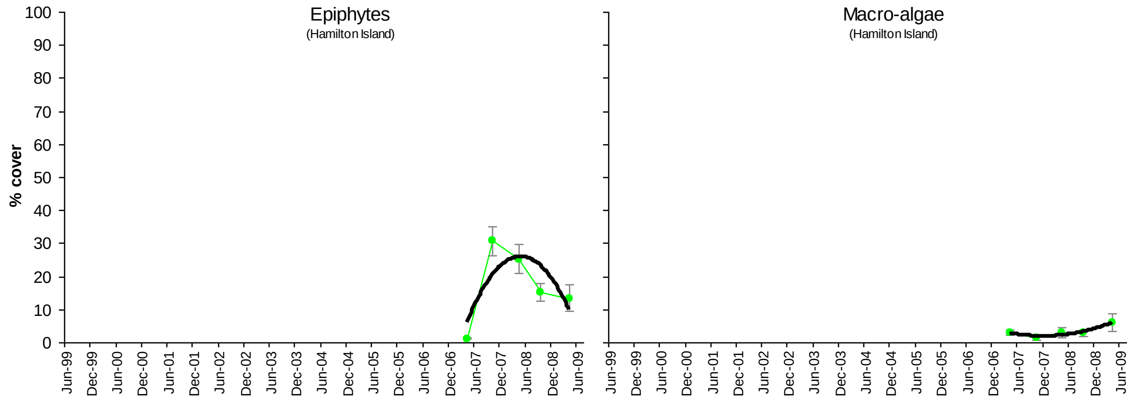


Figure 69. *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at intertidal reef seagrass monitoring location. NB: Polynomial trendline for all years pooled.*

Sediment nutrients

Adsorbed Phosphate levels at Hamilton Island and within Pioneer Bay were among the highest recorded at any site within the Marine Monitoring Program (Figure 70), yet values for Sarina Inlet were much reduced and similar to other catchments and locations. Levels of Phosphate were higher in 2008 than in 2007 at all sites. Levels recorded at Sarina Inlet were the highest recorded since commencement of monitoring in 2005. Alternatively, levels of Ammonium within seagrass sediments were at their lowest at all sites since monitoring commenced. Due to the elevated Phosphate and the decreased concentrations of Ammonium the N:P ratios had declined substantially at all sites in 2008 relative to 2007.

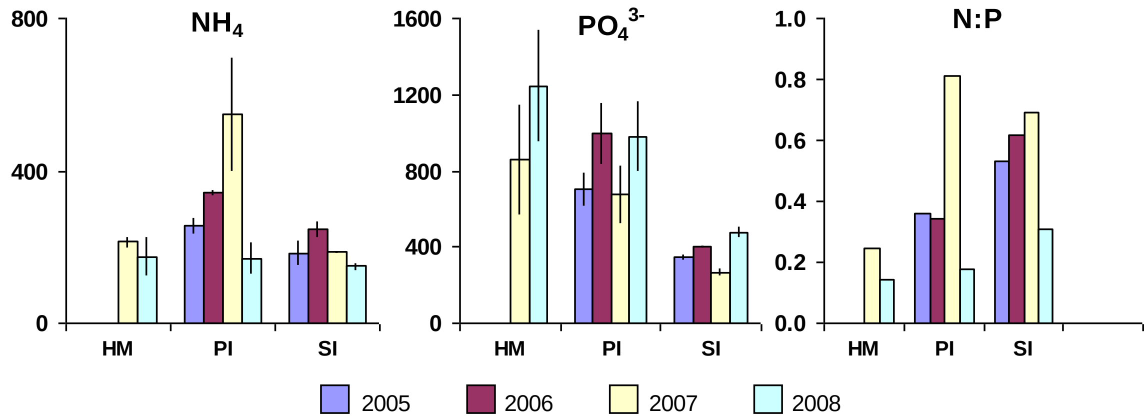


Figure 70. *Adsorbed nutrient levels within seagrass sediments of the Mackay and Whitsundays (ammonium (NH_4), phosphate (PO_4^{3-}), and the ratio of PO_4^{3-} to NH_4) at Hamilton Island (HM), Pioneer Bay (PI), and Sarina Inlet (SI), October 2005 to October 2008 (mean and ±SD displayed).*

Sediment herbicides

No herbicides were found above detectable levels in the sediments of the seagrass meadows at any of the monitoring sites in post-Monsoon 2009 (Table 11).

Table 11. *Concentration of herbicides ($\mu g\ kg^{-1}$) in sediments of seagrass monitoring sites in post Monsoon 2009. ND=not detectable, <0.1 $\mu g\ kg^{-1}$*

Site	Flumeturon	Diuron	Simazine	Atrazine	Desethyl Atrz.	Desisopropyl Atrz.	Hexazinone	Tebuthiuron	Ametryn	Prometryn	Bromacil	Terbutryn	Metolachlor
PI2	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*
PI3	*ND*	*ND*	*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*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*
SI2	*ND*	*ND*	*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 (Figure 71). Within canopy temperature was monitored at coastal and estuarine locations (Figure 71), and generally follows a similar pattern. No extreme temperatures (>40°C) were recorded over the last 12 months. Maximum temperatures peaked several times throughout the year at all locations, generally during the time of low spring tide of the early Monsoon season (Figure 71).

Mean within canopy temperature monitored at Pioneer Bay were within the 21 – 30°C range, with highest mean temperatures in December 2008. Hamilton Island temperatures were slight lower with the 20-29°C range and Sarina Inlet were slightly cooler again within 19-29°C range (Figure 72). The warmest month on average across all locations was December 2008.

Within canopy temperatures on average were warmer over the last monitoring period than previous years of monitoring.

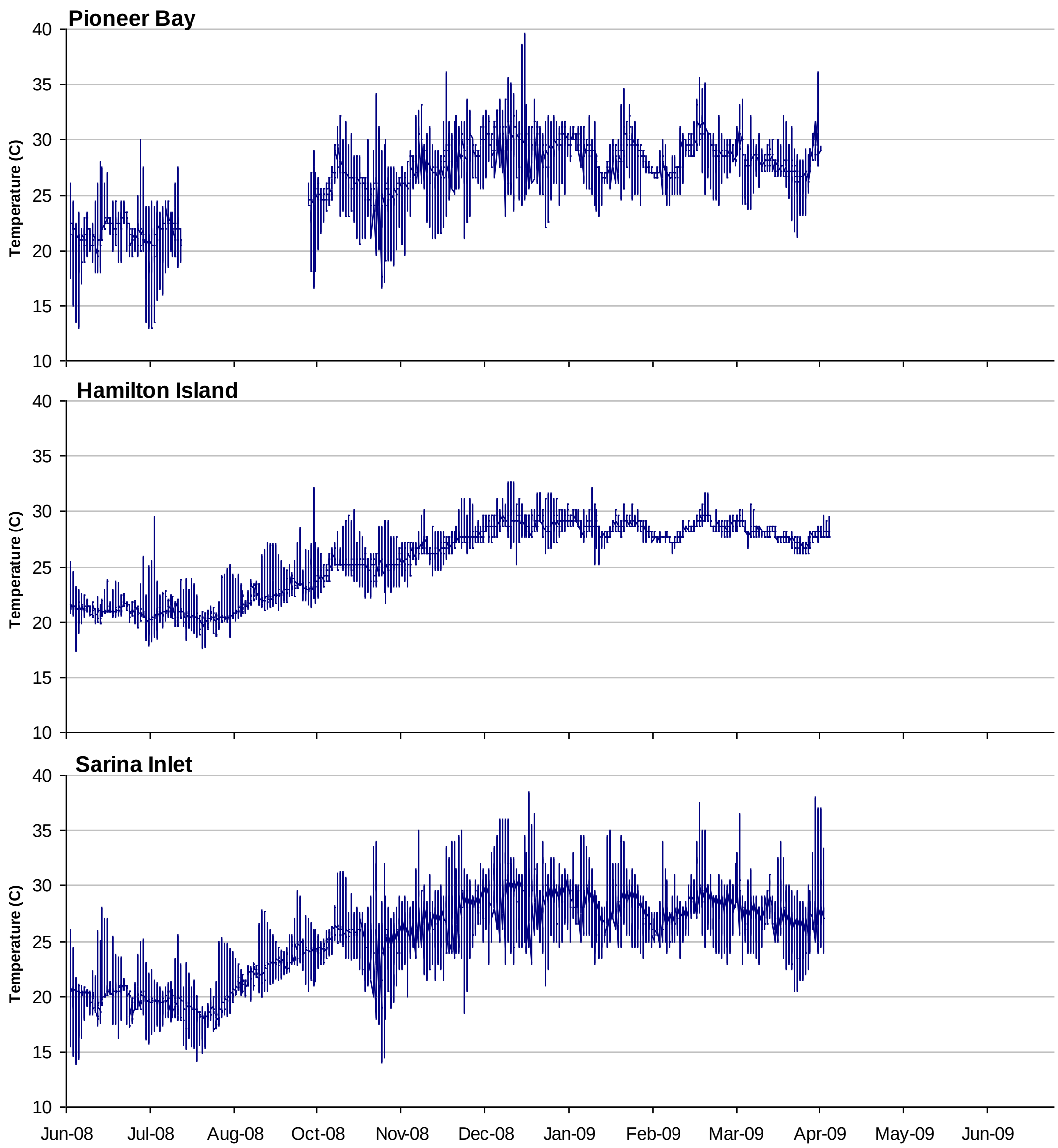


Figure 71. *Within seagrass canopy temperature (°C) at coastal (Pioneer Bay), estuarine (Sarina Inlet) and offshore fringing-reef (Hamilton Island) intertidal meadows within the Mackay Whitsunday region over the 2008/2009 monitoring period.*

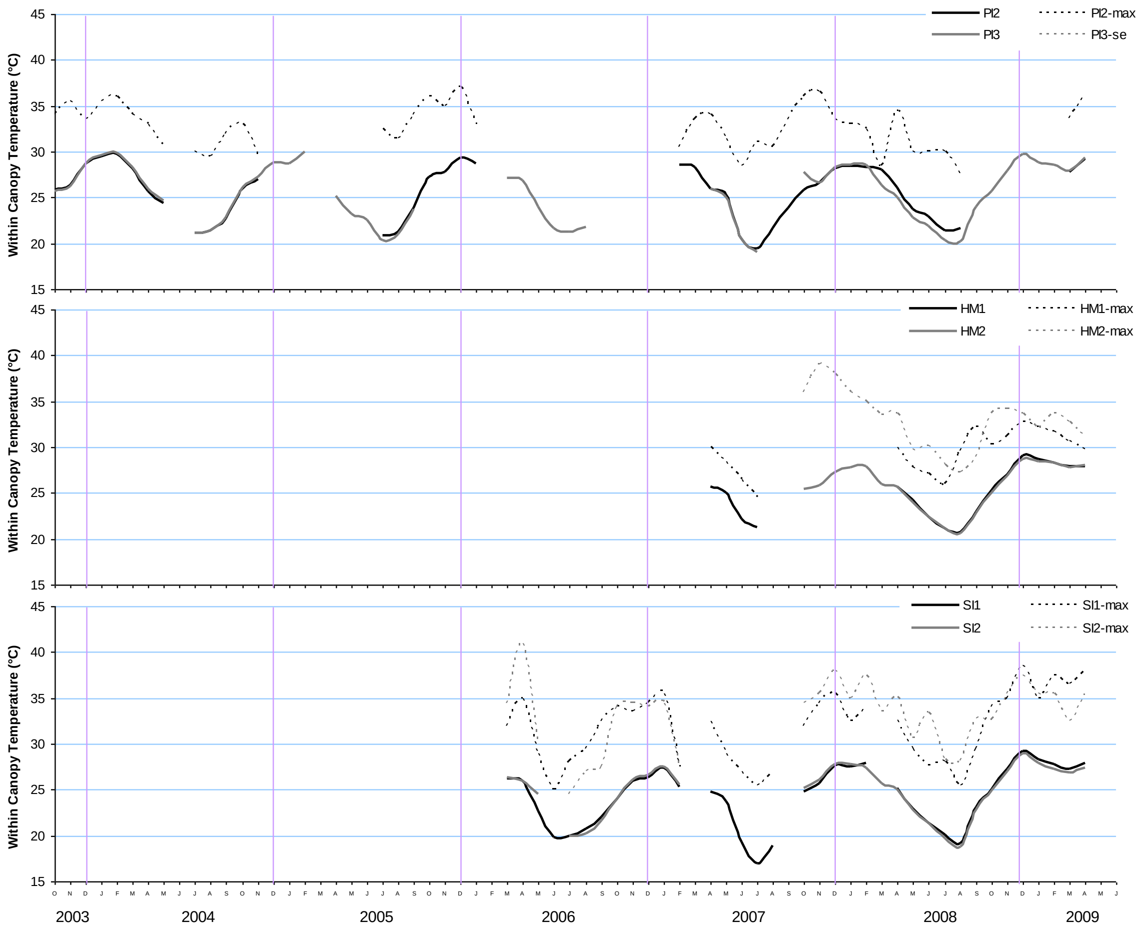


Figure 72. *Monthly mean and maximum within seagrass canopy temperature (°C) at intertidal meadows in coastal (Pioneer Bay), fringing-reef (Hamilton Island) and estuarine (Sarina Inlet) habitats within the Mackay Whitsunday region.*

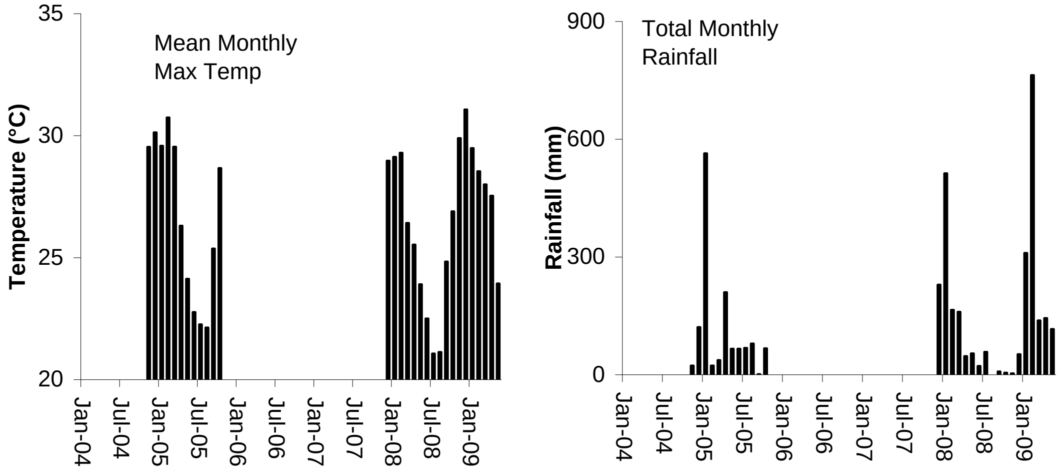
Regional Climate

Whitsundays – Hamilton Island and Pioneer Bay

Climate data availability for Hamilton Island is inconsistent between years; however temperatures for 2008 were 0.8°C below the 15 year average at 25.9°C. Rainfall was 36% below the average at 1087mm. No cloud cover data is available for Hamilton Island.

Mackay – Sarina Inlet

The mean maximum daily temperature recorded in Mackay during 2008 was 26.5°C; 0.1°C hotter than the 70 year average. Although this temperature is close to the average, it is lower than many of the recent years of monitoring. Mean annual rainfall in 2008 was 1808mm; this was 15% higher than the 50 year average and reflects consistently high rainfall during January, February and March. No cloud cover data is available for Mackay.



Mackay - Sarina Inlet Sites

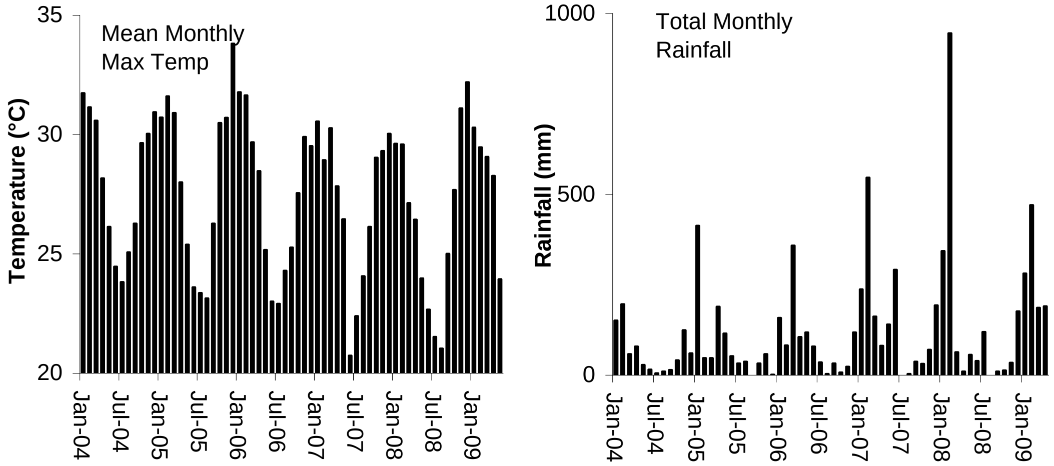


Figure 73. *Mean monthly daily maximum temperature (°C), and total monthly rainfall (mm) recorded at Hamilton Island (BOM station 033106) and Mackay Airport (BOM station 033045) (Source www.bom.gov.au). Mackay Airport used as a surrogate for the climate at Sarina Inlet, Hamilton Island also used as a surrogate for the climate at Pioneer Bay.*

Fitzroy

2008/2009 Summary

Intertidal seagrass meadows in the Fitzroy are abundant on the large sand/mud banks in sheltered areas of the region's estuaries and coasts, and occur on the fringing reef flat habitats of offshore islands. All three habitat types are monitored. Environmental drivers include high turbidity and desiccation (which is linked to the large tide regime).

- Estuarine and coastal meadows dominated by *Zostera capricorni*, and reef habitats mostly comprised of *Halodule uninervis*.
- Coastal and estuarine seagrass meadows remain highly variable, but reef seagrasses at Great Keppel have declined in abundance since 2007.
- Meadow area variable or stable.
- Epiphyte cover has not changed, while macro-algae declined.
- Tissue ratios of N:P indicate all habitat types nutrient replete.
- C:N tissue ratios indicate estuarine and reef as low light environments, but coastal meadows at Shoalwater have moderate light.
- C:P tissue ratios indicate reef and estuarine meadows nutrient rich, and coastal meadows nutrient poor.
- Sediment nutrients highly variable between years.
- No herbicides were detected in sediments.
- No extreme canopy temperatures (>40°C) were recorded over the last 12 months. All sites have been subjected to elevated rainfall during both the 2008 and 2009 wet seasons.

Background

The Fitzroy region covers an area of nearly 300,000 km^2. It extends from Nebo in the north to Wandoan in the south, and to the Gemfields in the west and encompasses the major systems of the Fitzroy, Boyne, and Calliope rivers as well as the catchments of the smaller coastal streams of the Capricorn and Curtis Coasts (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.

Reef Rescue 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 form 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 74). 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.

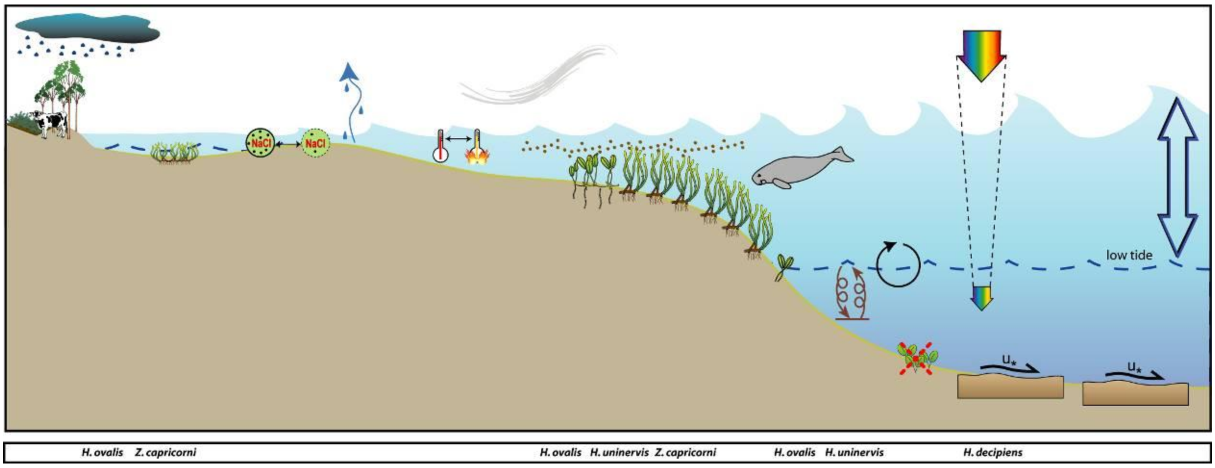


Figure 74. *Conceptual diagram of coastal habitat in the Fitzroy region – major control is pulsed light, salinity and temperature extremes: general habitat, seagrass meadow processes and threats/impacts (See Figure 2 for icon explanation).*

Estuarine seagrass habitats in the southern Fitzroy region tend to be intertidal, on the large sand/mud banks in sheltered areas of the estuaries. Tidal amplitude is not as great as in the north and estuaries that are protected by coastal islands and headlands support meadows of seagrass. These habitats feature scouring, high turbidity and desiccation (linked to this large tide regime), and are the main drivers of distribution and composition of seagrass meadows in this area (Figure 75). These southern estuary seagrasses (Gladstone) are highly susceptible to impacts from local industry and inputs from the Calliope River. The Gladstone region is highly industrial with the world's largest alumina refinery, Australia's largest aluminium smelter and Queensland's biggest power station. In addition, Port Curtis is Queensland's largest multi-cargo port with 53 million tonnes of cargo passing through the port in 2006.

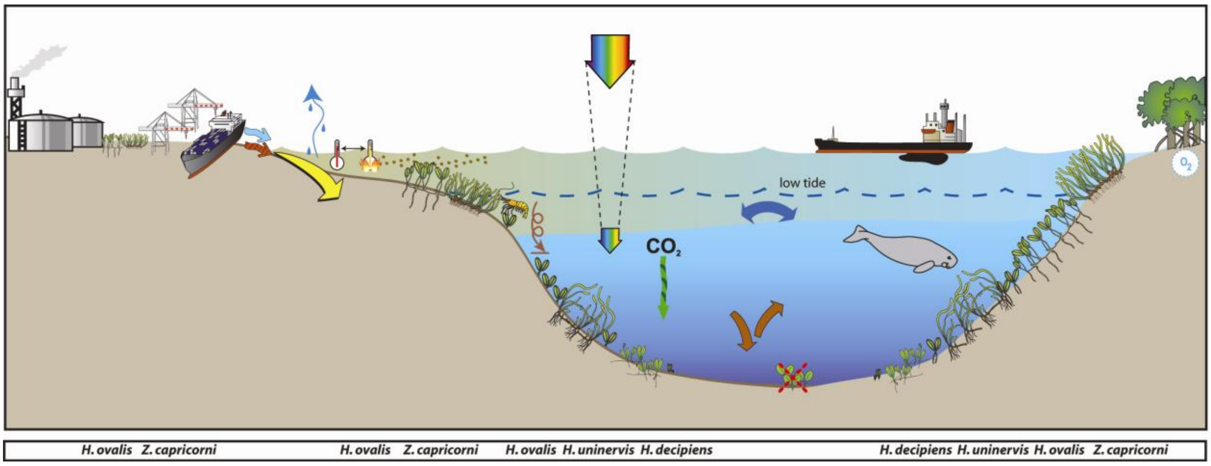


Figure 75. *Conceptual diagram of estuary habitat in the Fitzroy region – major control variable rainfall and tidal regime: general habitat, seagrass meadow processes and threats/impacts (See Figure 2 for icon explanation).*

Seagrass cover and composition

Seagrass species composition differed greatly between inshore (coastal and estuarine) and offshore (reef) habitats. Inshore coastal sites monitored in Shoalwater Bay were dominated by *Zostera capricorni* with some *Halodule uninervis* and minor quantities of *Halophiloa ovalis* (Figure 77). Seagrass cover over the last monitoring period has decreased slightly from the peak values observed in late Dry 2007, but remains higher than when monitoring first commenced in early 2002 (Figure 76). The overall trend in seagrass abundance over the last 7 years has been an increase.

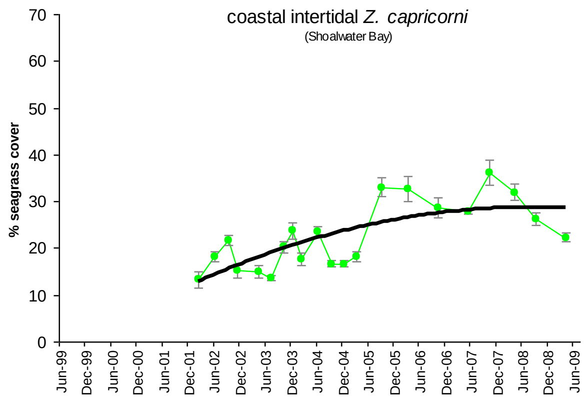


Figure 76. *Change in seagrass abundance (percentage cover) at coastal intertidal meadows in Shoalwater Bay (Fitzroy region).*

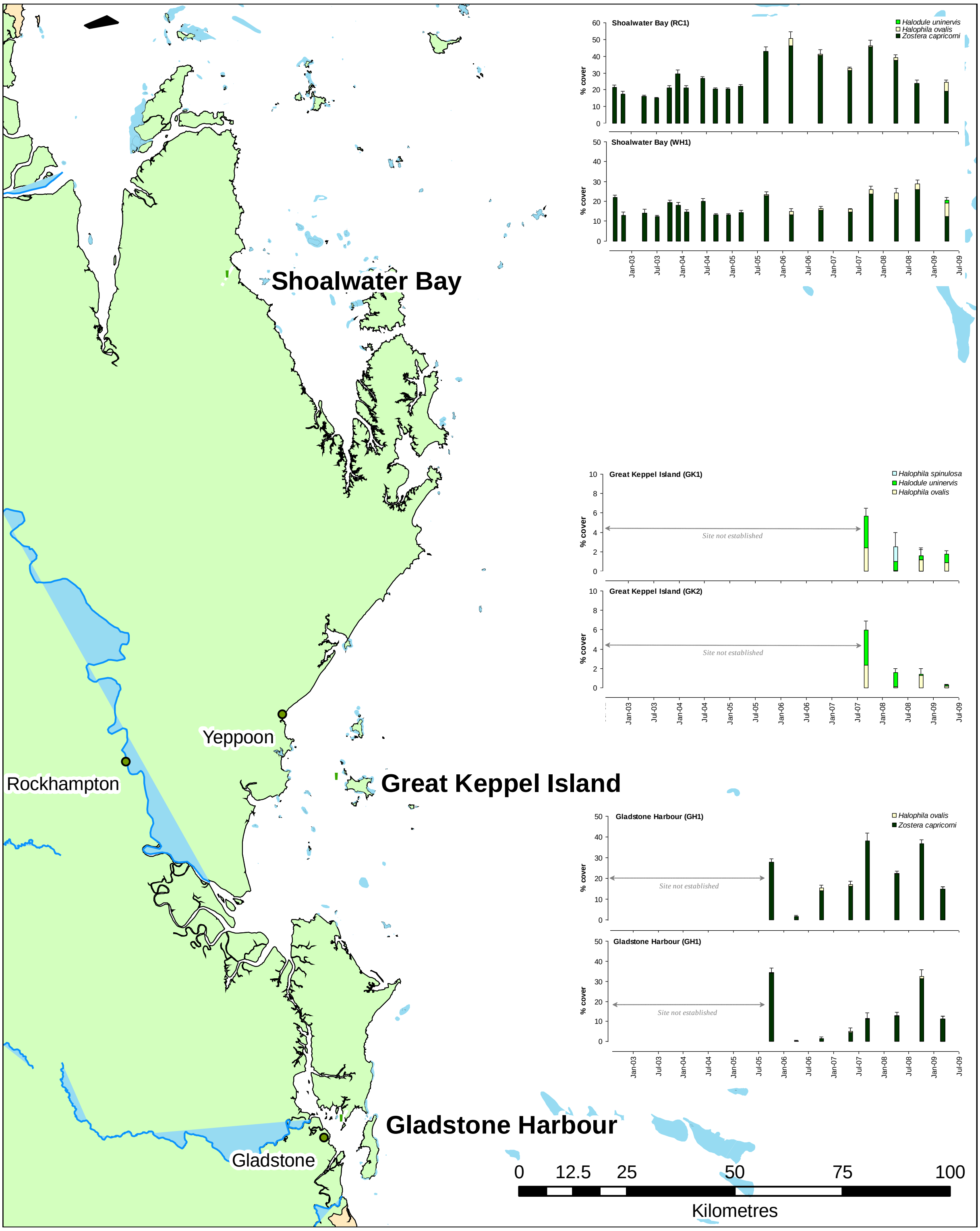


Figure 77. *Mean percentage cover for each seagrass species at Seagrass-Watch long-term monitoring sites in the Fitzroy Region (+ Standard Error). NB: if no sampling conducted then x-axis is clear.*

Quadrat at 5m on transect 1 at Wheelan's Hut (Shoalwater Bay WH1), on 17 September 2005 (left) and 4 April 2009 (right)

Shoalwater Bay seagrass abundance does not appear to show a clear seasonal pattern (Figure 78), but this may be a consequence of the long-term increase in abundance which could mask any inter annual changes.

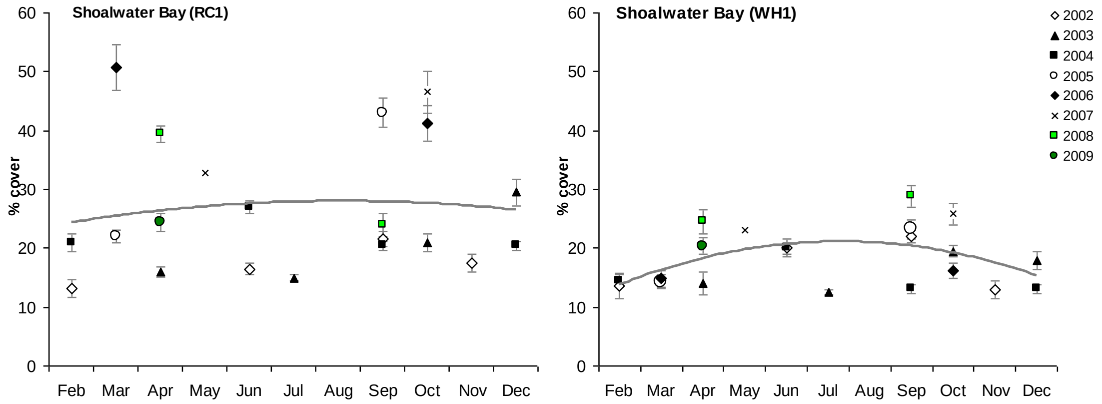


Figure 78. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Shoalwater Bay long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

Gladstone Harbour estuarine sites were located in a large *Zostera capricorni* dominated meadow (Figure 77) on the extensive intertidal Pelican Banks south of Curtis Island. Species composition has remained stable, however abundance has differed greatly between years (Figure 79). Abundance observed in late Dry 2008 was the highest recorded since monitoring was established in 2005. Abundance in late Monsoon 2008 was significantly lower than the same time in 2008.

Although data is limited, inter-annual abundances suggest a seasonal pattern of higher seagrass abundance in the late dry and lower in the late Monsoon (Figure 80).

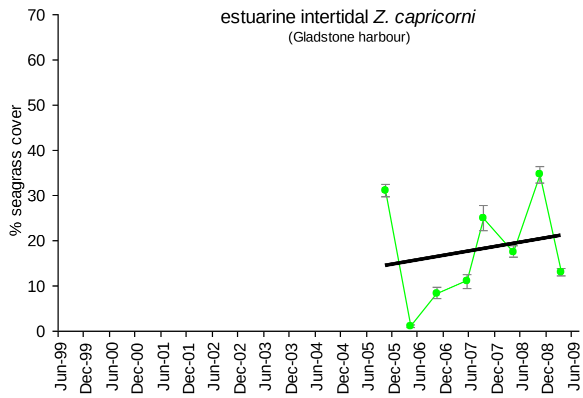


Figure 79. *Change in seagrass abundance (percentage cover) at estuarine intertidal meadows in Gladstone Harbour (Fitzroy region).*

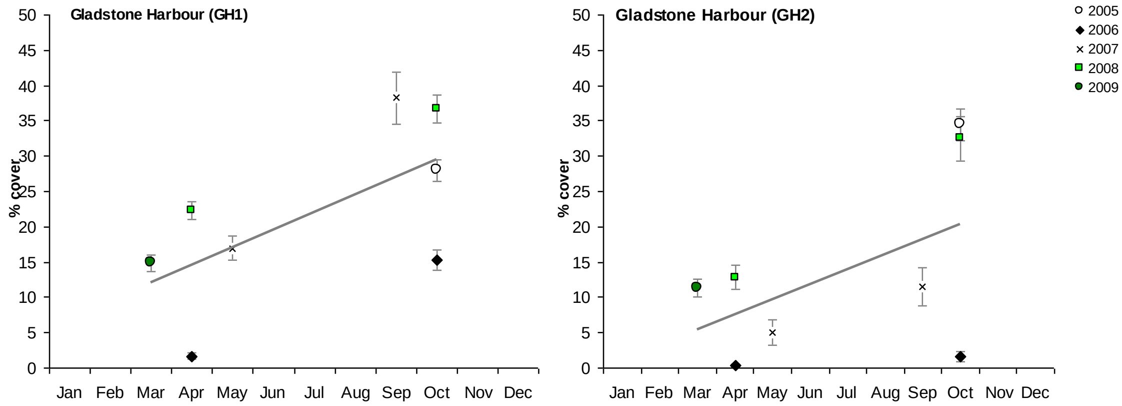


Figure 80. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Shoalwater Bay long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

The monitoring sites at Great Keppel Island (GK1 and GK2) differ greatly from the inshore sites, being composed predominately of *H. uninervis* on sand substrate (Figure 77). Seagrass abundance has continued to decline since monitoring was established in 2007 (Figure 81), and due to the paucity of data no seasonal patterns are apparent (Figure 82).

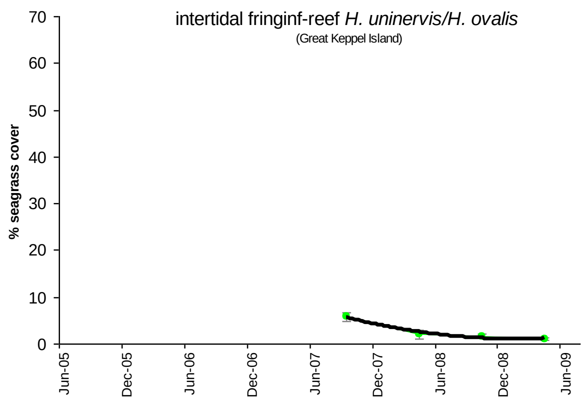


Figure 81. *Change in seagrass abundance (percentage cover) at intertidal fringing –reef meadows at Great Keppel Island (Fitzroy region).*

Halodule uninervis (left) and Halophila ovalis dominated (right) meadows at Great Keppel Island.

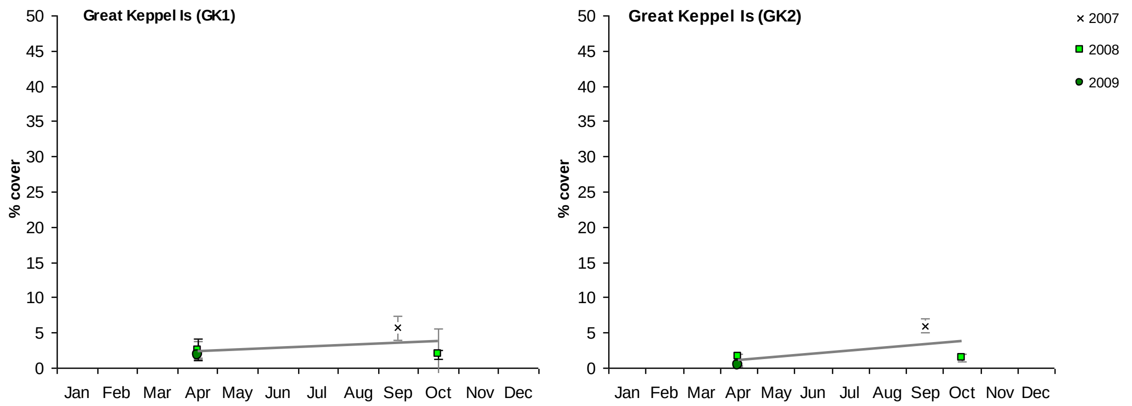


Figure 82. *Mean percentage seagrass cover (all species pooled) (± Standard Error) at Great Keppel Island long-term monitoring sites at time of year. NB: Polynomial trendline for all years pooled.*

Seagrass tissue nutrients

Seagrass meadows in the Fitzroy region at Gladstone Harbour and Great Keppel Island appear to be in low light environments due to their low C:N ratios (C:N < 20) (Figure 83). Shoalwater Bay however indicates moderate light availability as C:N ratios were mostly above 20. Ratios recorded for all species and at all sites were lower in late Dry 2008 relative to 2007, indicating a lower light environment. This was a significant difference for *Halophila ovalis* in Gladstone between years 2006 and 2008 ($F_{1,6}$=90.97 , p<0.001).

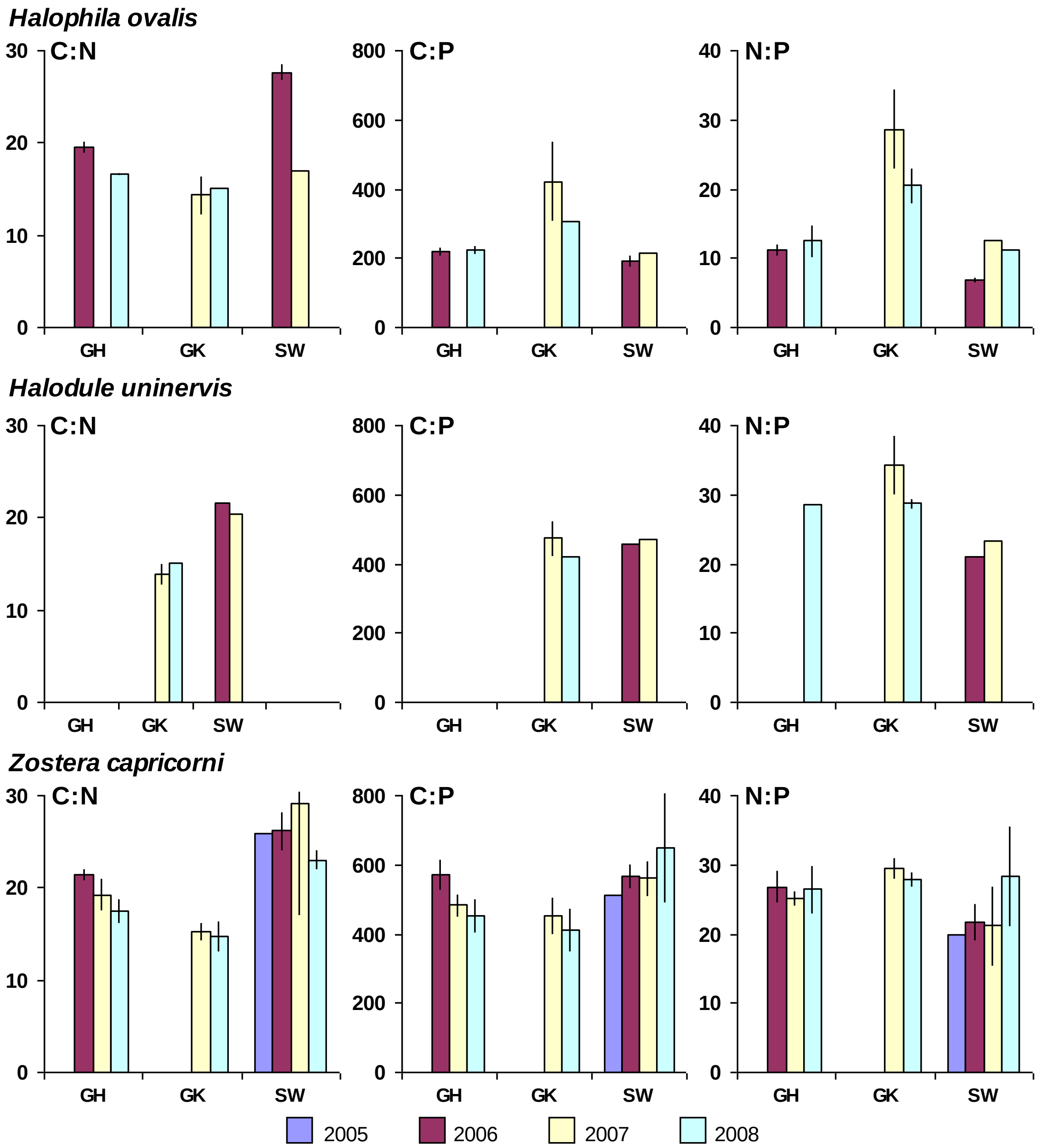


Figure 83. *Plant Tissue Ratios (a) C:N, (b) C:P and (c) N:P for Halophila ovalis, Halodule uninervis and Zostera capricorni in the Fitzroy region at Gladstone Harbour (GH), Great Keppell (GK), and Shoalwater (SW) (Mean and SD displayed).*

With the exception of *Zostera capricorni* in Shoalwater Bay, C:P ratios of all species at all sites in the Fitzroy region were below 500 (Figure 83), indicating that the presence of a relatively large P pool. At Great Keppel Island and Gladstone harbour, C:P ratios have declined (significant declines of *Z. capricorni*: $F_{2,8}$=6.42 , $p < 0.05$, but not for *Halophila ovalis*) indicating an increasing P pool. At Shoalwater Bay however, C:P ratios have consistently increased since commencement of monitoring, but these small incremental increases were not significant ($p > 0.05$).

The N:P ratios of all seagrass species at all sites in the Fitzroy region in late Dry 2008 were below 30 (Figure 83), indicating meadows that were either replete or potentially N limited. Within Great Keppel Island seagrass meadows, N:P ratios have declined since 2007 (significant declines of *Halophila ovalis*: $F_{1,10}$=8.09 , p<0.05, but not of *Halodule uninervis*), indicating increasing potential for N limitation. Within Gladstone Harbour however, these ratios have mostly remained unchanged. N:P ratio in Shoalwater Bay have consistently increased since 2005, from meadows that were N limited to those that are replete; however, due to the small incremental increases these differences were not significant ($p > 0.05$).

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 12). 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 84). In early 2006 the Gladstone Harbour meadow was absent, but recovered in distribution by October 2006. In the late Dry 2008 the meadow decreased in size due to the prevalence of drainage channels forming within 100m of the monitoring sites across the intertidal banks, however in late Monsoon 2009 the meadow extent was within 7% of the baseline (Table 12, Figure 84).

On the fringing reef platform of Great Keppel Island the seagrass meadows has fluctuated greatly and decreased in extent since monitoring began in 2007 (Table 12, Figure 84).. In the late Monsoon, the extent of the meadows was within 28 and 45% of the baseline at GK1 and GK2 respectively (Table 12, Figure 84).

Table 12. *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	October 2008	April 2009
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%, stable)*	5.396 *(0.3%, stable)*	5.396 *(0.3%, stable)*
WH1	**5.397**	5.397 *(No change)*	5.397 *(No change)*	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)*	5.074 *(-5.9%, increase overall)*	5.027 *(-6.8%, decrease shoreward)*
GH2	**5.174**	0 *(-100%, Meadow absent)*	5.394 *(4.3%, Meadow recovered)*	5.174 *(0.01%, decrease seaward)*	4.733 *(-8.5%, decrease seaward)*	5.087 *(-1.7%, increase shoreward)*	4.829 *(-6.7%, decrease seaward)*	5.281 *(2.1%, increase shoreward)*
GK1	*NA*	*NA*	*NA*	*NA*	2.513	0.526 *(-79.1%, decrease overall)*	0.933 *(-62.9%, increase overall)*	1.814 *(-27.8%, increase overall)*
GK2	*NA*	*NA*	*NA*	*NA*	3.998	2.368 *(-40.8%,decrease overall)*	3.201 *(-19.9%, increase overall)*	2.234 *(-44.1%, decrease overall)*

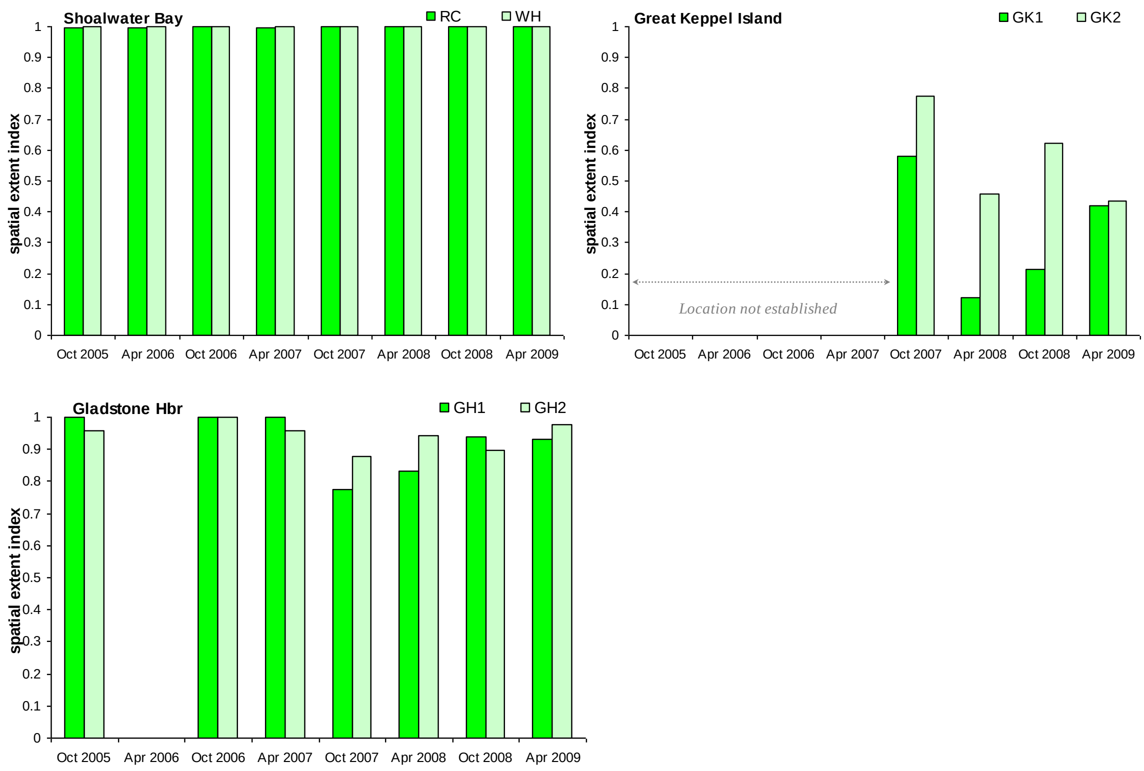


Figure 84. *Extent of area (100m radius of monitoring site) covered by seagrass at each monitoring site at Shoalwater Bay, Great Keppel Island and Gladstone Harbour locations.*

Epiphytes and Macro-algae

Epiphyte covers on seagrass leaf blades at Shoalwater Bay were relatively low but higher and more variable at Gladstone Harbour and Great Keppel Island (Figure 85, Figure 86, Figure 87). Epiphyte cover at coastal sites 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 85).

Epiphyte cover at Great Keppel Island appears higher during the late Monsoon compared to the late Dry is similar at each site, however due to the paucity of data it is not possible to compare between years (Figure 87).

Macro-algae cover is generally low at Showalter bay and Great Keppel Island, however it has fluctuated greatly at the estuarine sites in Gladstone Harbour (Figure 85, Figure 86, Figure 87).

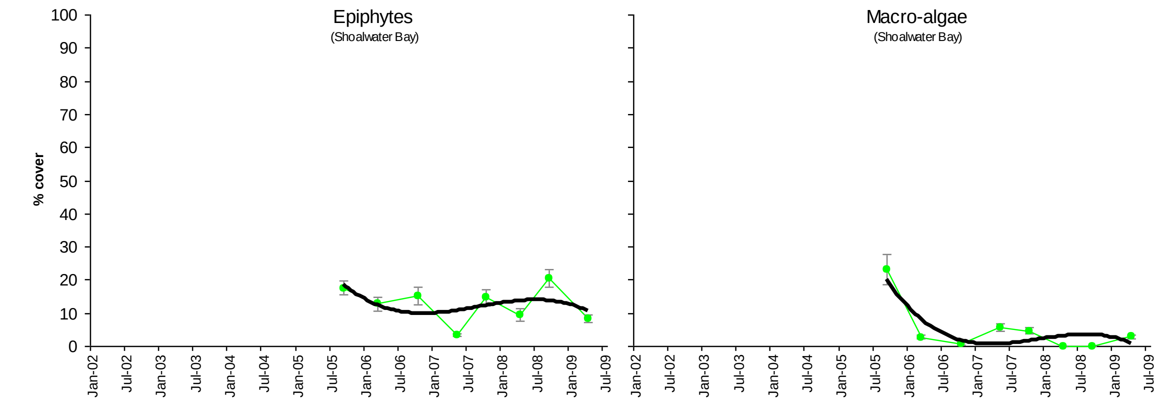


Figure 85. *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at intertidal coastal (Shoalwater Bay) seagrass monitoring sites. NB: Polynomial trendline for all years pooled.*

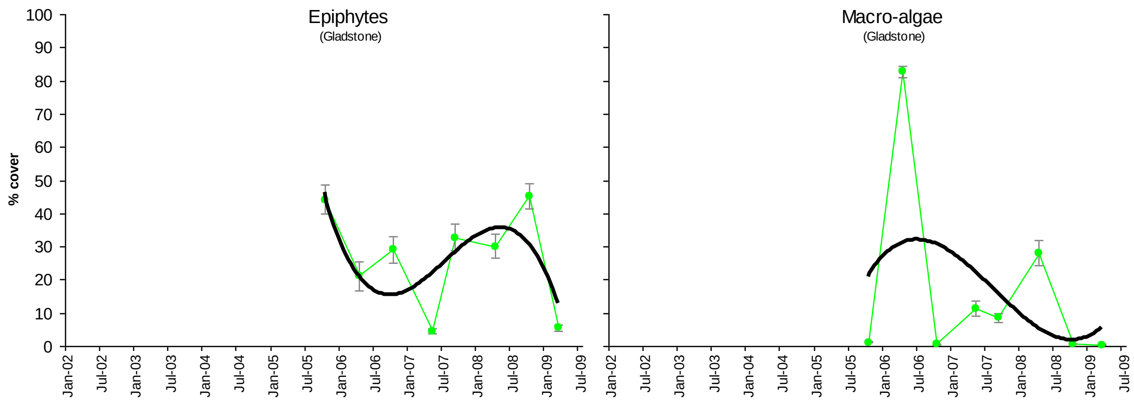


Figure 86. *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at intertidal estuarine (Gladstone Harbour) seagrass monitoring sites. NB: Polynomial trendline for all years pooled.*

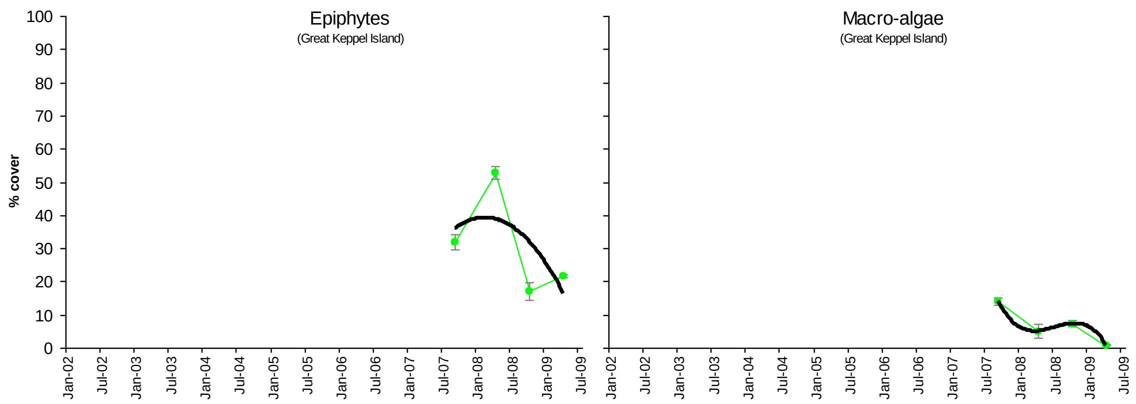


Figure 87. *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at the intertidal offshore reef (Great Keppel Island) seagrass monitoring location. NB: Polynomial trendline for all years pooled.*

Sediment nutrients

The levels of adsorbed Phosphate in seagrass meadows of the Fitzroy region were lower in late Dry 2008 than in all previous years at Shoalwater and Gladstone Harbour sites (Figure 88). This was in contrast to the observed levels at the reef sites of Great Keppel Island that had elevated levels relative to 2007.

Sediment Ammonium levels at Shoalwater and Great Keppel were elevated in 2008 relative to 2008 but were within the range of previous years, however levels in Gladstone harbour were reduced relative to 2007 (Figure 88).

The N:P ratio of sites in Gladstone Harbour has consistently declined since 2005, with the lowest recorded levels found in 2008 (Figure 88). Lowest recorded N:P ratios were also found at Shoalwater. N:P ratios of rhizosphere sediments at Great Keppel in 2008 were however elevated relative to 2007.

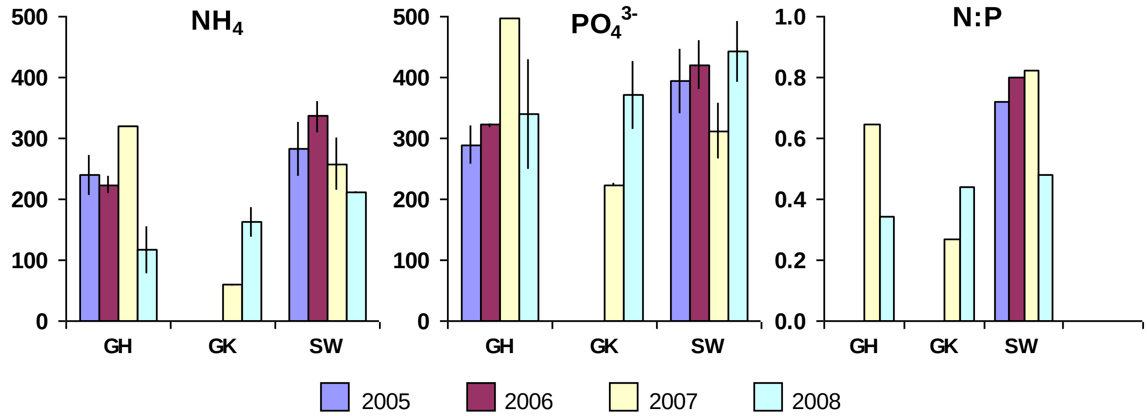


Figure 88. *Adsorbed nutrient levels within seagrass sediments of the Fitzroy region (ammonium (NH_4), phosphate (PO_4^{3-}), and the ratio of PO_4^{3-} to NH_4) at Gladstone Harbour (GH), Great Keppell (GK), and Shoalwater (SW), October 2005 to October 2008. Mean and SD displayed.*

Sediment herbicides

No herbicides were found above detectable levels in the sediments of the seagrass meadows at any of the monitoring sites in post-Monsoon 2009 (Table 13).

Table 13. *Concentration of herbicides ($\mu g\ kg^{-1}$) in sediments of seagrass monitoring sites in post Monsoon 2009. ND=not detectable, <0.1 $\mu g\ kg^{-1}$*

Site	Flumeturon	Diuron	Simazine	Atrazine	Desethyl Atrz.	Desisopropyl Atrz.	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*	*ND*	*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, however the loggers deployed in Shoalwater Bay over the Monsoon were lost which resulted in an incomplete dataset (Figure 89).

Mean within canopy temperature monitored at Great Keppel Island ranged from 17 – 29°C and at Gladstone harbour from18-29°C. The lowest mean temperatures across the region occurred in August and highest in December 2008. Temperatures were warmer across the region in the 08/09 monitoring period that the 07/08 period.

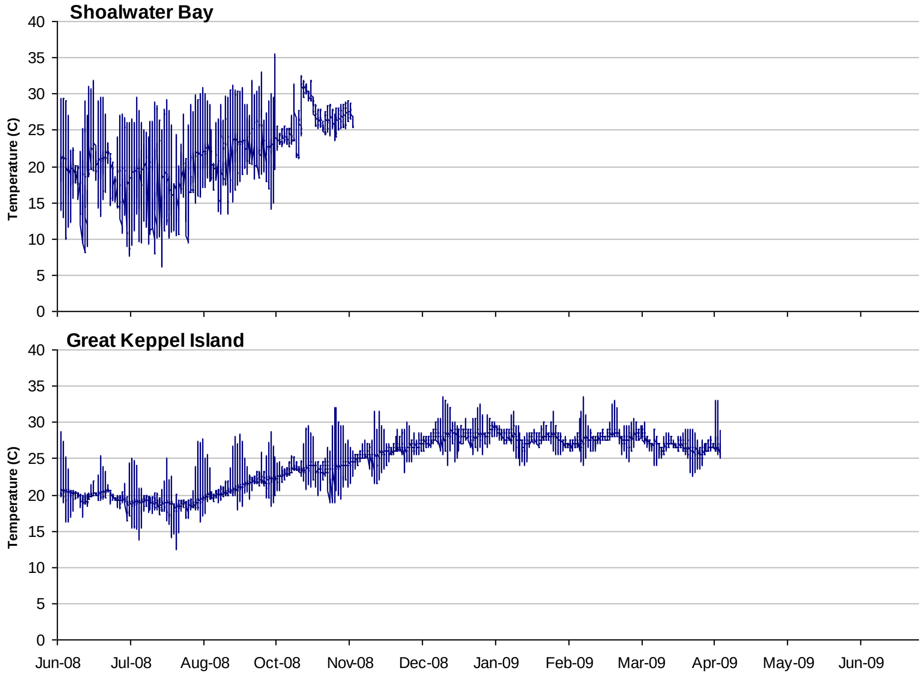


Figure 89. *Within seagrass canopy temperature (°C) at coastal (Shoalwater Bay) and offshore fringing-reef (Great Keppel Island) intertidal meadows within the Fitzroy region over the 2008/2009 monitoring period.*

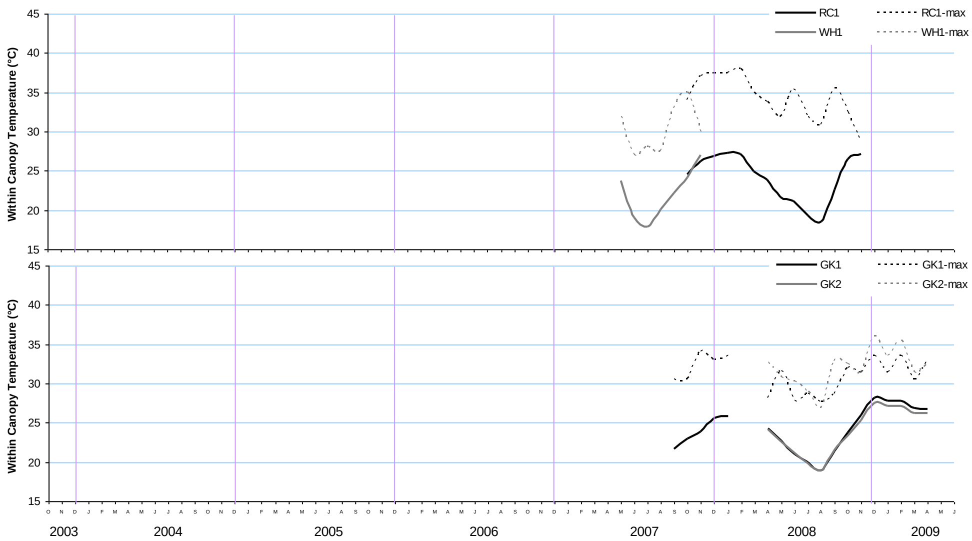


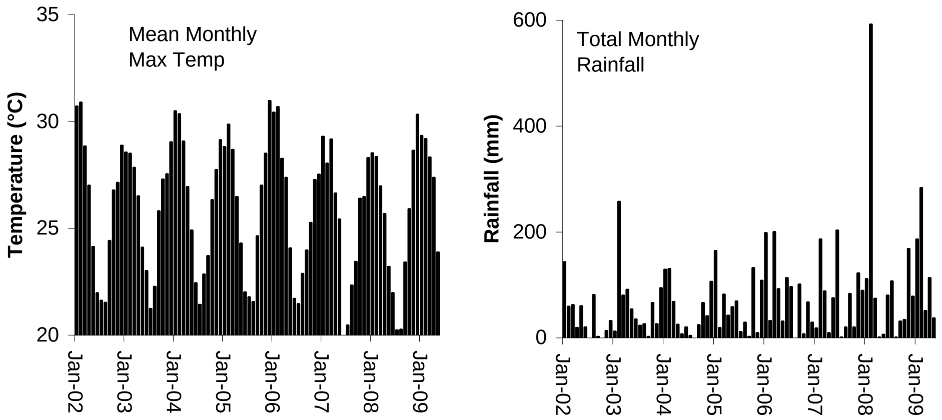
Figure 90. *Monthly mean and maximum within seagrass canopy temperature (°C) at intertidal meadows in coastal (Shoalwater Bay) and fringing-reef (Great Keppel Island) monitoring habitats within the Fitzroy region.*

Regional Climate

Yeppoon – Great Keppel Island and Shoalwater Bay

The mean maximum daily temperature recorded in Yeppoon during 2008 was 25.2°C, this was 0.4°C lower than the 30 year average, although these temperatures are close to average, this is higher than many of the recent years of the monitoring programme, specifically 2006 and 2007. Mean annual rainfall in 2008 was 1283mm; this was similar to the 30 year average, however these levels are higher than many of the recent years of the monitoring programme and relate to very high rainfall in February. No cloud cover data is available for Yeppoon.

Yeppoon - Shoalwater and Great Keppel Island Sites



Gladstone - Gladstone Harbour Sites

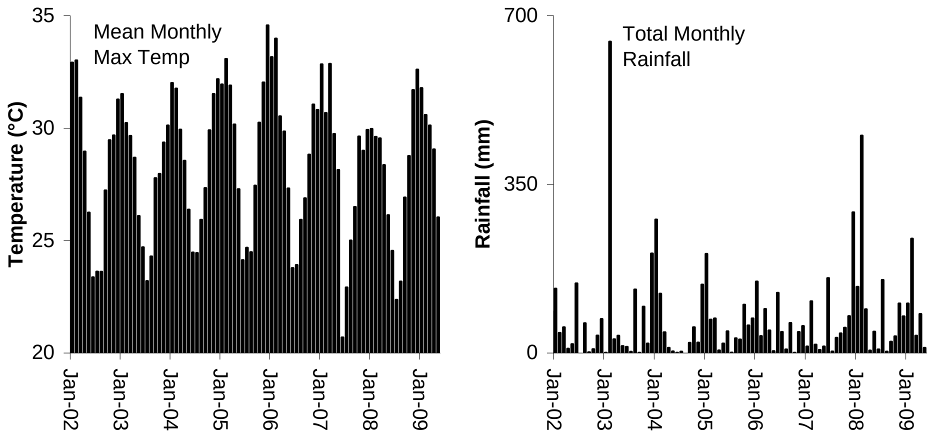


Figure 91. *Mean monthly daily maximum temperature (°C), and total monthly rainfall (mm) recorded at Yeppoon (BOM station 033106) and Gladstone Airport (BOM station 039123) (Source www.bom.gov.au). Gladstone Airport used as a surrogate for the climate at Gladstone Harbour, Yeppoon also used as a surrogate for the climate at Great Keppel Island and Shoalwater Bay.*

Gladstone – Gladstone Harbour

The mean maximum daily temperature recorded in Gladstone during 2008 was 27.8°C, this was 0.1°C higher than the 50 year average, although this temperature is close to average it is higher than during 2007. Mean annual rainfall in 2008 was 1127mm; this was 28% higher than the 50 year average, but this value is similar to many of the recent years of the monitoring programme. No cloud cover data is available for Gladstone.

Burnett Mary

2008/2009 Summary

Intertidal seagrass meadows monitored in the Burnett Mary region are in bays that are protected from the SE winds and wave action, these meadows are classified as estuarine habitats. No coastal or reef seagrasses are monitored within this NRM region. The main ecological drivers in these environments are temperature and desiccation stress, flood runoff and turbidity.

- Estuarine meadows of Urangan and Rodds Bay were dominated by *Zostera capricorni*.
- Seagrass within Urangan has undergone a long cycle of 'boom and bust', and is currently recovering from flood related loss in 2006.
- In Rodds Bay, large loss of seagrass abundance in 2009.
- Seagrass meadow area declined within both Rodds Bay and Urangan during 2009.
- Epiphytes remain variable and macro-algae stable.
- Tissue ratios of N:P ratio were unchanged and indicative of potential N limitation.
- C:N ratios indicate seagrass to be a lowlight environment within Urangan, and a moderate light environment within Rodds Bay.
- C:P ratios suggest environments to be nutrient rich.
- Sediment nutrients highly variable between years.
- No herbicides were detected in sediments during 2009 but elevated Diuron had been found at Urangan in 2006 and 2008.
- No extreme canopy temperatures (>40°C) were recorded over the last 12 months. These estuarine meadows have been subjected to elevated rainfall during both the 2008 and 2009 wet seasons.

Background

The Burnett-Mary region covers an area of 88,000km^2 and supports a population of over 257,000 people, largely in the main centres of Bundaberg, Maryborough, Gympie and Kingaroy. The region is comprised of a number of catchments including the Baffle Creek, Kolan, Burnett, Burrum and Mary Rivers (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 mouth of the Mary River.

Estuarine habitats occur in bays that are protected from the south easterly-winds and consequent wave action. The seagrasses in this area must survive pulsed events of terrestrial run-off, sediment turbidity and drops in salinity. Estuary seagrasses in the region are susceptible to temperature related threats and desiccation due to the majority being intertidal (Figure 92).

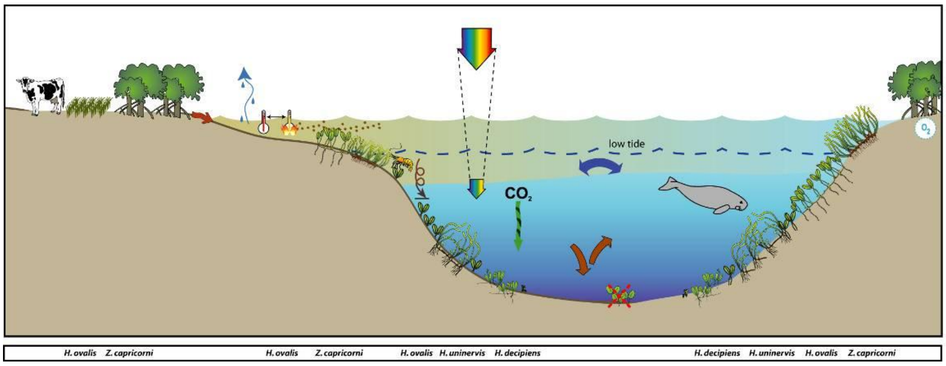


Figure 92. *Conceptual diagram of Estuary habitat in the GBRWHA section of the Burnett Mary region – major control is shelter from winds and physical disturbance: general habitat and seagrass meadow processes (See Figure 2 for icon explanation).*

Seagrass cover and species composition

The estuarine seagrass habitats in the region were dominated by *Zostera capricorni* with minor components of *Halophila ovalis* and some *Halodule uninervis* (Figure 94). The UG meadow at Urangan which has attempted to recover since it was lost in 2006, has show little improvement over the past 12 months (Figure 93). The aggregated patches of *Zostera capricorni* scattered across the intertidal banks in 2008 increased in cover in late Dry 2008 to approximately 3%, but in the late Monsoon 2009 had become more isolated with mean cover below <1% (Figure 93).

The biggest change over the past monitoring period was in Rodds Bay (RD1). Although the seagrass meadow at RD2 remains relatively unchanged, the meadow at RD1 which was more abundant in 2008 was completely absent in late Monsoon 2009 (Figure 94, Figure 93).

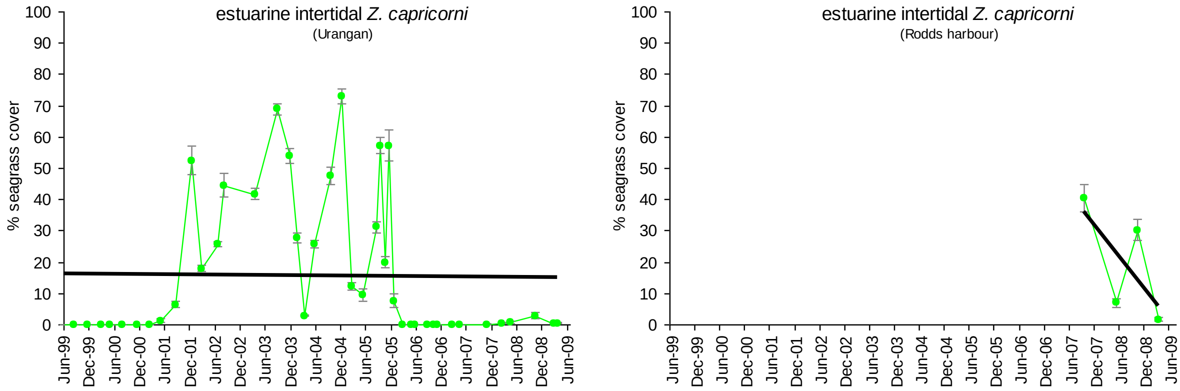


Figure 93. *Change in seagrass abundance (percentage cover ±Standard Error)) at estuarine (Urangan and Rodds Bay) intertidal seagrass meadows in Burnett Mary region.*

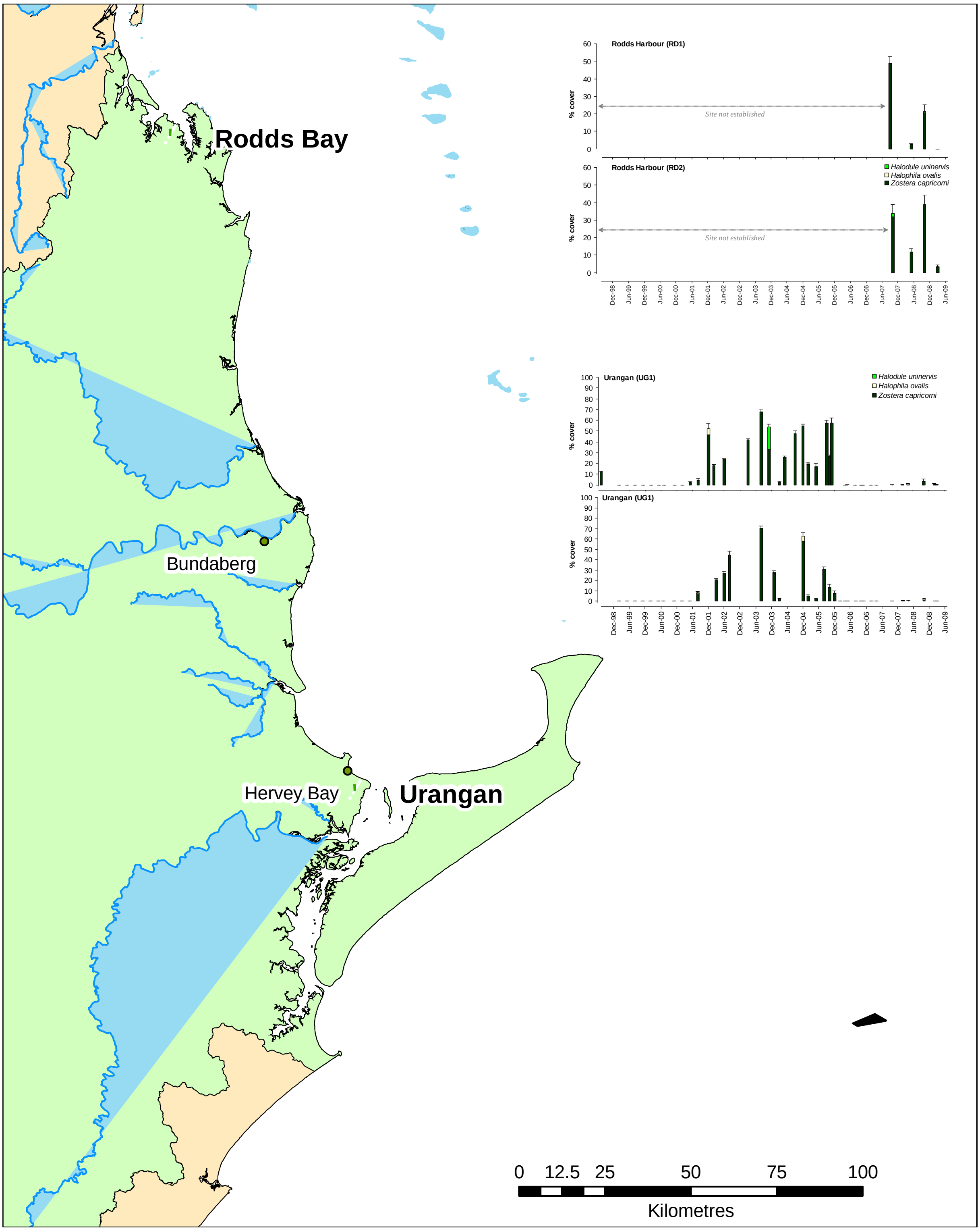
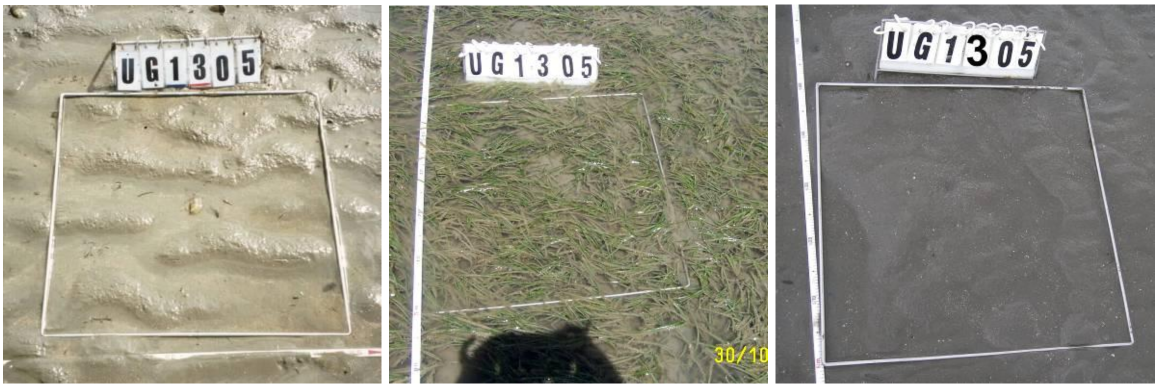


Figure 94. *Mean percentage cover for each seagrass species at Seagrass-Watch long-term monitoring sites in the Burnett Mary Region (+ Standard Error). NB: if no sampling conducted then x-axis is clear.*

Since monitored was established at this location in 1998, the Urangan meadow has come and gone on an irregular basis. It is unknown if this is a long-term pattern. Within years however, a seasonal pattern is apparent across both sites, with greater abundance in the late Dry season (Figure 95). Abundance is also significantly higher during the late Dry season in Rodds Bay, however the dataset is limited.



Quadrat at 5m on transect 3 at Urangan (UG1), on 22 November 1999 (left), 30 November 2005 (middle) and 11 October 2008 (right).

Urangan seagrass meadows at UG1 (left) and UG2 (right), 20 May 2008.

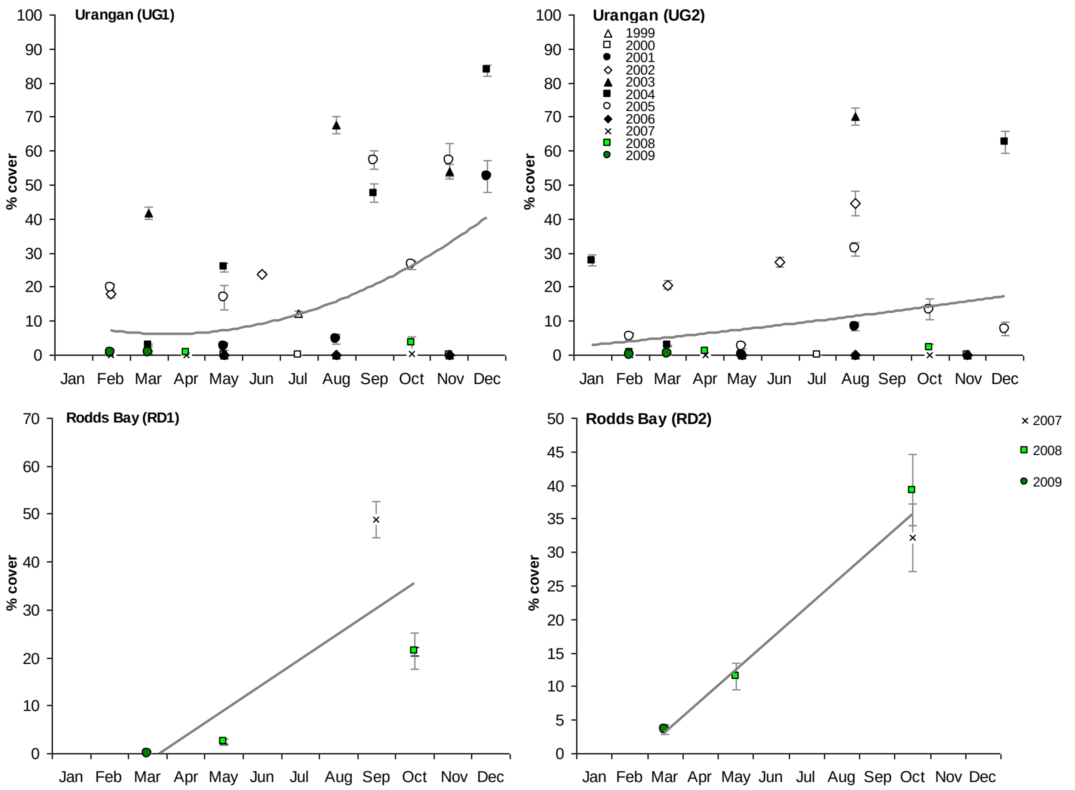


Figure 95. *Changes in above-ground biomass and distribution of estuarine intertidal Zostera meadows monitored in the Mary/Burnett region from 2002 to 2008.*

Seagrass tissue nutrients

Seagrass meadows in Rodds Bay were one of the few sites in 2008 to be defined as of a moderate light environment, with C:N values mostly above 20 (Figure 96). Levels of C:N in Rodds Bay showed no significant difference in 2008 relative to 2007. In Urangan, levels were lower and indicative of a low light environment, these levels at Urangan were higher in 2008, but remained within the variability of previous years values (*not statistically tested due to limited data from previous years*).

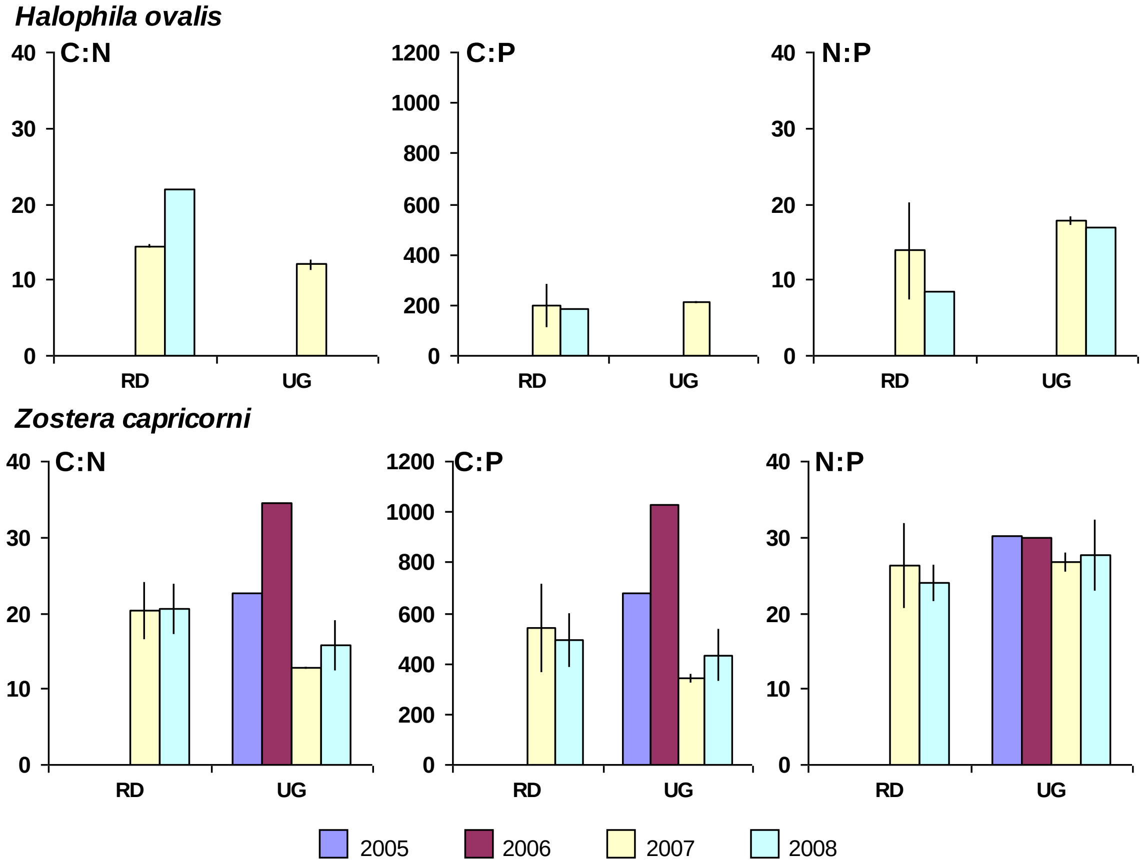


Figure 96. *Plant Tissue Ratios (a) C:N, (b) C:P and (c) N:P for Halophila ovalis and Zostera capricorni in the Burnett-Mary region at Rodds Bay (RD), and Urangan Creek (UG) (Mean and SD displayed).*

The late Dry season 2008 C:P ratios of seagrass in the Burnett Mary region were unchanged relative to 2007 (Figure 96); these were tested as having no significant difference ($p > 0.05$) at Rodds Bay, but the numbers of repeats were insufficient to test at Urangan. These levels were all below 500, indicating seagrasses with a relatively large P pool (nutrient rich). Levels of the N:P ratio were also unchanged and indicative of a replete or potentially N limited environment (Figure 96).

Seagrass meadow edge mapping

Over the last 12 months the seagrass meadows at Urangan decreased significantly (Figure 97, Table 14). Although expanding aggregated patches of seagrass were reported in the vicinity of the sampling sites during 2008, the meadow dramatically declined in late Monsoon 2009 (Table 14). The largest loss however occurred at RD1 in Rodds Bay, where the entire meadow was lost. The replicate site in Rodds Bay has remained stable in extent, similar to the 2007 baseline (Figure 97, Table 14).

Table 14. *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	October 2008	April 2009
UG1	5.266	0 *(meadow absent)*	0 *(meadow absent)*	0 *(meadow absent)*	0.003 *(-99.9%, increase overall)*	0.386 *(-92.7%, increase overall)*	0.343 *(-93.5%, negligible)*	0.044 *(-99.2%, decrease overall)*
UG2	5.326	0 *(meadow absent)*	0 *(meadow absent)*	0 *(meadow absent)*	0 *(meadow absent)*	1.559 *(-70.7%, increase overall)*	2.778 *(-47.8%, increase overall)*	0.470 *(-91.2%, decrease overall)*
RD1	*NA*	*NA*	*NA*	*NA*	0.96	1.291 *(34.5%, increase seaward)*	1.207 *(25.8%, decrease shoreward)*	0 *(meadow absent)*
RD2	*NA*	*NA*	*NA*	*NA*	3.573	3.511 *(-1.7%, decrease shoreward)*	3.618 *(1.3%, increase seaward)*	3.527 *(0.4%, negligible)*

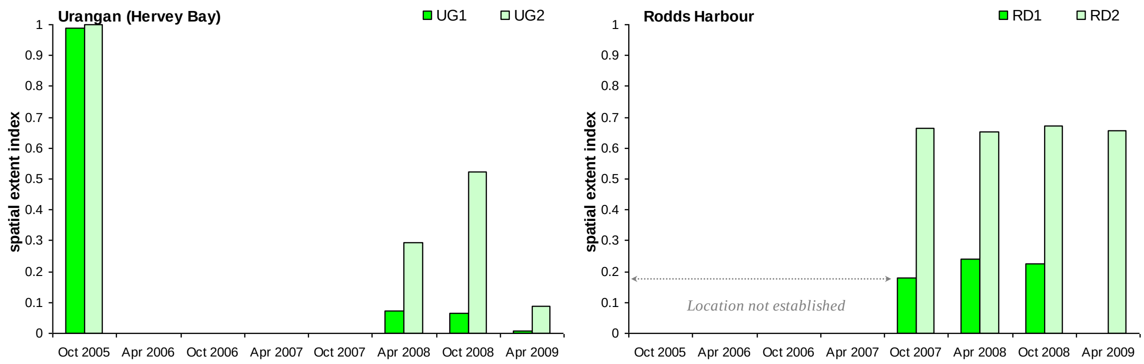


Figure 97. *Extent of area (100m radius of monitoring site) covered by seagrass at each monitoring site at Rodds Bay and Urangan locations.*

Epiphytes and Macro-algae

Epiphyte cover on the seagrass leaf blades at Urangan were highly variable over the years of monitoring and were higher in 2008 that the previous few years (Figure 98). Percentage cover of macro-algae has continued to remain low (Figure 98). Epiphyte cover and macro-alagl were similarly low in Rodds Bay (Figure 98).

Epiphytes on Zostera capricorni, Urangan (UG2), 20 May 2008.

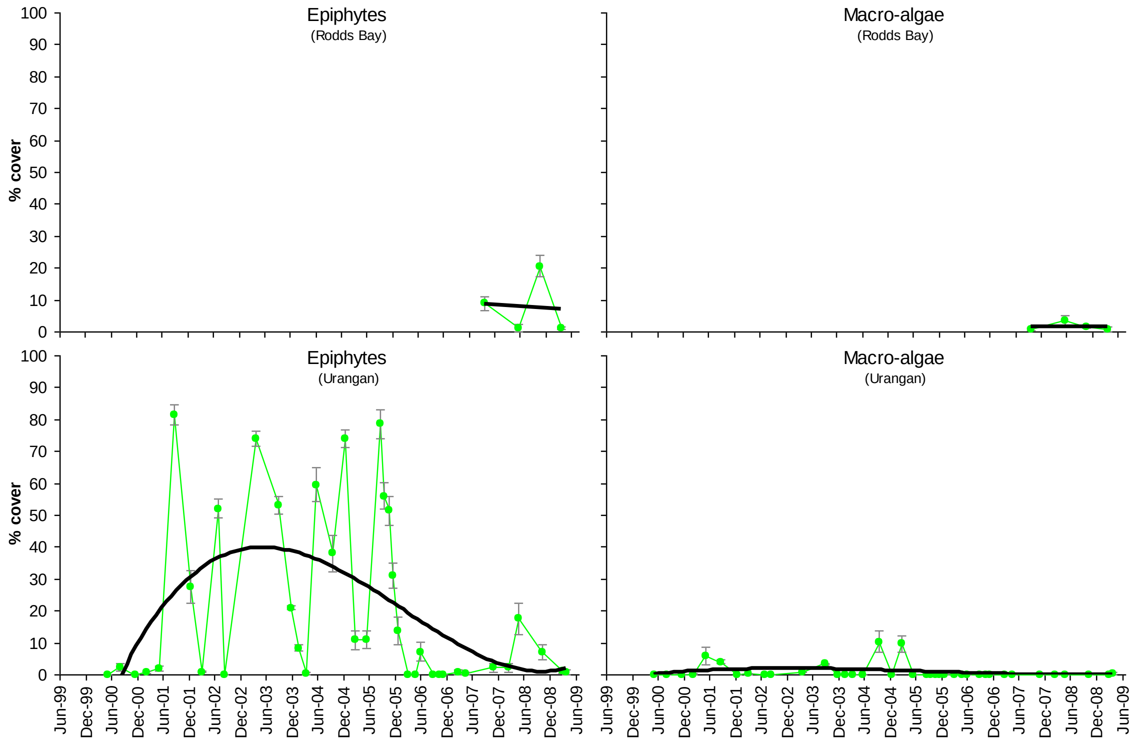


Figure 98. *Mean abundance (% cover) (± Standard Error) of epiphytes and macro-algae at intertidal estuarine (Rodds Bay and Urangan) seagrass monitoring locations. NB: Polynomial trendline for all years pooled.*

Sediment nutrients

Seagrass sediments within Urangan during 2008 were elevated in levels of both Phosphate and Ammonium relative to 2007, while sediments at Rodds Bay had declined in levels of both these nutrients. All levels observed in 2008 were within the range of previously recorded values (*data not statistically tested due to limited sample numbers within each year*).

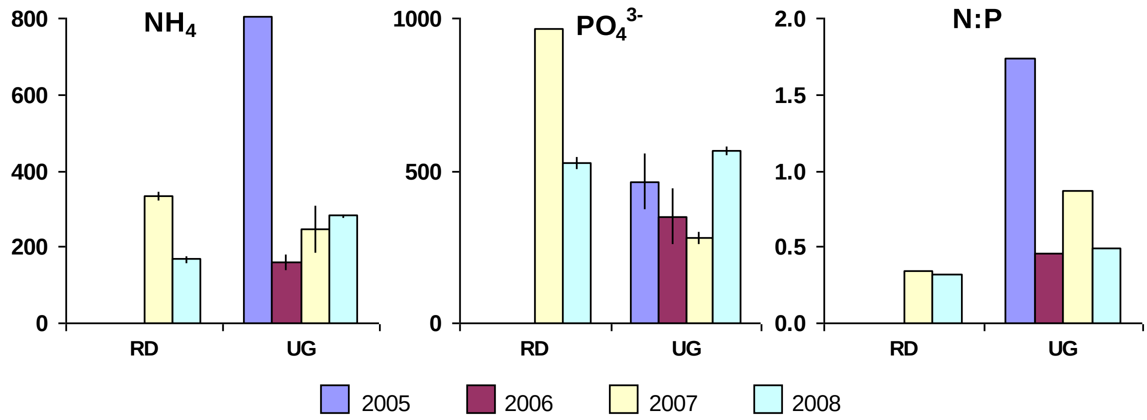


Figure 99. *Adsorbed nutrient levels within seagrass sediments of the Burnett-Mary region (ammonium (NH_4), phosphate (PO_4^{3-}), and the ratio of PO_4^{3-} to NH_4) at Rodds Bay (RD), and Urangan Creek (UG), October 2005 to October 2008. Mean and SD displayed.*

Sediment herbicides

No herbicides were found above detectable levels in the sediments of the seagrass meadows at any of the monitoring sites in post-Monsoon 2009 (Table 15).

Table 15. *Concentration of herbicides ($\mu g\ kg^{-1}$) in sediments of seagrass monitoring sites in post Monsoon 2009. ND=not detectable, <0.1 $\mu g\ kg^{-1}$*

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*	*ND*	*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 100). Although extreme temperatures (>40°C) were not recorded in the region, very high (38.1°C) within canopy temperatures were recorded at Rodds Bay in December 2008 (Figure 100).

Mean within canopy temperature monitored at Urangan was within the 15 – 28°C range, with highest mean temperatures in the December 2008 and February 2009 periods. The 2008/2009 sampling period was similar to the long-term average (Figure 101). At Rodds Bay, mean within canopy temperatures ranged from 17 - 29°C with highest mean temperatures in the December 2008 (Figure 101). Within canopy temperatures at Rodds Bay were warmer in 08/09 than previous year.

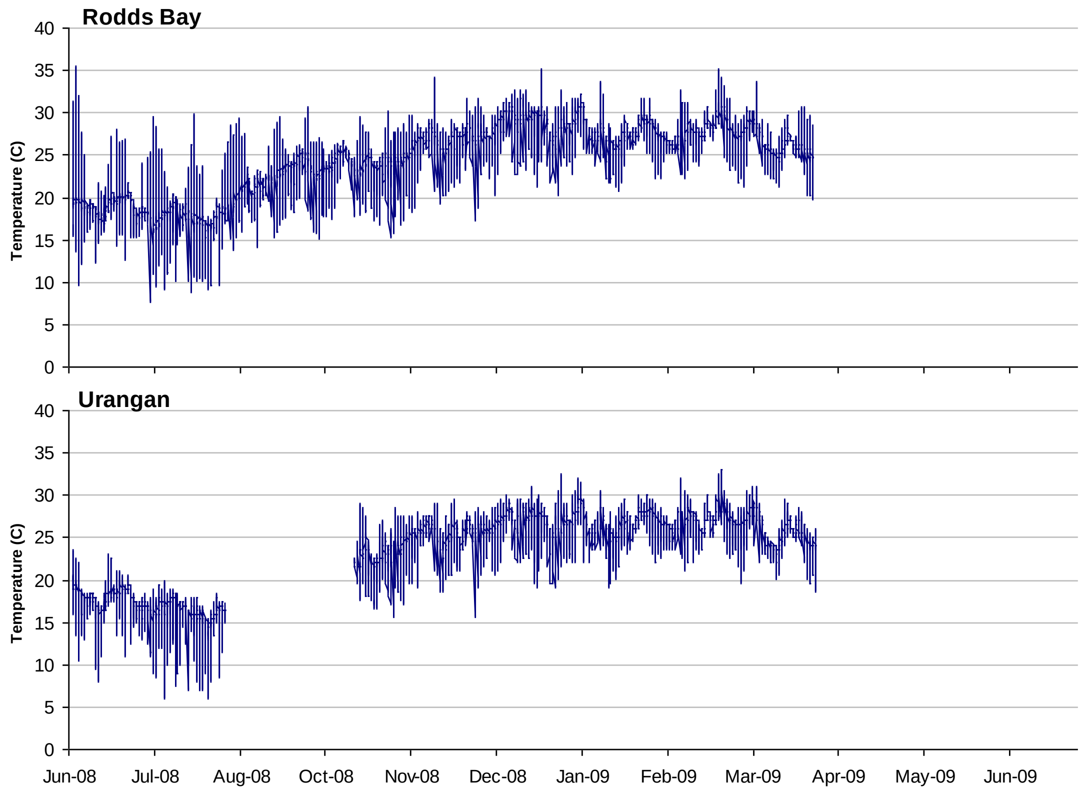


Figure 100. *Within seagrass canopy temperature (°C) at Rodds Bay and Urangan intertidal meadows over the 2008/2009 monitoring period.*

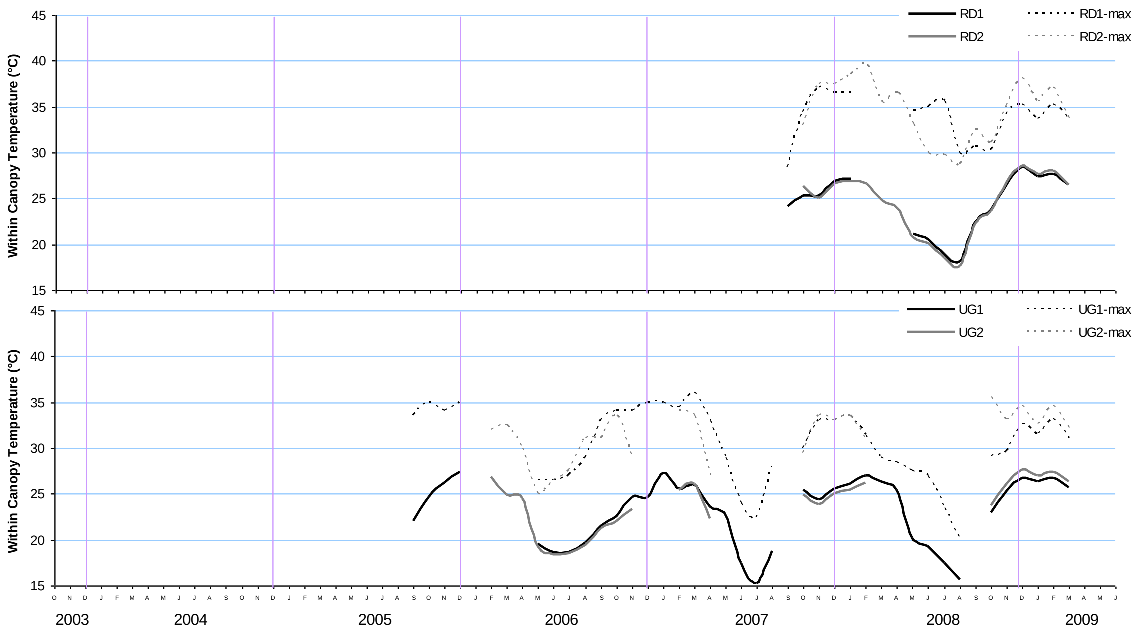
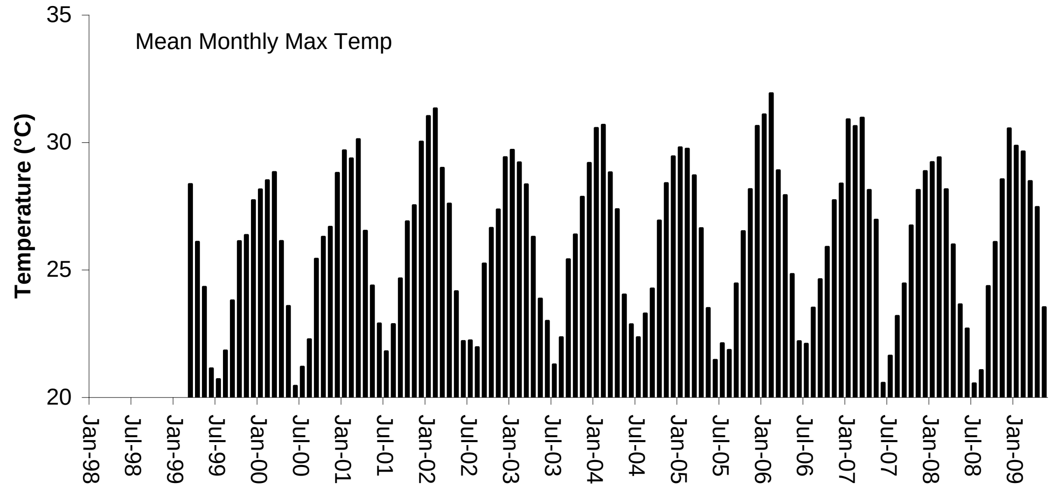


Figure 101. *Monthly mean and maximum within seagrass canopy temperature (°C) at intertidal meadows in estuarine (Rodds Bay and Urangan) monitoring habitats within the Burnett Mary region.*

Regional Climate

Hervey Bay - Urangan

The mean maximum daily temperature recorded in Hervey Bay during 2008 was 25.8°C, this was 1.1°C lower than the 100 year average. Although these levels are on average lower than the 100 year mean they are similar to recent years throughout the monitoring programme. Mean annual rainfall in 2008 was 1235mm; this was 6% higher than the 100 year average, but this value is higher than many of the recent years of the monitoring programme. No cloud cover data is available for Hervey Bay.



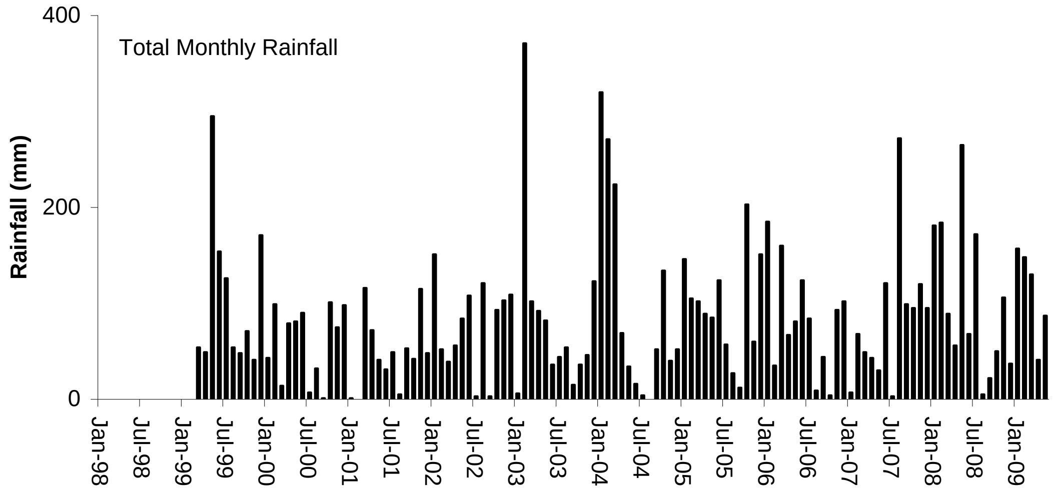


Figure 102. *Mean monthly daily maximum temperature (°C), and total monthly rainfall (mm) recorded at Hervey Bay Airport (BOM station 040405) (Source www.bom.gov.au). Hervey Bay Airport used as a surrogate for the climate at Urangan.*

Gladstone – Rodds Bay

The mean maximum daily temperature recorded in Gladstone during 2008 was 27.8°C, this was 0.1°C higher than the 50 year average, although this temperature is close to average it is higher than during 2007. Mean annual rainfall in 2008 was 1127mm; this was 28% higher than the 50 year average, but this value is similar to many of the recent years of the monitoring programme. No cloud cover data is available for Gladstone.

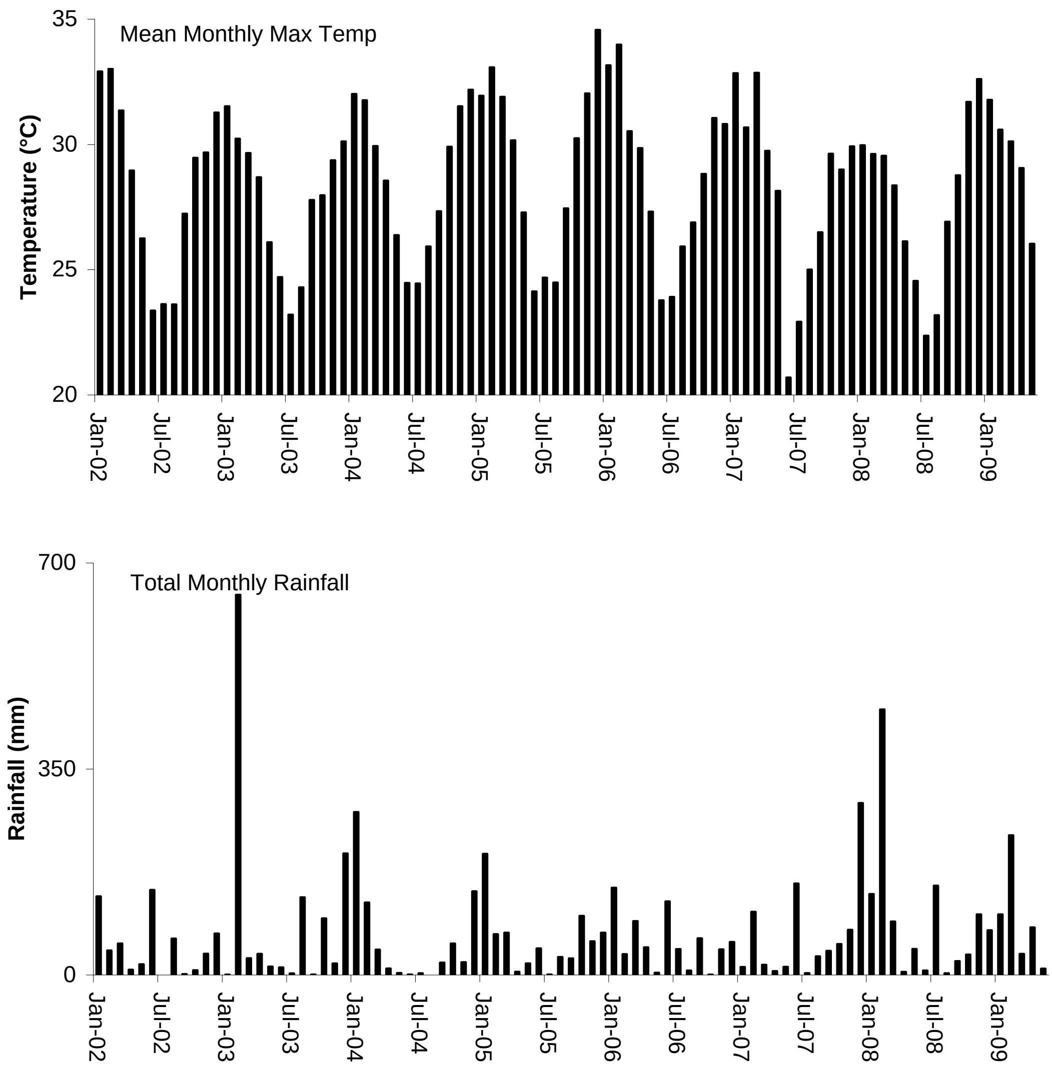


Figure 103. *Mean monthly daily maximum temperature (°C), and total monthly rainfall (mm) recorded at Gladstone Airport (BOM station 039123) (Source www.bom.gov.au). Gladstone Airport used as a surrogate for the climate at Rodds Bay.*

GBR Summary

Findings from this monitoring period indicated that inter-tidal seagrass meadows within the Great Barrier Reef World Heritage Area appear to be in a fair state in terms of seagrass abundance and composition (rating as per Campbell and McKenzie 2001b). Abundance of inter-tidal seagrasses at locations in Cape York and the Wet Tropics are stable, however locations from the Dry Tropics to the southern GBRWHA are either variable or have declined over the past 6 months. For locations which had severe losses in 2006 (eg Gladstone and Urangan) the significant increases in abundance in the late-Dry 2008 were followed by significant declines in the post-Monsoon 2009 (Table 16). Most of these declining locations have no seed reserves (Table 16), suggesting that recovery time may take around 18 months to 3 years as it will be dependent on vegetative growth and/or translocation of vegetative fragments.

The average seagrass percent cover (over the past 10 years of Seagrass-Watch monitoring) at each of the intertidal seagrass habitats within the GBRWHA are relatively similar: 20% for estuarine, 19% for coastal and 24% for reef. However the patterns of abundance over the years are very different, depending on habitat (Figure 104).

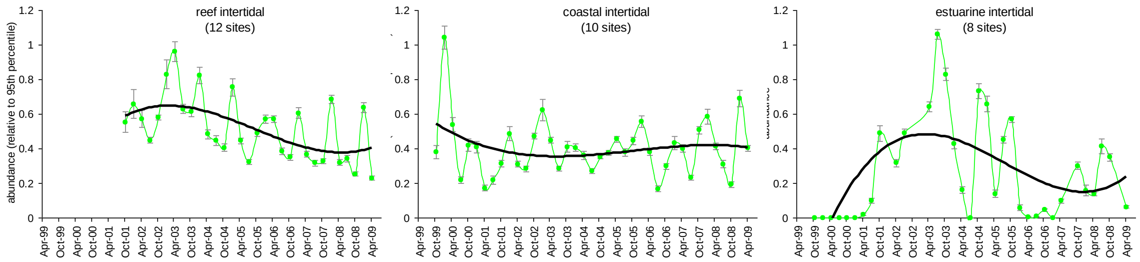


Figure 104. *Generalised trends in seagrass abundance for each habitat type (sites pooled) relative to the 95th percentile (equally scaled). The 95th percentile is calculated for each site across all data.*

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 continues to vary greatly seasonally, with significant “boom and bust” patterns (Figure 104). Abundances show a dramatic decline in late Monsoon 2009, possibly a consequence of the flooding across the regions (Figure 104). Seed banks however, have continued to decline at estuarine intertidal sites (Table 16), indicating a relatively low capacity to recover from any significant losses. Low abundances of germinated seeds suggest that increases in abundance in the 2008 growing season (Aug-Nov) were primarily the result of vegetative growth.

Table 16. *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 Oct08 – Apr09 (long term average in parenthesis). NA= insufficient data as sites established within last 12-18 months.*

NRM	Catchment	Location	% cover Long Term Average	% cover late-Dry		% cover late- Monsoon		Overall trend since late-Dry 2005				
				2008	% Difference 2008 to 2007	2009	% Difference 2009 to 2008	Seagrass Cover	Seagrass Seeds	Meadow	Epiphytes	Macro-Algae
Cape York	Endeavour	Archer Point	18.5 ±1.8	13.7 ±2.0	similar	20.6 ±3.0	>20% increase	stable	76 - 229 (138) increase	variable	19 - 14 (26) decline	3 - 1 (10) decline
Wet Tropics	Barron Russell / Mulgrave Johnstone	Yule Point	15.6 ±1.2	22.7 ±1.4	>20% increase	27.2 ±1.7	similar	increase	170 - 679 (424) increase	increase	30 -53 (20) increase	2 - 1 (2) decline
		Green Is	41.1 ±2.3	28.0 ±1.4	>20% decrease	35.9 ±1.8	similar	stable	nil	stable	27 - 63 (26) increase	3 - 4 (4) stable
	Tully – Murray	Lugger Bay	4.3 ±0.6	7.9 ±0.7	>20% increase	3.5 ±0.5	>20% decrease	variable	0 - 0 (4) variable	variable	2 (3) variable	0 (<1) stable
		Dunk Is	11.8 ±1.3	15.0 ±1.5	similar	13.9 ±14.7	similar	stable	0 - 0 (1) variable	stable	27 - 70 (25) increase	7 – 7 (6) stable
Burdekin Dry Tropics	Burdekin	Townsville	18.6 ±2.2	9.2 ±1.4	>20% decrease	5.8 ±1.2	>20% decrease	decline	2348 – 1715 (2113) stable	decline	7 - 15 (17) decline	2 - 1 (4) variable
		Magnetic Is	35.8 ±2.7	31.5 ±1.8	>20% decrease	20.5 ±2.0	>20% decrease	variable	34 - 34 (41) variable	stable	38 - 2 (42) decline	13 - 4 (7) stable
Mackay Whitsunday	Proserpine	Pioneer Bay	20.2 ±1.6	27.4 ±2.0	similar	24.1 ±1.9	>20% increase	variable	59 - 136 (247) variable	increase	4 - 20 (14) stable	1 (11) stable
		Hamilton Is*	7.3 ±1.1	7.9 ±1.3	similar	1.6 ±0.5	>20% decrease	decline	nil	variable	15 - 14 (17) decline	3 - 6 (3) stable
	Pioneer	Sarina Inlet	15.2 ±1.6	23.6 ±1.9	>20% increase	4.9 ±0.7	>20% decrease	variable	0 (41) decline	variable	68 - 2 (14) variable	<1 (2) variable
Fitzroy	Fitzroy	Shoalwater	22.6 ±1.4	26.4 ±1.3	>20% decrease	22.4 ±1.0	>20% decrease	decline	nil	stable	21 - 8 (13) stable	5 - <1 (6) decline
		Great Keppel	2.7 ±0.6	1.7 ±0.4	>20% decrease	1.1 ±0.3	>20% decrease	decline	nil	variable	17 - 22 (31) variable	7 - 1 (7) decline
	Boyne	Gladstone	17.7 ±1.2	34.6 ±1.9	>20% increase	13.1 ±0.9	>20% decrease	variable	nil	variable	45 - 6 (27) variable	<1 (17) decline
Burnett Mary	Burnett	Rodds Bay	19.9 ±2.4	30.3 ±3.4	>20% decrease	1.8 ±0.4	>20% decrease	decline	0 (2) NA	decline	21 - 1 (8) variable	2 - 1 (2) stable
	Mary	Urangan	15.6 ±1.0	2.9 ±1.0	>20% increase	0.5 ±0.2	>20% decrease	variable	nil	decline	7 - 1 (20) variable	<1 (1) stable

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, (Figure 104, Table 16). Seed banks continued to decline in 2008 until late Monsoon 2009. The decline in 2008 of the seed banks also corresponds with the increase in germinated seeds and consequently seagrass abundance.

Six reef habitat locations were monitored by the Reef Rescue MMP within the GBRWHA in the Cape York, Wet Tropics, Burdekin Dry Tropics and Mackay Whitsunday NRMs over the past 12 months. Reef habitats are more seagrass species diverse. 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 associated with continental islands or coral cays. Seagrass abundance has fluctuated at intertidal reef-platform seagrass meadows in the last eight years, but the last 4 years are lower that the previous 4 years (Figure 104). Within years, seagrass abundance fluctuates greatly between seasons.

Seed banks are very low at reef habitats compared to both estuarine and coastal intertidal habitats (Table 16). Seed abundance also appears to fluctuate greatly both within and between years, which is possibly a consequence of the species diversity with relatively low occurrence of *Halodule uninervis*.

GBR Seagrass tissue nutrients

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

Tissue nitrogen concentrations (%N and %P) have increased since monitoring began across all habitats (species pooled), however the 2005 values may be unreliable due to contamination of the samples during the grinding phase (see McKenzie *et al.* 2006a). The progressive increase in reef habitats is of particular note (Figure 105).

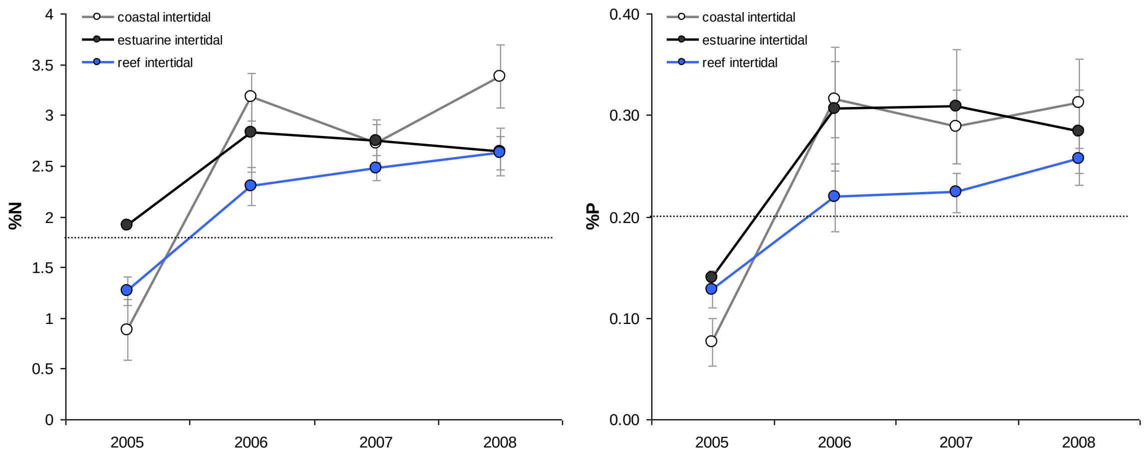


Figure 105. *Mean tissue nutrient concentrations (±95% confidence interval) in seagrass leaves for each habitat type (species pooled) over the entire monitoring program. Dashed lines indicate global threshold values of 1.8% and 0.2% for tissue nitrogen and phosphorus, respectively (Duarte 1990).*

Since 2005, mean tissue concentrations have exceeded the global threshold values of 1.8% and 0.2% for tissue nitrogen and phosphorus, respectively (Duarte 1990; Schaffelke *et al.* 2005) (Figure 106). Although some concerns have been raised as to accuracy of the global tissue nutrient values (Schaffelke *et al.* 2005), tissue concentrations in 2008 were higher than those from the same location by previous studies (Table 17).

C:N ratios <20 are indicative of low light environments. In 2008, all three habitat types (coast, reef and estuary) and species had C:N ratios <20; these levels have mostly declined since 2005, with levels of C:N within *Halophila ovalis* significantly ($F_{2,37} = 4.22$, $P<0.05$) and consistently declining from 2006 to 2008. These low C:N levels in 2008 potentially indicate reduced light availability (Figure 106).

Table 17. *The tissue nutrient values in seagrass leaves obtained in this study for were much higher than the values from the literature from the same location (italics) obtained using the same techniques (global average shaded).*

Species		%N	%P	Year (month)	Citation
H. uninervis	Lugger Bay	*4.64 ±0.27*	*0.28 ±0.01*	1994 (July)	Mellors *et al.* (2005)
		5.07 ±0.1	0.33 ±0.01	2008 (Sep)	This study
	Cape Pallarenda	*1.91*	-		Lanyon (1991)
		3.32 ±0.08	*0.32 ±0.01*	1994 (July)	Mellors *et al.* (2005)
		3.63 ±0.14	0.25 ±0.01	2008 (Sep)	This study
	Green Island	*2.4*	*0.26*		Udy *et al.* (1999)
		1.99 ±0.11	0.18±0.02	2008 (Oct)	This study
	Cockle Bay	*0.92*	*0.15*		Birch (1975)
		2.32 ±0.17	0.20±0.01	2008 (Sep)	This study
	Coastal average	4.12 ±0.17	0.29±0.02	2008	This study
	Estuarine average	2.2	0.17	2008	This study
	Reef average	2.63 ±0.14	0.22 ±0.01	2008	This study
	Global average	2.4	0.19		Duarte (1990)
H. ovalis	Cockle Bay	*0.72*	*0.16*		Birch (1975)
		2.45±0.15	0.45±0.03	2007 (Oct)	This study
	Picnic Bay	*2.36 ± 0.02*	*0.36 ± 0.19*	1994 (July)	Mellors *et al.* (2005)
		1.95±0.05	0.43±0.05	2007 (Oct)	This study
	Coastal average	3.21 ±0.22	0.49 ±0.05	2008	This study
	Estuarine average	2.57± 0.28	0.44±0.03	2008	This study
	Reef average	2.63±0.14	0.39±0.03	2008	This study
	Global average	0.7	0.18		Duarte (1990)
Z. capricorni	Coastal average	2.42±0.19	0.22±0.02	2008	This study
	Estuarine average	2.69±0.14	0.22±0.01	2008	This study
	Reef average	3.28±0.4	0.26±0.03	2008	This study
	Global average	1.5	0.26		Duarte (1990)
C. rotundata	Reef average	2.24±0.15	0.21±0.02	2008	This study
C. serrulata	Reef average	2.23±0.14	0.18±0.01	2008	This study
	Global average	1.5	0.19		Duarte (1990)
T. hemprichii	Reef average	2.48±0.19	0.19±0.01	2008	This study
	Global average	1.6	0.14		Duarte (1990)

C:P values <500 may indicate nutrient rich habitats. Such conditions were present in reef, estuary and coastal habitats for all species (except coastal *Zostera capricorni* in 2008) (Figure 106). These values have mostly decreased since 2005 indicating increasing nutrient enrichment of seagrass sediments.

Tissue N:P levels of 25-30 indicate seagrass to be nutrient replete, and potentially eutrophic. Within all species and habitats (except *Halodule uninervis* in coastal habitats) levels of N:P were below 30 in 2008, indicating potential limitation of N, and enrichment of P. Specifically within reef and estuary environments *H. uninervis* and *Zostera capricorni* were replete. Within coastal habitats these levels have consistently increased since 2005, indicating increasing levels of nitrogen enrichment. This was a significant trend of increase within *H. uninervis* ($F_{3,88}$=5.46, p<0.01) (the dominant coastal species). Within estuary and reef habitats, N:P has remained mostly unchanged between years.

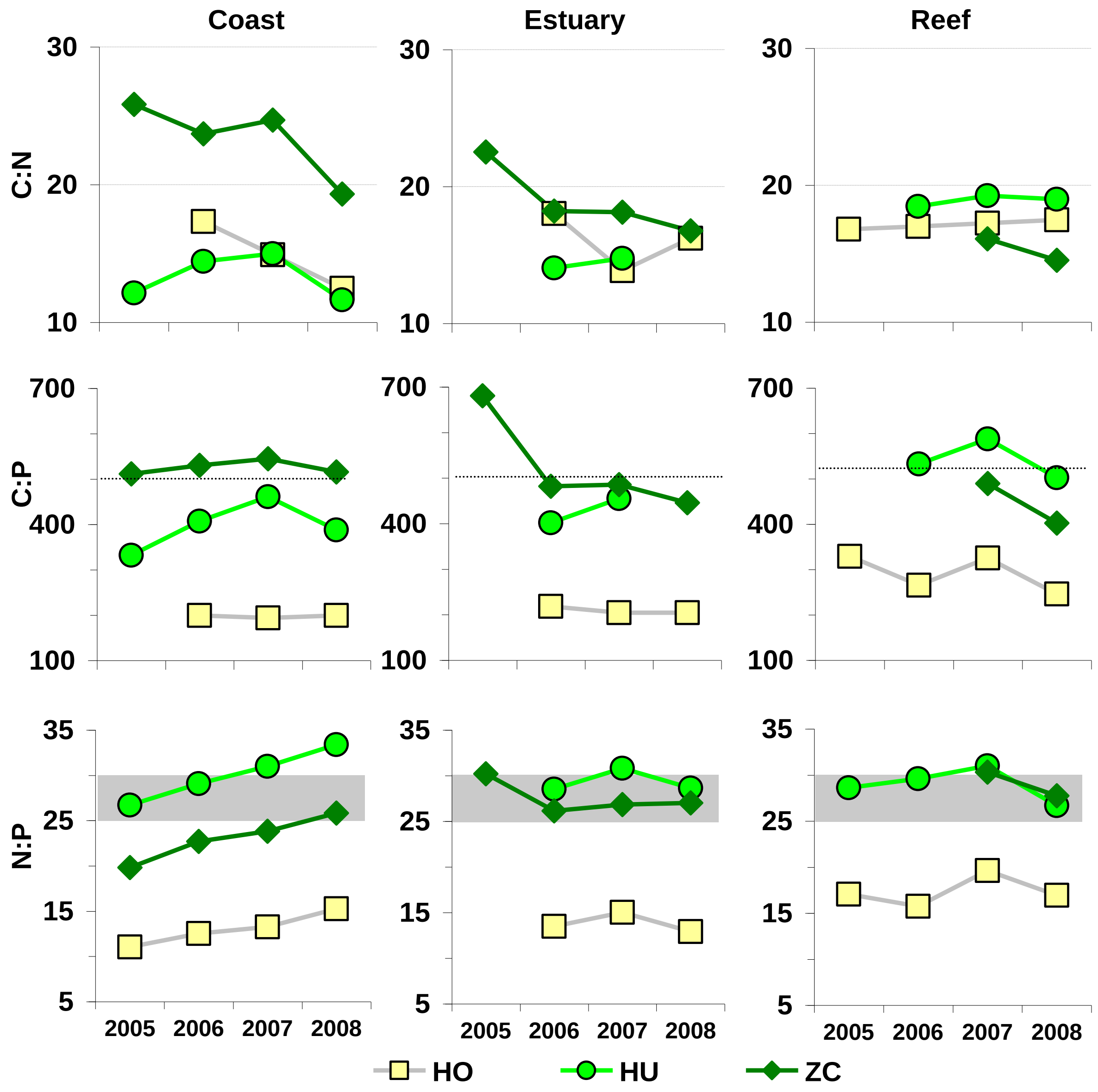


Figure 106. *Elemental ratios (atomic) of seagrass leaf tissue C:N, N:P and C:P for each habitat and targeted species each year. Horizontal shaded band on the N:P ratio panel represents the range of value associated with N:P balance ratio in the plant tissues, i.e. a seagrass "Redfield" ratio (Atkinson and Smith, 1983; Duarte, 1990; Fourqurean et al., 1992; Fourqurean & Cai 2001). N:P ratio above this band indicates P limitation and below indicates N limitation.*

Locations where seagrass are growing in generally low light environments (C:N is low), with a relatively large P pool (C:P is rich) and an even larger N pool (N:P is P limited) would indicate relatively poor water quality. Three coastal locations met these criteria in the

2008/2009 monitoring period: Lugger Bay and Yule Pt (both Wet Tropics) and Townsville (Burdekin Dry Tropics).

There exists high inter-site variability in seagrass % cover. For example, the mean seagrass at two coastal sites (Lugger Bay and Bushland Beach) in October (averaged between 2005 and 2008) is over six times higher at Bushland Beach (29.7 ± 2.7 % cover) than Lugger Bay (4.2 ± 1.4% cover). Light is the major driving factor influencing seagrass distribution and productivity, therefore as the ratio of C:N is a potential indicator of light availability these differences were investigated relative to C:N. Molar ratios of seagrass tissue carbon relative to nitrogen (C:N) show a significant polynomial relationship with seagrass cover at coastal and estuarine sites. Seagrass tissue C:N ratios between late Dry 2005 and late Dry 2008 explain 58% of the variance of the inter-site seagrass cover data (Figure 107). No relationship between % seagrass cover and tissue nutrients was observed for reef sites.

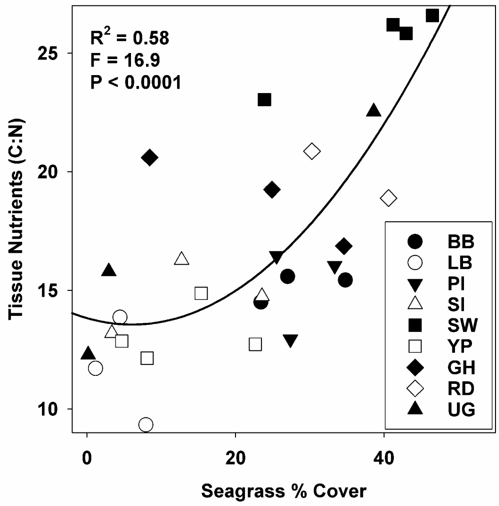


Figure 107. *Mean % seagrass cover (during October) averaged between 2005 and 2008 at coastal and estuary meadows (BB: Bushland beach, SW: Shoalwater, LB: Lugger Bay, PI: Pioneer Bay, SI: Sarina Inlet, SW: Shoalwater, YP: Yule Pt, GH: Gladstone Harbour, RD: Rodds Bay, UG: Urangan Creek) plotted relative to observed molar seagrass tissue ratios of carbon and Nitrogen (C:N). GH, RD and UG are all estuarine sites while all others are coastal.*

GBR seagrass meadow edge mapping

Intertidal seagrass meadow distribution has changed little since monitoring was established. Some localised changes have occurred (e.g. late Monsoon 2006 and 2009) and over the last 2 monitoring periods the seagrass extent has not differed significantly (Figure 108).

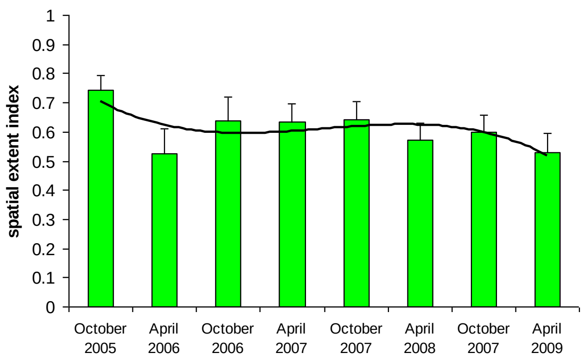


Figure 108. *Extent of seagrass meadows covering the area within 100m radius of monitoring sites (all sites pooled).*

GBR seagrass epiphytes and macro-algae

Epiphyte abundance was dependent on time of year/season for some habitats. In coastal habitats, epiphyte cover was significantly higher in the Monsoon period (ANOVA, d.f.=3, F=5.03, p=0.06), however in estuarine habitats, epiphyte cover was significantly higher in the late Dry than the late Monsoon (ANOVA, d.f.=3, F=3.53, p=0.04). At intertidal reef habitats, there was no difference in epiphyte abundance between seasons (ANOVA, d.f.=3, F=1.45, p=0.2). Generally trends in epiphyte cover are similar to seagrass abundance (Table 16), however epiphyte abundance appears to be increasing at coastal habitats (Figure 109).

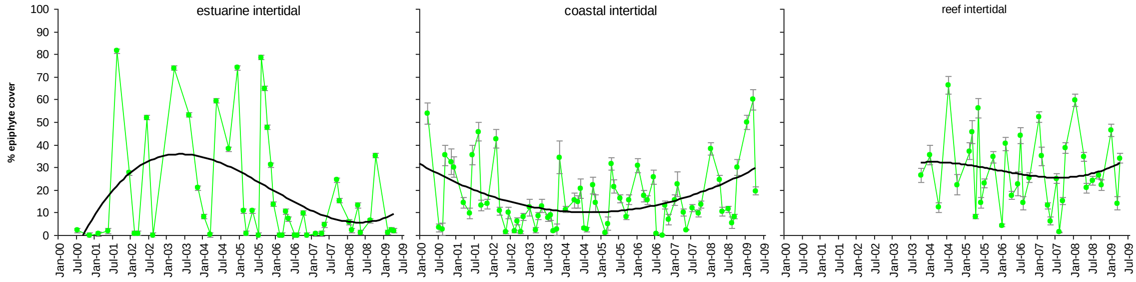


Figure 109. *Epiphyte abundance (% cover) at each seagrass habitat monitored (sites pooled) (±SE).*

Some macro-algal overgrowth was reported at monitoring sites, but abundance was not as high as for epiphytes. Since monitoring began, macro-algal abundance has remained low on average (Table 16).

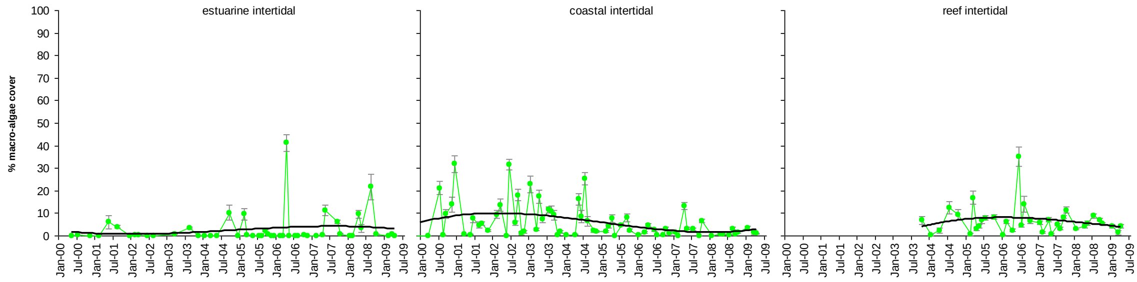


Figure 110. Macro-*algal abundance (% cover) at each seagrass habitat monitored (sites pooled) (±SE).*

Epiphytes and macro-algae fluctuate greatly at intertidal estuarine habitats and correlate highly with seagrass abundance. Epiphytes are more abundant in the Dry season (Figure 109, Figure 110), however this is also the seagrass senescent season, when plant growth and leaf turnover are low. Overall, there does not appear to be any long-term trend in abundance of either epiphytes or macro-algae.

Epiphytes and macro-algae fluctuate greatly at intertidal coastal habitats and appear more abundant in the Dry season (Figure 109, Figure 110). Overall, there appears to be an increase in epiphytes over the last 2-3 years.

Although epiphyte abundances fluctuate within and between years at intertidal reef habitats, abundance has continued to increase over the past 9 years (Figure 109). Macro-algae abundance however has remained low and relatively stable (Figure 110). .

GBR seagrass sediment nutrients

Sediment rhizosphere nutrient concentrations were extremely variable between years, both across locations and within locations between years. By pooling locations across habitat types, some trends are apparent (Figure 111). Changes in Ammonium between years have not been consistent between habitats; in 2008 concentrations were highest within Reef environments, while in 2007 they were highest within Coastal meadows. In Estuary environments, Ammonium levels have declined since the last monitoring period at Coastal and Estuarine habitats, but remain within the levels of the variability of previous years (Figure 111). Similarly, Ammonium levels have increase since the last monitoring period at Reef habitats, but remain within the levels of the variability of previous years.

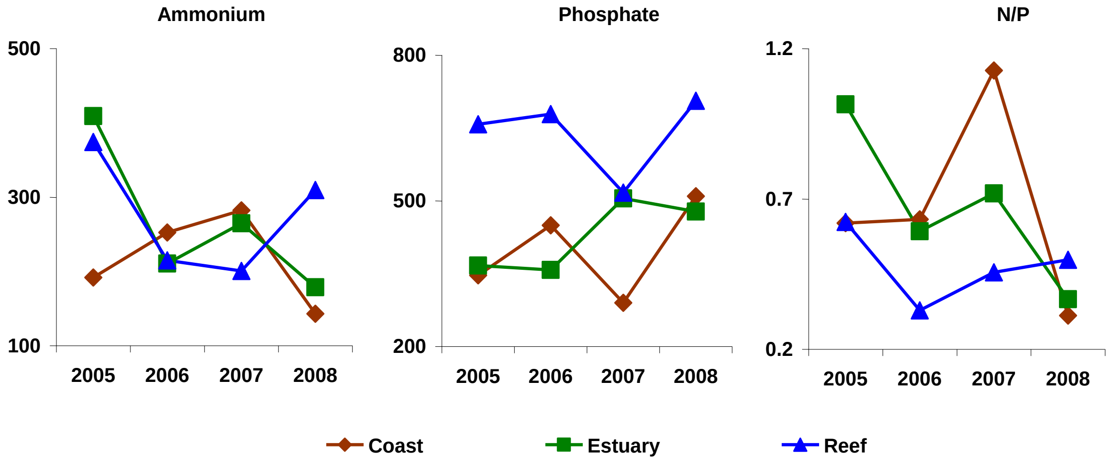


Figure 111. *Adsorbed seagrass sediment nutrient concentrations for each habitat type each year*.

Sediment rhizosphere Phosphate levels were high in 2008 within all habitats relative to previous years; this was highest within reef habitats. Reef and coastal sediment phosphate levels have both followed a similar trend of inter-annual fluctuations, with lowest levels recorded in 2007, and highest in 2008 (Figure 111). Estuary habitats have varied differently between years, with levels unchanged between 2007 and 2008, but elevated relative to 2005 and 2006.

N:P ratios in late Dry 2008 within coastal and estuary habitats were low relative to previous years (Figure 111). N:P ratios with these habitats have mostly declined since 2005, indicating these meadows have become richer in P relative to N. In reef environments the N:P ratio has increased since 2006, and in 2008 had a higher ratio than coastal and estuary habitats.

GBR seagrass sediment herbicides

None of the thirteen herbicides (organics) analysed were found above detectable limits in the sediments of the seagrass monitoring sites during the post Monsoon 2009 (Figure 112).

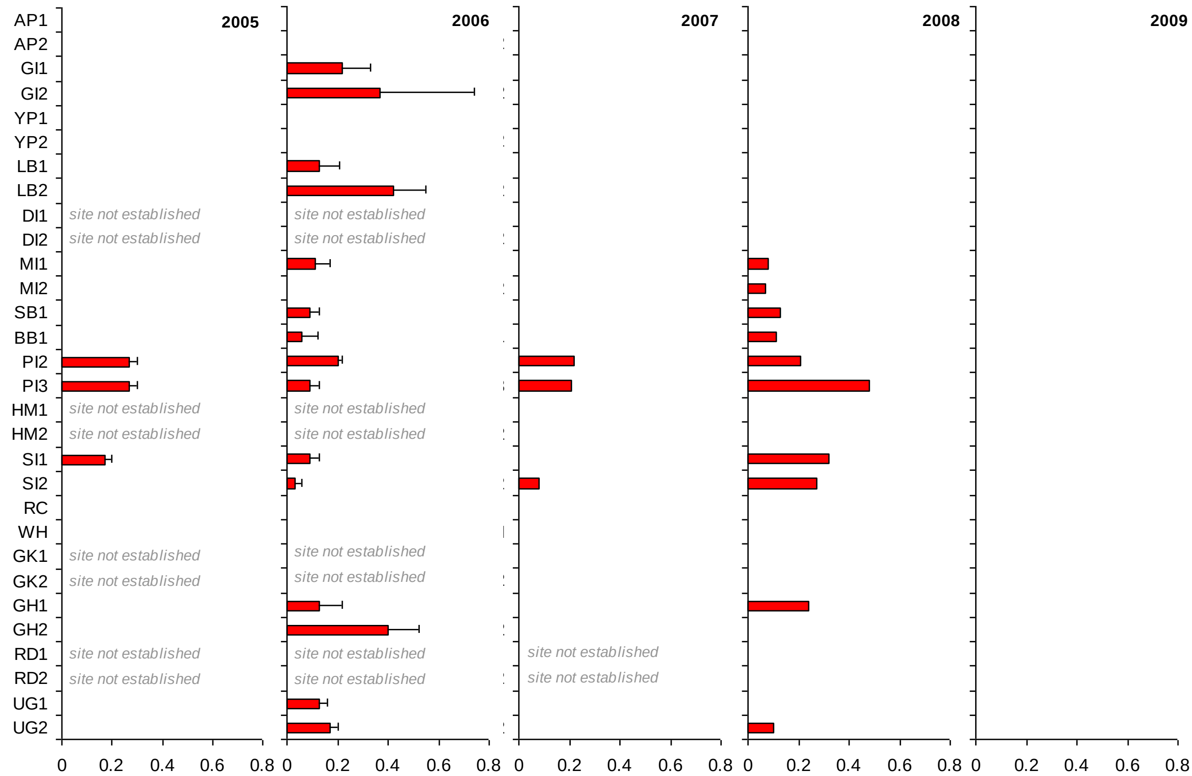


Figure 112. *Concentration of Diuron (µg/kg DW) in sediments of intertidal monitoring sites during the late Monsoon.*

4. Discussion

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

ANNEX (Annual Network Nutrient EXport) modelling indicates that in many rivers, loads of total nitrogen and total phosphorus may have increased by factors of 2–5, and 2–10, since European settlement (Brodie et al 2008). Current data indicates that most terrestrially-derived nutrients delivered into the GBRWHA are, in the long-term, restricted mainly to the coastal zone (Alongi and McKinnon 2005). River exports are equal to 40–80% of C, 13–30% of N and 2–5% of P mineralised by the GBRWHA benthos (Alongi and McKinnon 2005).

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

In seagrass ecosystems, nutrients and light are the most common limiting factors that control abundance and these factors are interrelated. Low nutrient, oligotrophic systems tend to have high light availability reaching the benthos, while high nutrient, eutrophic ecosystems have little light reaching the benthos (Johnson *et al.* 2006). Monitoring of C:N:P ratios may be advantageous for the early detection of changes in nutrient regimes for environmentally sensitive seagrasses (Johnson *et al.* 2006).

One important finding from the reporting period is that seagrass tissue elemental (C:N:P) data from coastal habitats in the Wet and Dry Tropics (Yule Point, Lugger Bay and Townsville) indicates that the environment is low light and saturated with Nitrogen. Over the past 4 years of monitoring, Nitrogen in these habitats has shown an increasing trend (significant for one dominant species).

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

Flood plume modelling estimates that Yule Point is within a zone impacted yearly (Devlin *et al.* 2001). The major river impacting Yule Point would be the Barron. The Barron River discharges $0.1x10^6$ tonnes of fine sediment, 70 tonnes of phosphorus and 500 tonnes of nitrogen per year (from Table 1 *in* Brodie *et al.* 2009). During major flood events, plumes from the Mulgrave-Russell and Johnstone Rivers could also impact Yule Point. The Mulgrave-Russell discharges $0.21\ x10^6$ tonnes of fine sediment, 320 tonnes of phosphorus and 2200 tonnes of nitrogen per year (Brodie *et al.* 2009). The Johnstone discharges $0.26\ x10^6$ tonnes of fine sediment, 580 tonnes of phosphorus and 2,250 tonnes of nitrogen per year (Brodie *et al.* 2009).

In the southern section of the Wet Tropics, the coastal seagrass meadows of Lugger Bay would be influenced primarily by the Tully and Murray Rivers (approximately 8 km and 15 km south of Lugger Bay respectively) (Devlin and Schaffelke 2009). Both the Tully and Murray Rivers have been labelled as medium/high risk to inshore areas by the Great Barrier Reef Marine Park Authority (GBRMPA 2001). Of the two rivers, the Tully is the largest with an annual discharge of $0.12x10^6$ tonnes of fine sediment, 125 tonnes of phosphorus and 1,300 tonnes of nitrogen (Brodie *et al.* 2009). The smaller river, the Murray, discharges $0.05x10^6$ tonnes of fine sediment, 58 tonnes of phosphorus and, 620 tonnes of nitrogen per year (Brodie *et al.* 2009). The largest river in the region is the Herbert River, which is 60 km to the south and discharges $0.54\ x10^6$ tonnes of fine sediment, 250 tonnes of phosphorus and 1,900 tonnes of nitrogen (Brodie *et al.* 2009).

Tissue elemental N:P ratios have progressively increased at Lugger Bay since the MMP was established in 2005. Over this time, *H. uninervis* has changed from replete to P-limited; indicating elevated available Nitrogen in the environment. Although the values in the 08/09 monitoring period were the highest record since 2005, they remain lower than value reported in 1994 by Mellors (2003) at the same location.

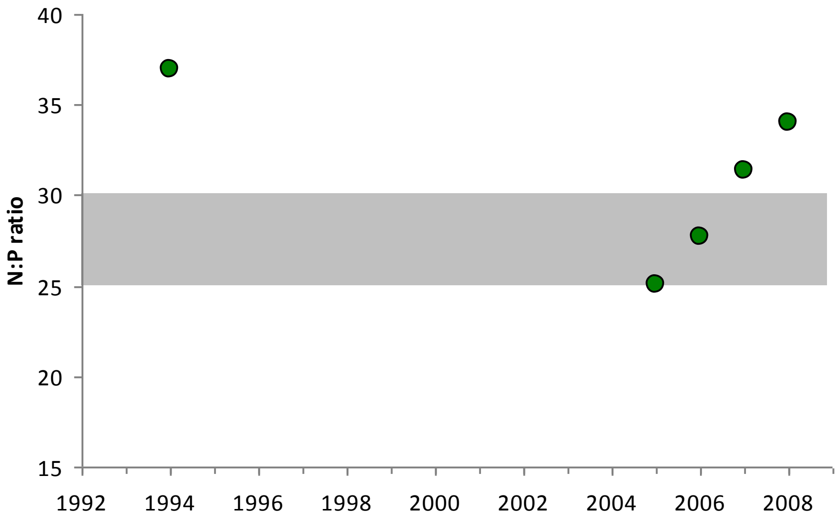


Figure 113. *Elemental ratios (atomic) of seagrass leaf tissue N:P reported from Lugger Bay in July 1994 (Mellors 2003) and the present monitoring program. Horizontal shaded band on the N:P ratio panel represents the range of value associated with N:P balance ratio in the plant tissues, i.e. a seagrass "Redfield" ratio (Atkinson and Smith, 1983; Duarte, 1990; Fourqurean et al., 1992; Fourqurean & Cai 2001). N:P ratio above this band indicates P limitation and below indicates N limitation.*

Devlin and Schaffelke (2009) reported that approximately 93% of seagrass meadows within the Tully marine area were inundated every year by primary flood plumes, exposing the seagrass to intermittently high sediment and high nutrient concentrations and potentially high loads of sedimenting particles. Lugger Bay and Dunk Island are also located within the modelled diuron (0.1-0.9 µg/l) first flush plume zone for the Tully-Murray Rivers (Lewis *et al.* 2009). Although no herbicides were present in seagrass sediments in the 2008/2009 monitoring period, they have been reported previous from Lugger Bay in April 2006 (McKenzie *et al.* 2006a). Herbicides have never been reported from seagrass sediments on Dunk Island, however monitoring was not established at this location until late Dry 2006.

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 (Ralph *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. 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). 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 ~10 µg 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 µg kg^{-1}. 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).

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

The Burdekin River has the largest annual exports of sediment, phosphorus and nitrogen of any catchment in the GBRWHA, with an annual discharge of 4.6×10^{6} tonnes of fine sediment, 2,030 tonnes of phosphorus and 12,100 tonnes of nitrogen (Brodie *et al.* 2009). During episodic flooding, high concentrations of dissolved nutrients are experienced off Townsville and in Bowling Green Bay, up to 50 km north of the Burdekin River mouth, for periods of up to three weeks (Maughan *et al.* 2008).

Tissue elemental N:P ratios have consistently increased at Cape Pallarenda for the dominant seagrass species since the MMP was established in 2006. In mid 1994, *H. uninervis* at Cape Pallarenda was reported by Mellors (2003) to be N-limited, however since 2006 it has been P-limited, indicating elevated available Nitrogen (Figure 114).

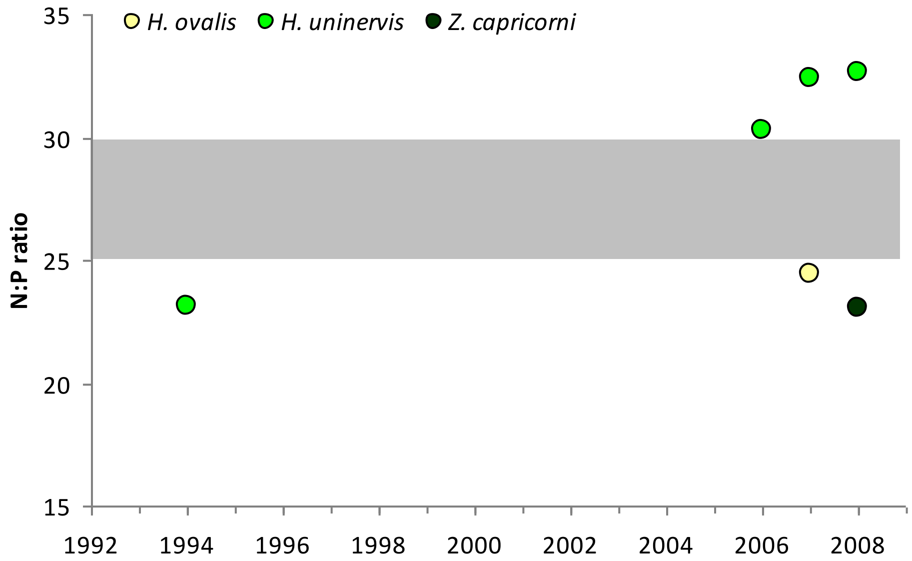


Figure 114. *Elemental ratios (atomic) of seagrass leaf tissue N:P reported from Cape Pallarenda (Townsville coast) in July 1994 (Mellors 2003) and the present monitoring program. Horizontal shaded band on the N:P ratio panel represents the range of value associated with N:P balance ratio in the plant tissues, i.e. a seagrass "Redfield" ratio. N:P ratio above this band indicates P limitation and below indicates N limitation.*

Although coastal seagrass habitats within the Wet and Dry Tropics have exceeded thresholds indicating poor water quality, mid-shelf reefs within the regions also suggest declining water quality. Water discharging from rivers in the Wet and Dry Tropics not only travel north, but during flooding events can reach the mid-shelf reefs of Green Island and Magnetic Island (Maughan *et al.* 2008).

At Green Island in the Wet Tropics, elemental ratios (atomic) of seagrass leaf tissue N:P have increased significantly over the past 15 years, although they were lower in Dry 2008 than 2007 (Figure 115). The only species which does not appear to have significantly increased is

Halophila ovalis. Seagrass at this location was considered N-limited in the early 1990s (Udy *et al.* 1999) but is now becoming P-limited (Figure 115).

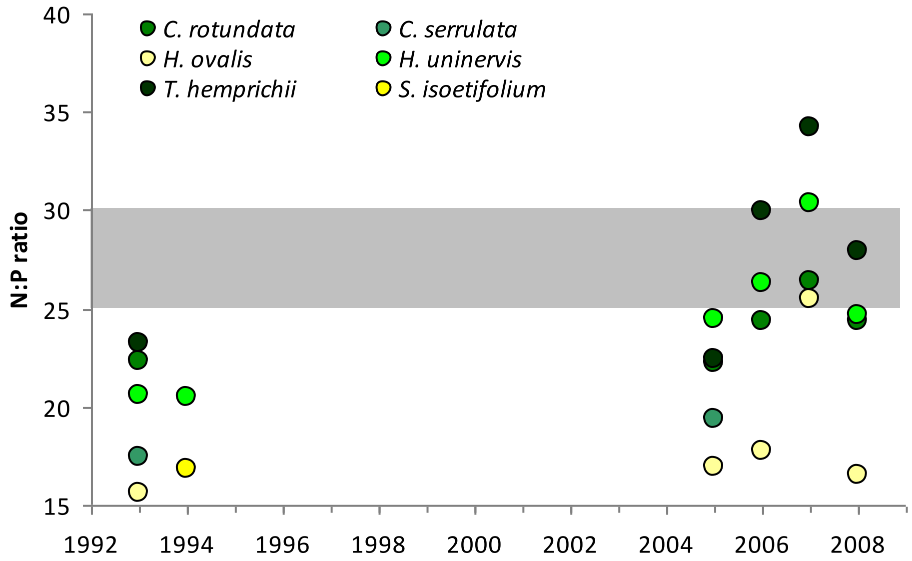


Figure 115. *Elemental ratios (atomic) of seagrass leaf tissue N:P reported from Green Island in 1993 (FQ unpublished data), 1994 (recalculated from Udy et al 1999) and the present monitoring program. Horizontal shaded band on the N:P ratio panel represents the range of value associated with N:P balance ratio in the plant tissues, i.e. a seagrass "Redfield" ratio. N:P ratio above this band indicates P limitation and below indicates N limitation.*

In the Dry Tropics, tissue elemental N:P ratios have increased at Cockle Bay (Magnetic Island) over the past 40 years. Over this time, *H. uninervis* has changed from N-limited to more replete; indicating elevated available Nitrogen in the environment. Although the values in the 08/09 monitoring period were the highest recorded since 2005, they remain lower than value reported in 1994 by Mellors (2003) at the same location (Figure 116).

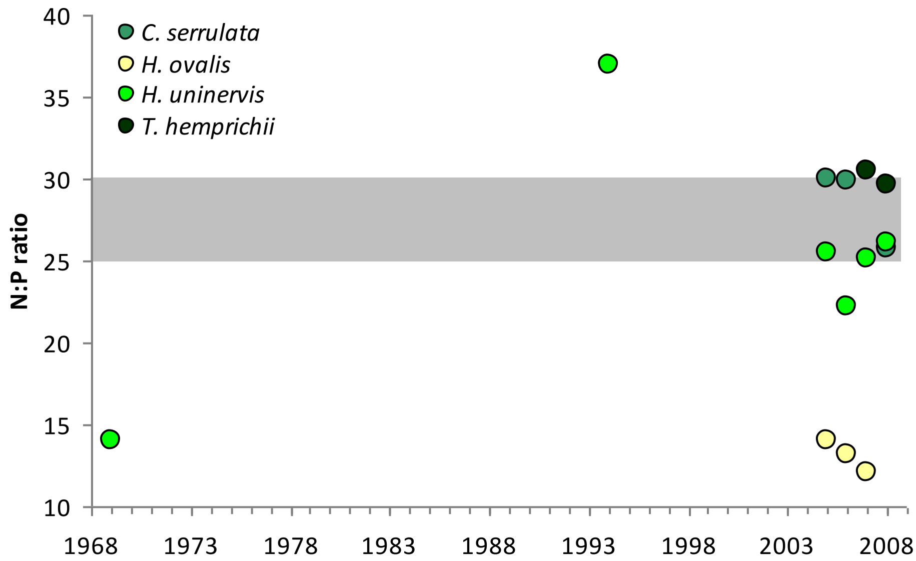


Figure 116. *Elemental ratios (atomic) of seagrass leaf tissue N:P reported from Cockle Bay (Magnetic Island) in 1968 (Brich 1975), July 1994 (Mellors 2003) and the present monitoring program. Horizontal shaded band represents the range of value associated with*

N:P balance ratio in the plant tissues, i.e. a seagrass "Redfield" ratio. N:P ratio above this band indicates P limitation and below indicates N limitation.

The consequences of degraded water quality (low light, elevated N) reported at some seagrass locations in this study are unclear. Although little is known about the physiological mechanisms that control seagrass responses to nutrient enrichment, increased growth is generally expected until light interactions result in seagrass decline (Touchette and Burkholder, 2000; Burkholder *et al.* 2007). Seagrasses also respond at the meadow scale to nutrient enrichment. Shifts in seagrass dominance as a consequence of nutrient enrichment have been reported in tropical seagrasses, where species with higher elemental requirements have a competitive advantage (Fourqurean *et al*. 1995; Burkholder *et al.* 2007). Elevated nutrient content of plants can also increase rates of herbivory. For example, Boyer *et al*. (2004) reported nutrient enrichment increased consumption by 30%. Grazing by macro-herbivores (dugong, green sea turtle), has a significant impact on the structure of seagrass communities in northern Australia (Carruthers *et al*. 2002)

Seagrasses also respond to light limitation at the plant (eg pigment content, leaf morphology) and meadow scales (eg distribution and species composition) (Ralph *et al.* 2007). As minimum light requirements for seagrasses are generally species specific, species better adapted to low light would be competitively advantaged by lower light environments (Ralph *et al.* 2007). However, seagrasses will only persist until light conditions are insufficient to maintain a positive carbon balance, leading to a decline in seagrass growth and distribution (Ralph *et al.* 2007). The threshold at which this occurs is currently being investigated as part of a collaborative research project through the MTSRF.

5. Conclusions

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

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. Of concern is the findings from seagrass tissue elemental (C:N:P) data, in particular the indication of less light and consistent increases in tissue Nitrogen in Wet and Dry Tropic coastal and mid-shelf reef habitats. Continued monitoring is important to measure if the trends abate and possibly reverse, indicating water quality and aquatic health has improved.

The seagrass monitoring component of the Reef Rescue 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.

6. References

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