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Port of Karumba Long Term Seagrass Monitoring

October 2008

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DPI&F Publication PR09–4227

Queensland Government
Department of Primary Industries and Fisheries

Ports Corporation of Queensland

Publication No. PR09-4227

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PR09-4227

First published in 2009

This publication has been produced by:

Marine Ecology Group
Northern Fisheries Centre
PO Box 5396
Cairns, QLD, 4870, Australia

The correct citation of the following document is:

Unsworth, R.K.F., McKenna, S.A. and Rasheed, M.A. (2009). Port of Karumba Long Term Seagrass Monitoring, October 2008. DPI&F Publication PR09–4227 (DPI&F, Northern Fisheries Centre, Cairns) 25 pp.

Acknowledgements

This project was funded by the Ports Corporation of Queensland Limited and the Queensland Department of Primary Industries and Fisheries.

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EXECUTIVE SUMMARY

Seagrass habitats are valuable fisheries resources that provide critical ecological functions within the coastal zone. The wide distribution of seagrasses in Queensland and their capacity to show measurable, short-term responses to changes in water quality, make them ideal candidates for monitoring the health of marine and coastal environments.

A network of long term seagrass monitoring sites has been established at various port locations throughout Queensland to assist port managers in the planning and development of port operations to achieve minimal impacts on the marine environment and fish habitats. The programs are also used as an indicator of the overall marine environmental health of ports and are an example of international best practice in the management of port environments.

This report details the latest findings of the Port of Karumba long-term seagrass monitoring program incorporating data from the most recent survey conducted in October 2008. The Karumba monitoring program aims to ensure port activities have a minimal impact on seagrasses. It is also used to provide a measure of the marine environmental health of the port.

Results of the 2008 monitoring find seagrass in Karumba to be in a healthy state, supporting dugong populations and providing a fisheries resource. Inter-annual variation in seagrass meadow area and density (i.e. biomass) continues to be large. Here we report strong evidence to suggest that throughout 15 years of monitoring seagrass variability has not been caused by local anthropogenic factors. Inter-tidal seagrass meadows in Karumba are thought to be principally driven by atmospheric temperature, tidal exposure and catchment rainfall.

In conclusion, this survey indicates that human activities in Karumba, including dredging and other port and urban activities were unlikely to have had a significant impact on seagrasses in the area, and that the marine environment of the port was in a healthy condition.

INTRODUCTION

Consultancy Brief

The Ports Corporation of Queensland Limited (PCQ) is the port authority for the Port of Karumba. PCQ has identified seagrass meadows as an important component of Karumba's marine ecology. Maintenance dredging of the Karumba port entrance and Norman River channel is required to allow the passage of ships associated with the Zinnifex Century Mine Export Facility (Lead and Zinc), and for live cattle export. PCQ is responsible for dredging in the port.

A six year (1994-2000) seagrass monitoring program was commissioned by PCQ as part of a wider range of environmental studies to assess and monitor the impacts of dredging and other port developments (Rasheed *et al.* 2001). Following the initial seagrass monitoring program, a long term seagrass monitoring (LTSM) strategy for the Port of Karumba was developed. This current survey is the eighth of the planned annual LTSM events funded by the PCQ and Department of Primary Industries and Fisheries (DPI&F), and is the 15th year that annual seagrass monitoring in Karumba has taken place. For the 2008 survey the following objectives were set:

➊ Monitor the seagrass species composition and abundance of the two seagrass meadows identified for monitoring on Alligator Bank between the Norman and Bynoe Rivers;

➋ Assess changes in seagrass meadows that have been measured since the baseline and monitoring programs were established.

Results of the seagrass monitoring program are used by PCQ to help identify any possible detrimental effects of port operations and developments (e.g. dredging) on seagrasses and assist in formulating management measures for the port. The program also forms part of DPI&F's network of long term monitoring sites for important fish habitats.

BACKGROUND & METHODOLOGY

A survey of seagrass monitoring meadows in the Port of Karumba was conducted between 21st – 23rd October 2008. The two meadows selected for monitoring (Core and Fringing meadows) were based on the previous seagrass monitoring program for the Port of Karumba (Rasheed *et al.* 1996, Rasheed *et al.* 2001). The two monitoring meadows are located on Alligator Bank between the Norman and Bynoe Rivers. The "Core" monitoring meadow consists of a continuous cover of seagrass that covers the majority of Alligator Bank. The "Fringing" monitoring meadow has a patchy seagrass distribution and substantially lower biomass (density) than the Core meadow. A complete background site description and detailed methodology of the monitoring program are presented in the report "Port of Karumba Seagrass Monitoring Baseline Surveys" (Rasheed *et al.* 1996) and the detailed report of 2001 (Rasheed *et al.* 2001).

The boundaries of seagrass meadows were interpreted from aerial (helicopter) surveys conducted at low tide when seagrass meadows were exposed. Waypoints (i.e. sites) were recorded around the edge of the meadow using a global positioning system (GPS) and were digitised on to a Geographic Information System (GIS) basemap. The GIS basemap was constructed from a 1:25000 vertical aerial photograph rectified and projected to Geodetic Datum of Australia (GDA 94) coordinates.

Seagrass meadow characteristics were collected at seagrass habitat characterisation sites scattered randomly within seagrass meadows. The number of sites placed within each meadow was based on a power analysis of the baseline survey results described in (Rasheed *et al.* 1996). Seagrass habitat characteristics—including seagrass species composition, above-ground biomass, percent algae cover, sediment type and GPS fixes—were recorded at each sampling site from a helicopter hovering within a metre of the ground when meadows were exposed at low tide.

Seagrass biomass (above-ground) was determined using a modified "visual estimates of biomass" technique as described by (Mellors 1991). Briefly, an observer ranks above-ground seagrass biomass within three random placements of a 0.25m^2 quadrat at each site. Measurements are later calibrated for each observer to biomass from quadrats harvested and dried in the lab to determine mean above-ground biomass in g DW m^{-2} at each site. The relative proportion of each seagrass species within each survey quadrat was also recorded.

Sampling of the seagrass seed bank (i.e. seeds stored in the sediments) was also undertaken for the core monitoring meadow. A Van Veen sediment grab (0.0625m^{-2}) was used to collect samples at sites randomly scattered throughout the meadow. The collected sediment/seed samples were sorted by passing the sample through a 1mm sieve. Any seagrass seeds in the 1mm fraction were identified and counted for each site. The 1mm mesh size on the sieve was small enough to retain seeds of *Halodule uninervis* and fruits of *Halophila ovalis*. Seeds of *Halophila ovalis* were not measured because their small size allows them to pass through the sieve mesh.

Habitat Mapping and Geographic Information System

Spatial data from the field surveys were incorporated into the PCQ/DPI&F Karumba Geographic Information System (GIS). Three GIS layers were created:

- **Site information** - site data containing above ground biomass (for each species), sediment type, time, GPS fixes (±1.5m) and sampling technique.
- **Seagrass meadow biomass and community types** - area data for seagrass meadows with summary information on meadow characteristics. Seagrass community types were determined according to species composition from nomenclature developed for seagrass meadows of the Queensland region (Table 1). Abundance categories (light, moderate, dense) were assigned to community types according to above ground biomass of the dominant species (Table 2).
- **Seagrass landscape category** – area data showing the seagrass landscape category determined for each meadow

Isolated seagrass patches
The majority of area within the meadows consisted of unvegetated sediment interspersed with isolated patches of seagrass

Aggregated seagrass patches
Meadows are comprised of numerous seagrass patches but still feature substantial gaps of unvegetated sediment within the meadow boundaries

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

Table 1 Nomenclature for community types

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

Table 2 Density categories and mean above ground biomass ranges for each species used in determining seagrass community density

Density	**Mean above ground biomass (g DW m^{-2})**	
	***Halodule uninervis* (narrow)**	***Halophila ovalis***
Light	< 1	< 1
Moderate	1 - 4	1 - 5
Dense	> 4	> 5

Each meadow was assigned a mapping precision estimate (in meters) based on mapping methodology utilised for that meadow (Table 3). Mapping precision ranged from ±5m to ±10m for the monitoring meadows (see McKenzie *et al.* 2001). The mapping precision estimate was used to calculate a range of meadow area for each meadow and was expressed as a meadow reliability estimate (R) in hectares. Additional sources of mapping error associated with digitising and rectifying aerial photographs onto base maps and with GPS fixes for survey sites were embedded within the meadow reliability estimates.

Table 3 Mapping precision and methodology for seagrass meadows

Mapping precision	**Mapping methodology**
± 5m	All meadow boundaries mapped in detail by GPS using a combination of the helicopter, divers and/or walking; Intertidal meadows completely exposed or visible at low tide; Relatively high density of mapping and survey sites; Recent aerial photography aided in mapping.
± 10m	Inshore meadow boundary mapped in detail by GPS using a combination of the helicopter and/or walking; Offshore meadow boundary mapped by GPS using a combination of the helicopter and divers; Relatively high density of mapping and survey sites; Recent aerial photography aided in mapping.

RESULTS

Seagrass distribution and abundance

1462 ± 20 ha of seagrass habitat was mapped in the two Alligator Bank monitoring meadows by aerial and ground survey. The Core monitoring meadow covered an area of 942 ± 9 ha of continuous cover while the Fringing monitoring meadow covered 520 ±11 ha (Map 1, Figure 1) as aggregated patches. 84 sites were randomly sampled within the seagrass meadows, 83 of which contained seagrass (Map 1).

Two seagrass species were found in the survey (Plate 1):

Family Cymodoceaceae
Halodule uninervis (Forsk.) Aschers. in Boissier

Family Hydrocharitaceae
Halophila ovalis (R. Br.) Hook.*f*.

(A) (B)

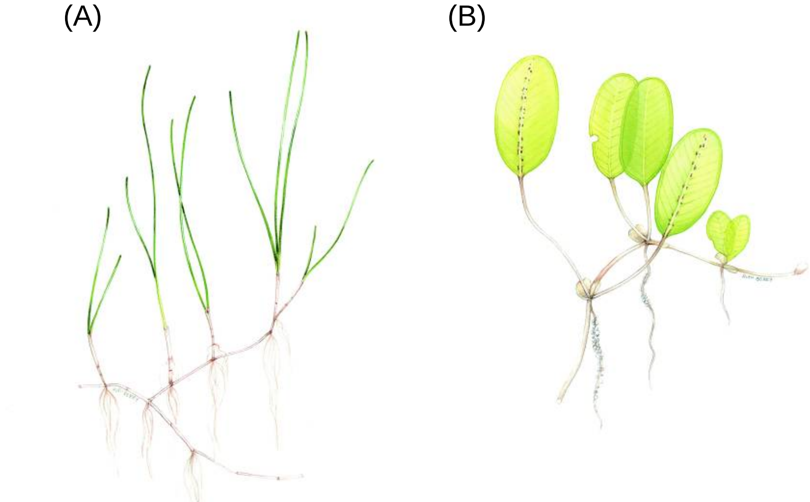
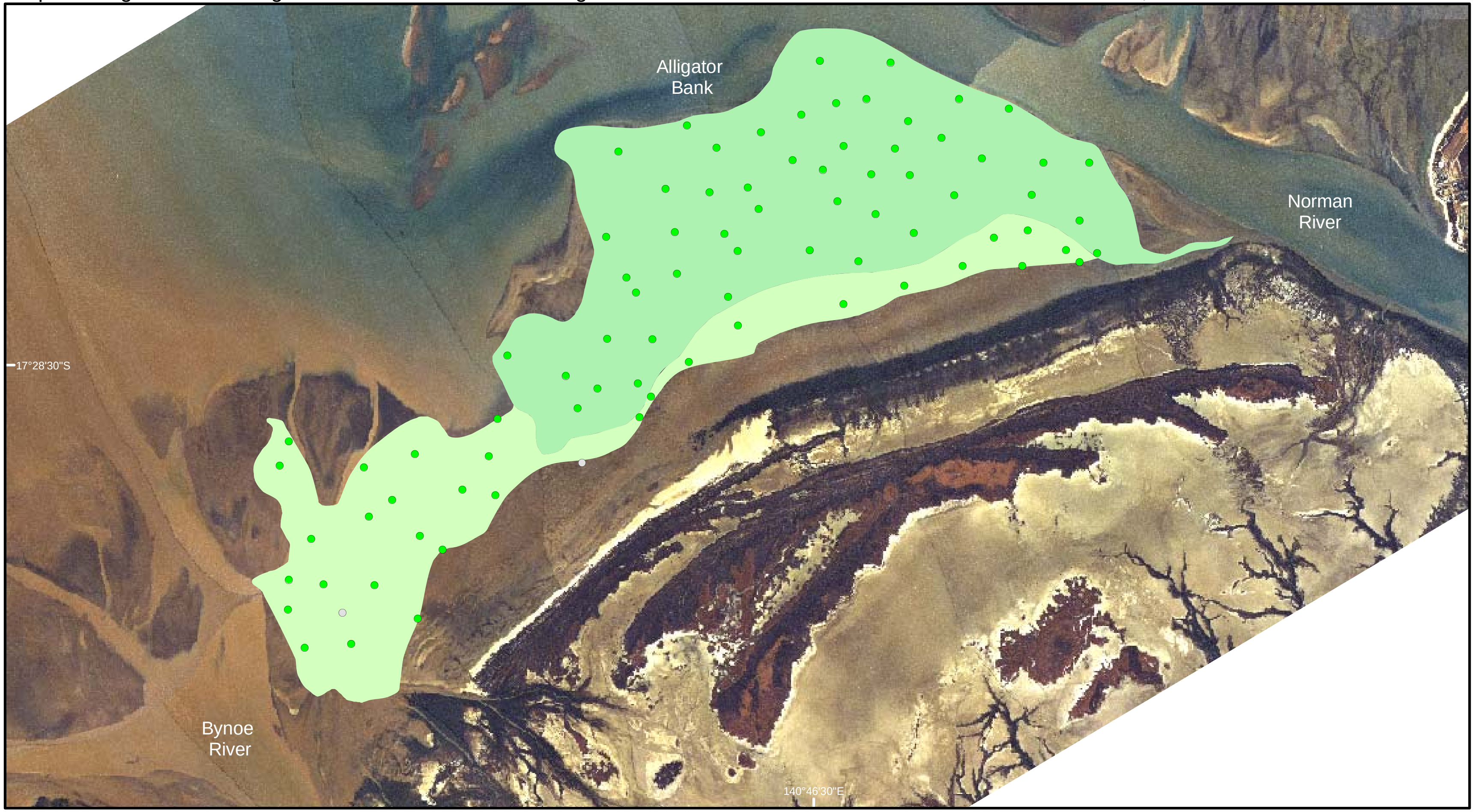


Plate 1 Seagrass species found in Karumba: (A) *Halodule uninervis* (narrow leaf form); (B) *Halophila ovalis* .

Halodule uninervis (narrow leaf form) was the dominant species in both monitoring meadows (Figure 2) which occurred predominantly on mud sediment. Average above-ground biomass was dense in the Core meadow (14.2 ± 0.5 g DW m^{-2}) while the Fringing meadow was classified as moderate (3.0 ± 0.9 g DW m^{-2}) (Figure 1).

Seed sampling was conducted at 15 sites on Alligator Bank (Map 2). *Halodule uninervis* seeds and pieces of seed pericarp (outer casing of seeds) were found scattered throughout the meadow along with flowers (Map 2). Mean *Halodule uninervis* seed density for the meadow was 54.4 ± 18.7 seeds m^{-2} and density of pericarp pieces was 58.7 ± 15.0 pieces m^{-2}. *Halophila ovalis* fruits were also found in high numbers throughout the meadow with mean fruit density of 29.9 ± 12.0 fruits m^{-2} (Table 4).

Map 1. Seagrass monitoring meadows and location of seagrass habitat characterisation sites in the Port of Karumba, October 2008.



Legend

Seagrass characterisation sites

- Seagrass absent
- Seagrass present

Community type

- Core meadow - Dense *Halodule uninervis*
- Fringing meadow - Moderate *Halodule uninervis*

N

0 1 2

Kilometers

Source:
Unsworth, R.K.F, McKenna, S.A. and Rasheed, M.A. (2009) Port of Karumba Long Term Seagrass Monitoring, October 2008. DPI&F Publication PR09-4227 (DPI&F, Cairns) pp24.

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Produced by the Marine Ecology Group, Queensland Department of Primary Industries and Fisheries, Northern Fisheries Centre, Cairns, 2009.

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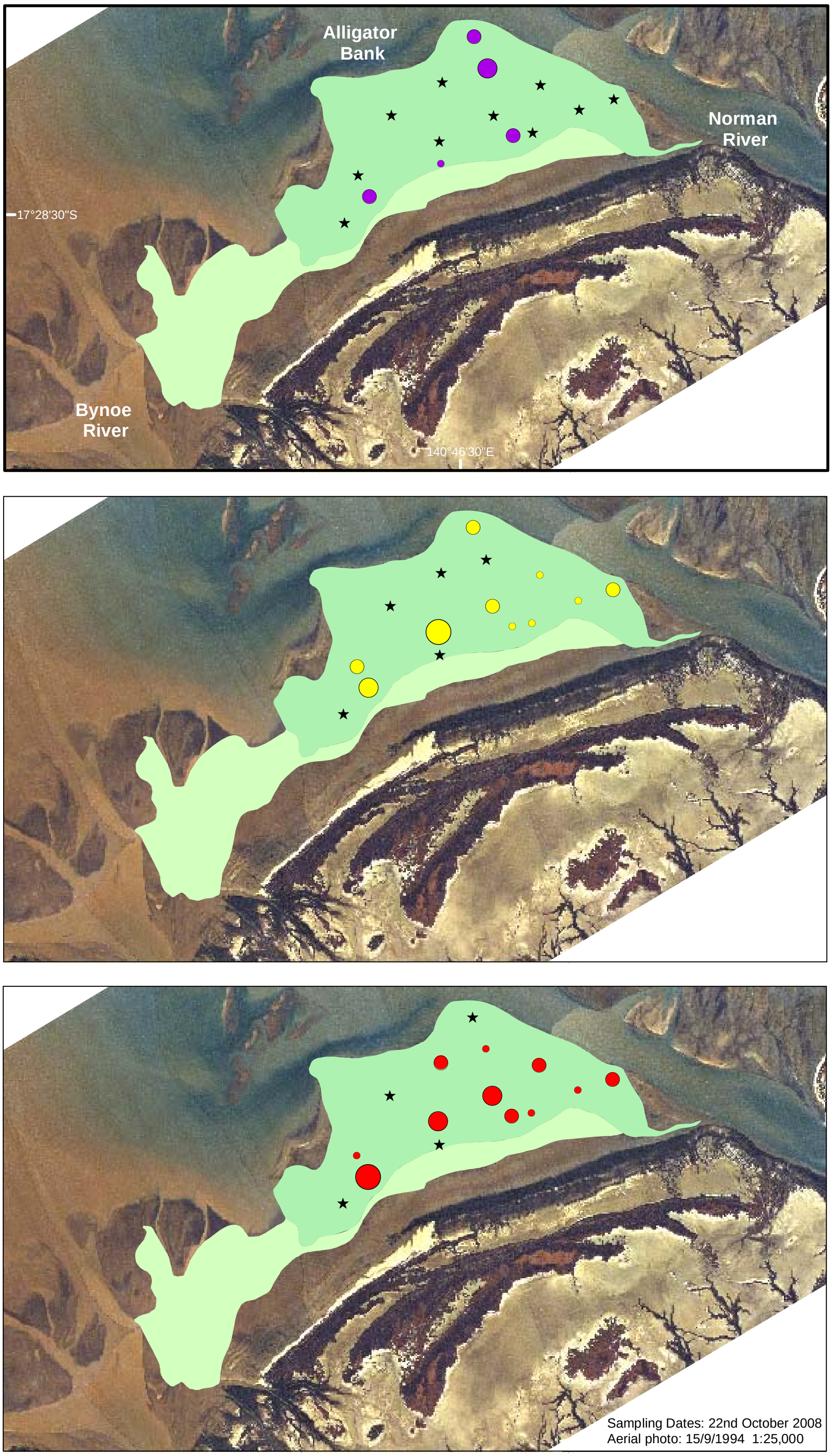
Map 2. Density of *Halodule uninervis* seeds, broken pericarp pieces and *Halophila ovalis* fruits on Alligator Bank in the Port of Karumba, October 2008.



Legend

Community type

- Core Meadow - Dense *Halodule uninervis*
- Fringing Meadow - Moderate *Halodule uninervis*

Density of *Halophila ovalis* fruits (m^{-2})

- 0
- 1 - 50
- 51 - 100
- 100 - 150
- 151 - 200

Density of *Halodule uninervis* seeds (m^{-2})

- 0
- 1 - 50
- 51 - 100
- 101 - 200
- 201 - 300

N

0 1 2

Kilometers

Density of pericarp seed pieces (m^{-2})

- 0
- 1 - 50
- 51 - 100
- 101 - 150
- 151 - 200

Source:
Unsworth, R.K.F, McKenna, S.A. and Rasheed, M.A. (2009) Port of Karumba Long Term Seagrass Monitoring, October 2008. DPI&F Publication PR09-4227 (DPI&F, Cairns) pp24

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Comparison with Previous Monitoring Surveys

The total area of the seagrass monitoring meadows in 2008 (1462 ± 20 ha) was above the 15 year (1994-2008) average (1246 ± 47 ha), however this was a 13% decrease on the area recorded in 2007 (Figure 1).

The decrease in total area of seagrass was mostly due to the reduction in the near-shore Fringing and Core meadows at their extreme points close to the Bynoe and Norman Rivers (Map 3; Figure 1). Despite the decrease, the core meadow remained within the range of previous years (Map 3; Figure 1).

Average seagrass biomass of the two meadows (9.8 ± 0.8 g DW m^{-2}) was the second highest recorded throughout 15 years of monitoring. The increase in biomass from 2007 to 2008 was principally due to a statistically significant 49% increase in the Core meadow (see Appendix). Increases in biomass were largely due to increases in *Halodule uninervis* (narrow) (Figure 1).

Halodule uninervis has been the dominant species within the Core meadow throughout the 15 year monitoring program with *Halophila ovalis* a minor component of the assemblage (14% of overall biomass). During 2008, *Halodule uninervis* in the Core meadow recorded its highest contribution to total biomass of 98.6% (Figure 2).

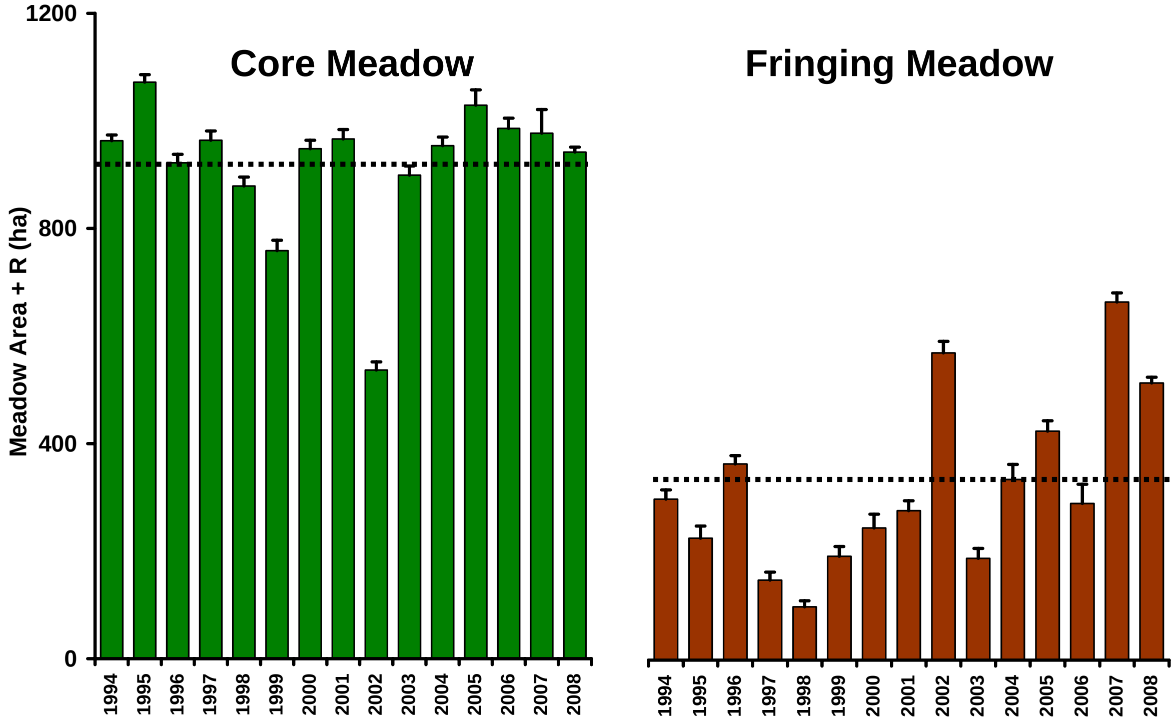
In contrast to the Core meadow, the Fringing meadow did not record a significant change in biomass from 2007 but did record its highest biomass level (3.0 ± 0.8 DW m^{-2}) since commencement of monitoring in 1994. This was again the result of increased species dominance by *Halodule uninervis* (Figure 2).

High *Halodule uninervis* biomass relative to *Halophila ovalis* in 2008 likely yielded the very high numbers of *Halodule uninervis* seeds (highest density since commencement of monitoring) and consequential decrease in levels of *Halophila* fruits (Table 4). Levels of *Halodule uninervis* pericarps were also high in 2008.

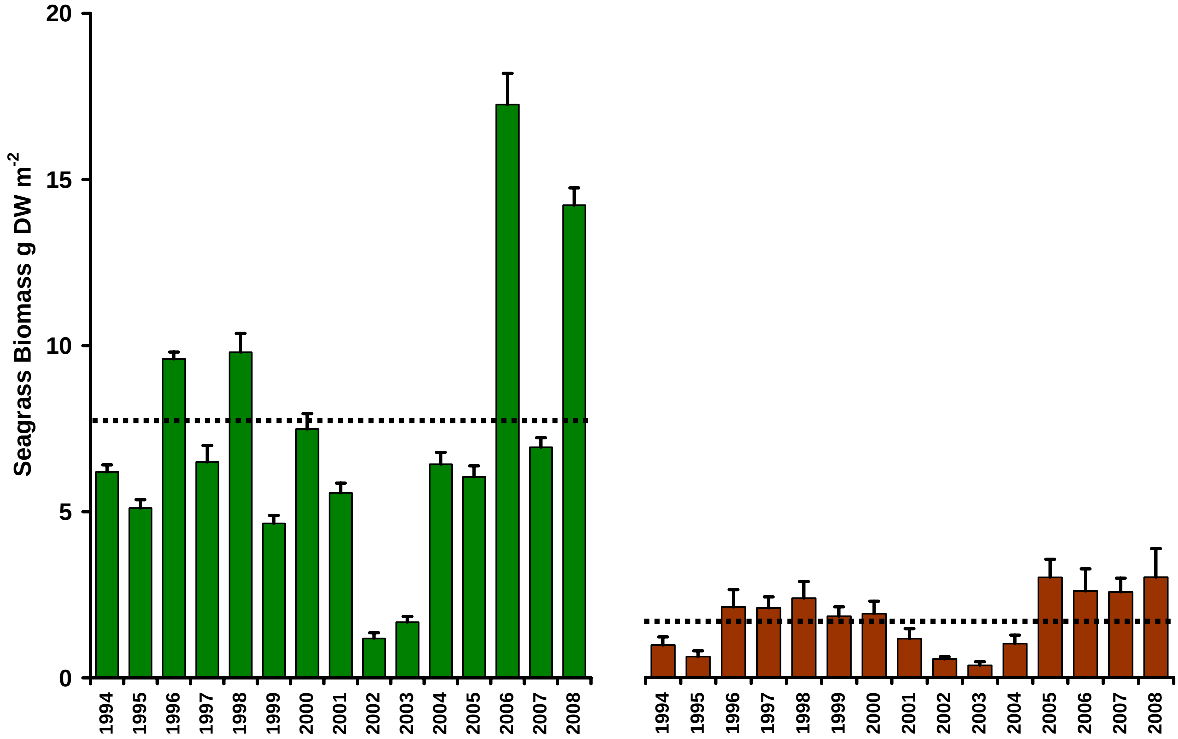
There has been consistent evidence of dugong activity on the Karumba seagrass meadows throughout the monitoring program. Field observations in 2008 indicated a high level of dugong activity with feeding trails present in at least 24% of seagrass meadow sites surveyed.

Climate Analysis

In October 2008, the maximum daily air temperature was close to the average maximum temperature over the 15 years of monitoring; this was following a period of below average temperatures during 2006 and 2007 (Figure 4A). Although local annual rainfall was down in 2008, analysis of the catchment as a whole and the flow of the Norman River indicate that coastal habitats would have received above average levels of freshwater inputs during 2008 Figure 4 & 5). The number of clear days in 2008 was near average (Figure 4B) while tidal exposure of the inter-tidal seagrass meadows was at its lowest value in the 15 years of monitoring (Figure 6).



(A)



(B)

Figure 1 Mean (A) meadow area (± Reliability) and (B) above ground biomass (g DW m^{-2}) of monitoring meadows (+ SE) for each October seagrass survey of Karumba (1994 to 2008). Dotted lines are the 15 year average values (1994 to 2008).

Table 4 Mean density ± SE of *Halodule uninervis* seeds & pericarp pieces and *Halophila ovalis* fruits for the Core monitoring meadow.

Year	*Halodule* seeds m^{-2}	*Halodule* pericarp pieces m^{-2}	*Halodule* flowers m^{-2}	*Halophila* fruits m^{-2}
2003	26 ± 9.0	105 ± 28.0	-	not sampled
2004	3.6 ± 1.6	26 ± 6.6	-	77.3 ± 30.0
2005	30 ± 13.0	26 ± 7.0	-	76 ± 20.0
2006	26 ± 9.8	20 ± 5.9	-	31 ± 13.0
2007	35 ± 14.2	14 ± 4.6	-	160 ± 33.9
2008	54.4 ± 18.7	58.7 ± 15.0	7.5	29.9 ± 12.0

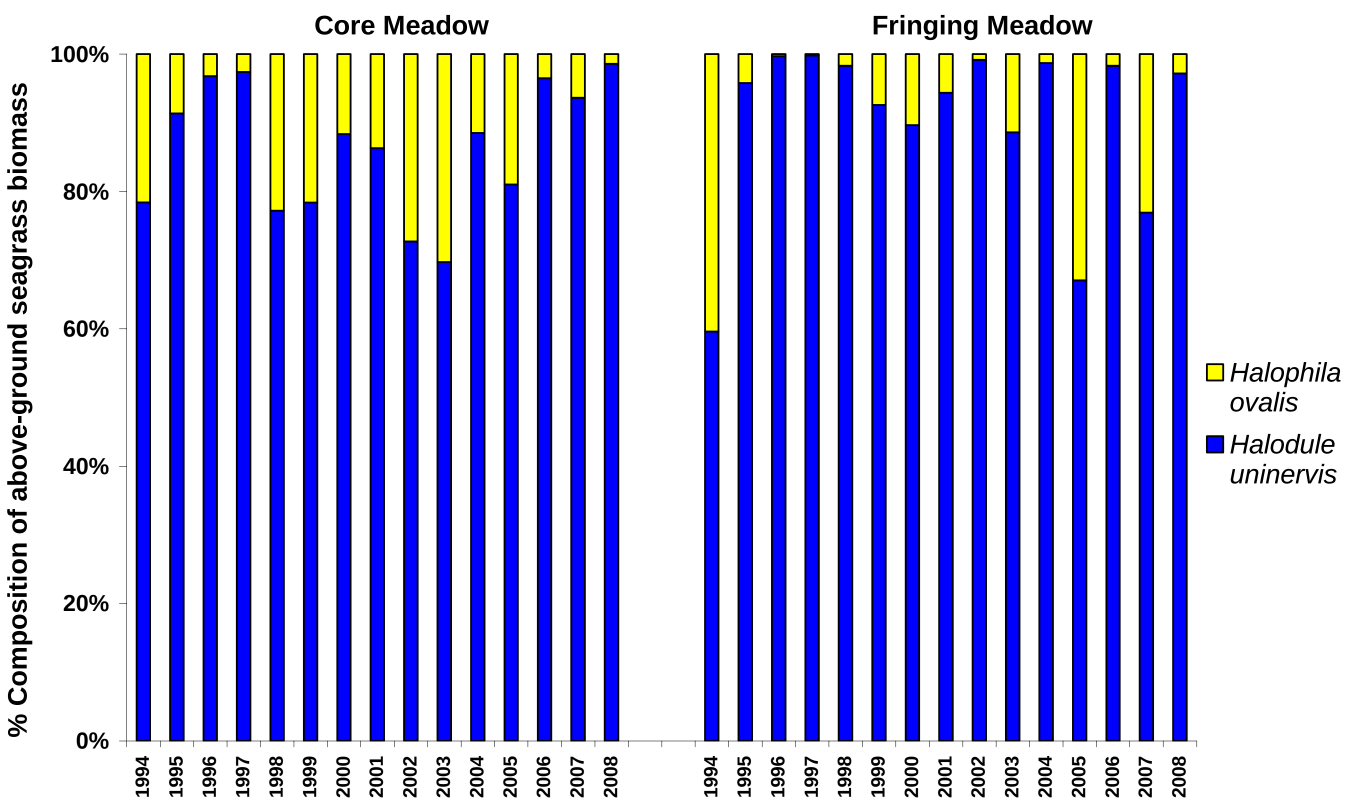


Figure 2 Percent composition of above ground biomass for seagrass species at each monitoring meadow in October from 1994 to 2008.

Sampling Intensity

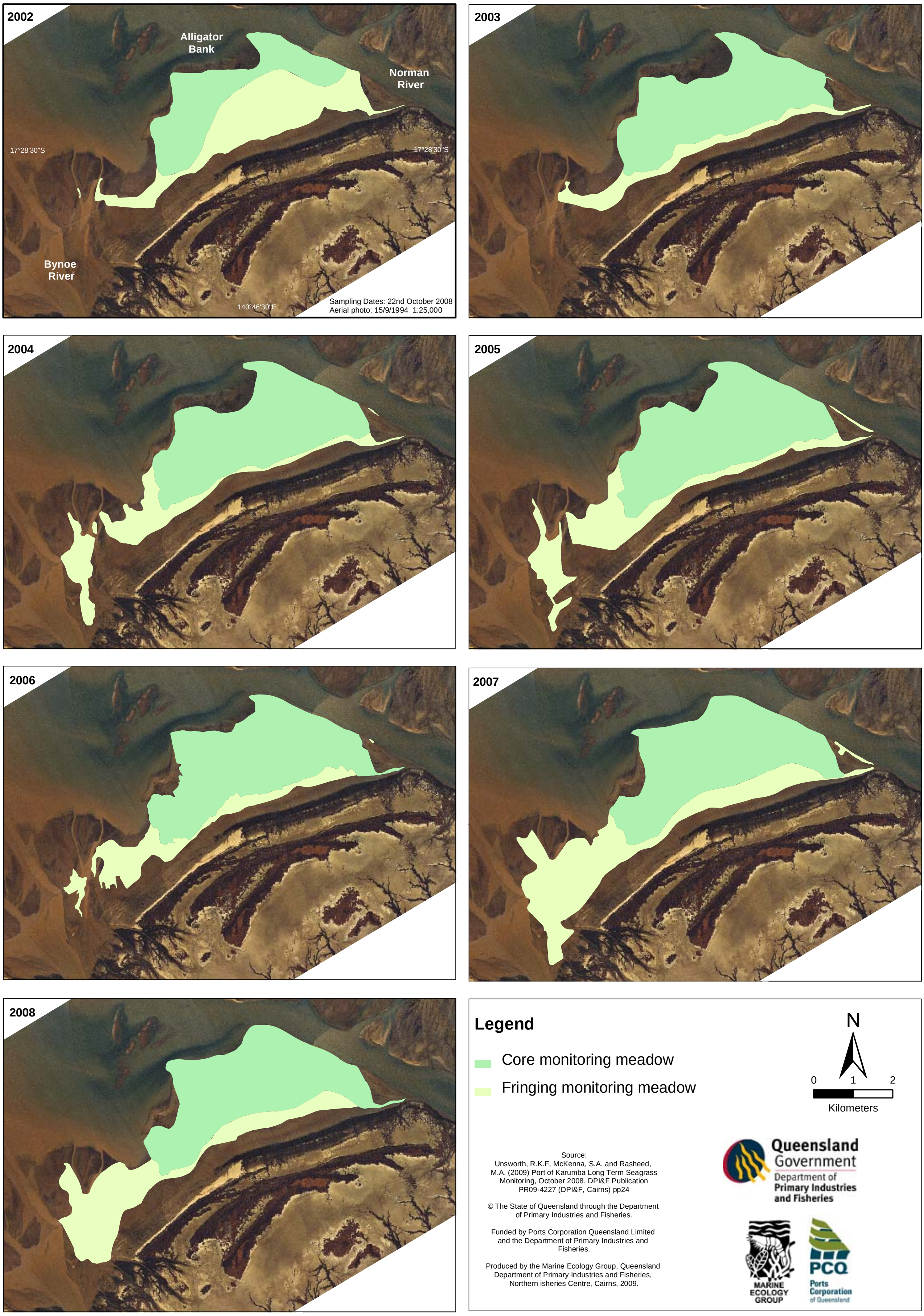
Prior to baseline surveys being conducted in 1994 and 1995, statistical power analysis was conducted to determine a statistically suitable sample size for each meadow (Rasheed *et al.*, 1996). This analysis was revisited in 2000 following six years of monitoring (Rasheed *et al.*, 2001). Due to the large inter-annual variation observed throughout the meadows between 2003-2008 we have chosen to reconsider these analyses in order to make future monitoring programs more statistically effective (Table 5). Using data collected in 2007 and 2008, the Minimal Detectable Difference (MDD) was calculated for each meadow during 2007 and 2008 and analysed relative to mean values for the previous year. Calculation of MDD follows the methods of (Bros *et al.*, 1987) and (Burdick *et al.*, 2001) and was based on change being detected with 90% power (i.e. Type I error or 10%) and with 90% probability of detecting a true difference (i.e. Type II error of 10%).

Results found that in 2007, the MDD within the Core meadow was 19% but increased to 37% in 2008, this indicates that some years are more variable than others. A similar pattern is observed within the fringing meadow. As a result of these analyses we propose to increase the power of the sampling in 2009. This will be done by increasing the number of samples to a total of 110 across the two meadows, enabling monitoring in the core meadow to detect a 30% change, whilst monitoring of the fringing meadow will be able to detect 50% change (Table 5).

Table 5 Minimal detectable difference (MDD) (%) of the biomass of seagrass meadows in the Port of Karumba during 2007 and 2008, and the number of samples necessary to detect 30% and 50% changes in biomass relative to previous data. Shaded cells indicate new proposed minimum samples to be collected

	2007		**2008**	
	Core Meadow	**Fringing Meadow**	**Core Meadow**	**Fringing Meadow**
Current %MDD	19%	64%	37%	153%
Current sample numbers	48	36	50	33
Samples required to detect 30% MDD	15	75	**55**	65
Samples required to detect 50% MDD	8	50	28	**55**

Map 3. Changes in the Port of Karumba seagrass monitoring meadows October 2002 to October 2008.



DISCUSSION

The 2008 monitoring survey of the Port of Karumba found that seagrass remains in an overall healthy and productive state. Meadows in 2008 were spatially expansive and had the second highest density (biomass) recorded in the 15 year monitoring program.

Seagrass meadows in Karumba have shown considerable inter-annual and intra-site variability during the 15 years of monitoring. Recent statistical regression modeling of these Karumba meadows found that the biomass of inter-tidal seagrass meadows in Karumba correlates with changes in climatic factors, mainly rainfall and air temperature (Rasheed *et al.* In review). Therefore, seagrass dynamics in the Port of Karumba may be partly due to natural fluctuations in environmental conditions.

Despite seagrass area being high and above average in 2008 there was a slight reduction from 2007 surveys. Loss was mostly within the near-shore areas of the fringing meadow towards the Bynoe River where changes may have been influenced by river flow. Although seagrass area decreased in both meadows, mean seagrass biomass significantly increased within the core meadow to the second highest level recorded throughout the 15 years of monitoring and was at its highest recorded level within the fringing meadow. The increase in inter-tidal *Halodule uninervis* biomass, particularly within the Core meadow, reflects similar changes and meadow dynamics that have occurred in the Torres Strait (Unsworth *et al.* 2008) and in Weipa (Rasheed *et al.* 2008).

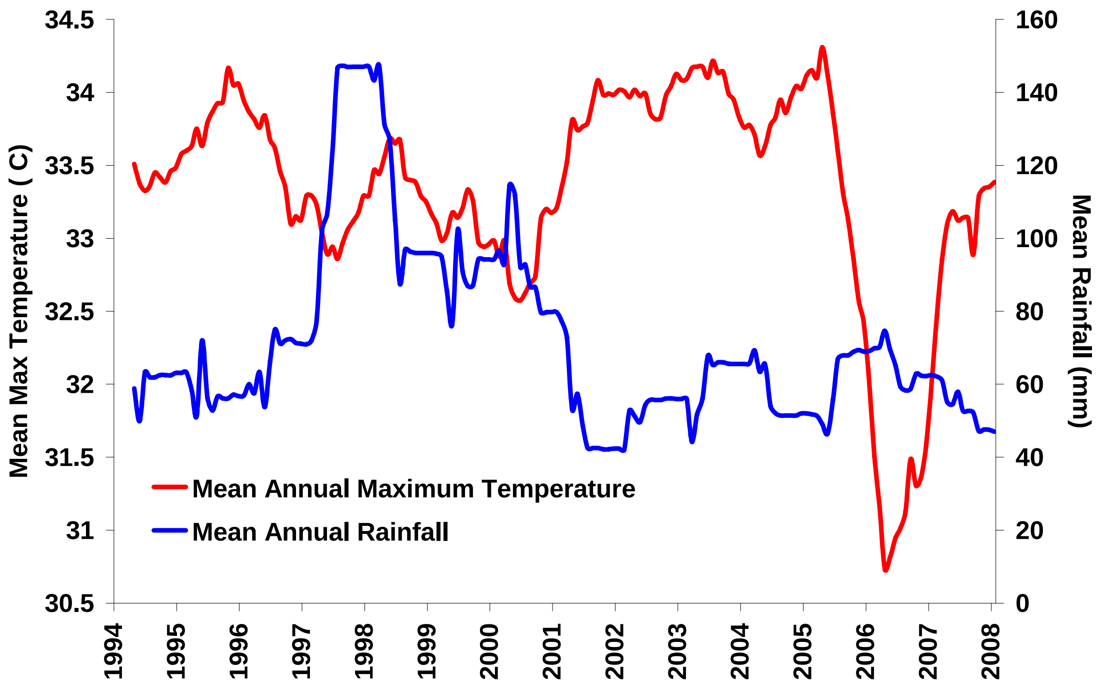
The changes in Torres Strait and Weipa seagrasses were mainly linked to climatic and tidal variables such as exposure, temperature and solar irradiance (Rasheed *et al.* 2008). The year 2008 was marked by reduced periods of tidal exposure, high catchment rainfall and intermediate temperatures. Long-term statistical modeling of seagrasses in Karumba has found that these are all important variables in determining dry-season biomass (Rasheed *et al.* In review). These mild conditions may have had a positive impact upon seagrass meadows in 2008 enabling biomass to increase and *Halodule uninervis* to become more dominant. *Halophila ovalis* was a minor component of both meadows in 2008. As a colonizing species, it is much more likely to dominate during periods of turbulence and environmental change, such as in 2002 and 2003 when overall biomass reduced during times of drought.

The large increase in biomass from 2007 to 2008 may also reflect high capacity for the meadow to recover from perturbation. This is likely due to the presence of a the seed bank observed in 2007 and the capacity of the species for rapid asexual colonisation. In 2008, seagrass meadows also contained high densities of seeds, the highest recorded at the site to date. These findings indicate the meadows have a high capacity to remain resilient to future disturbances and climatic variability (Rasheed 2004, Bell *et al.* 2008).

The increased biomass in 2008 is likely to benefit the faunal communities inhabiting these seagrass meadows. This will provide a more abundant food source for dugong utilising the region and an enhanced value as fisheries nursery habitat. There is evidence that declines in commercial catches of barramundi and grey mackerel in Karumba have coincided with declines in seagrass abundance in the past (Gribble *et al.* 2005). The high abundance of seagrasses over the last few years may have flow on effects to the productivity of the local ecosystem and fisheries.

Results of this survey indicate that human activities in Karumba including dredging and other port and urban activities were unlikely to have had a significant impact on seagrasses in the area and that the marine environment of the port was in a healthy condition.

(A)



(B)

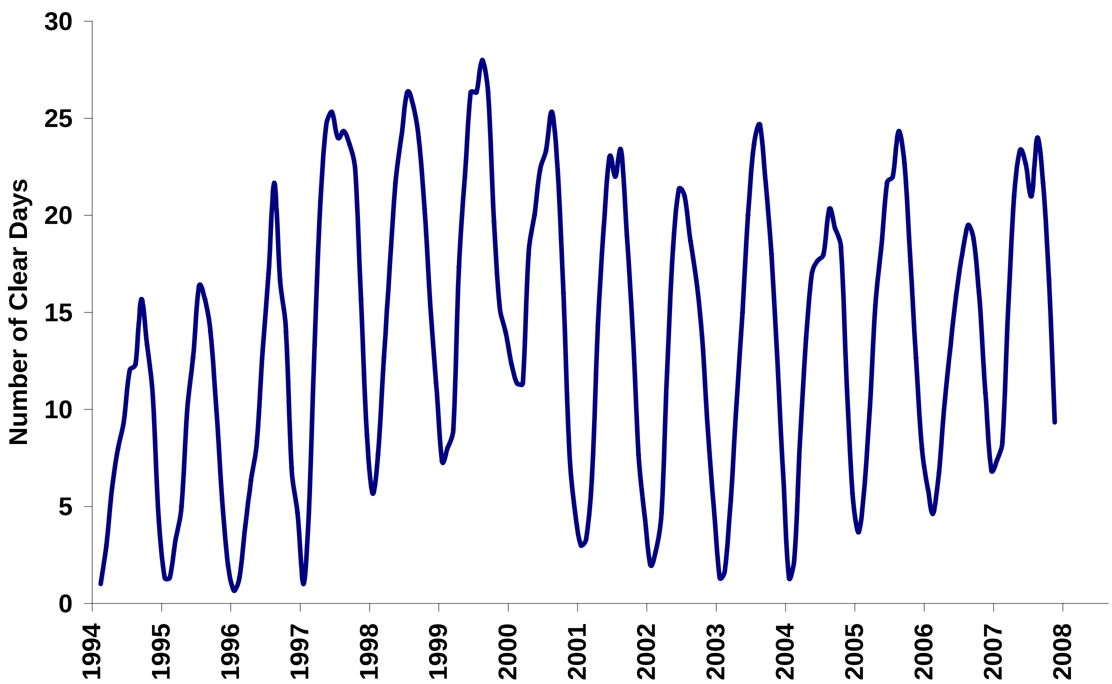
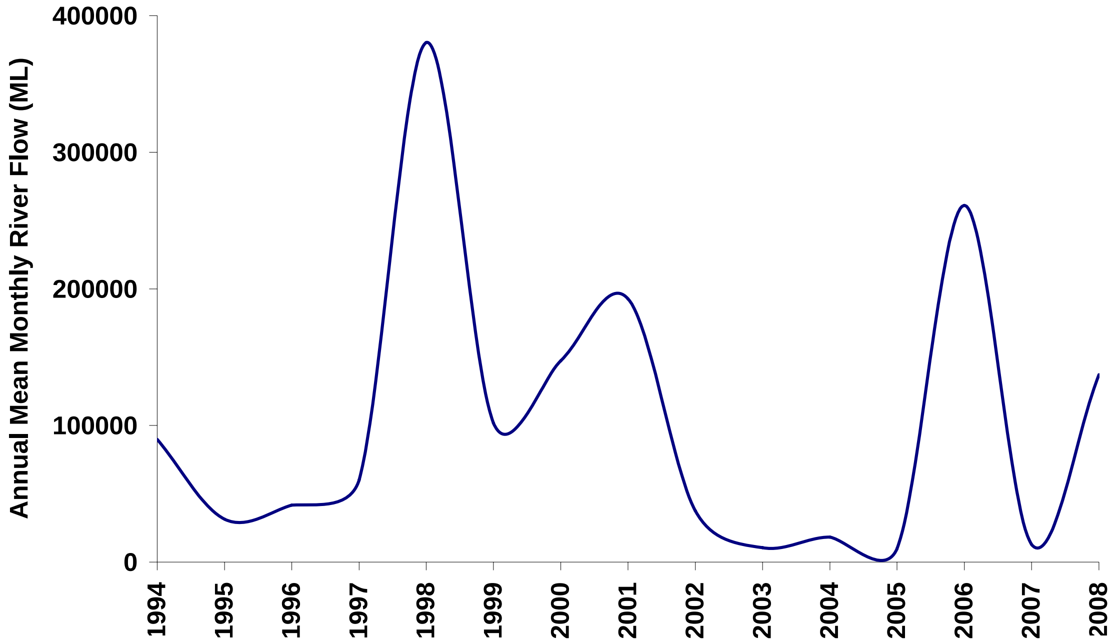


Figure 4 (A) Annual running average of rainfall (mm) and air temperature (°C) at Normanton from January 1994 to October 2008, (B) Annual running average number of clear days at Normanton (Source: Bureau of Meteorology, 2008).

(A)



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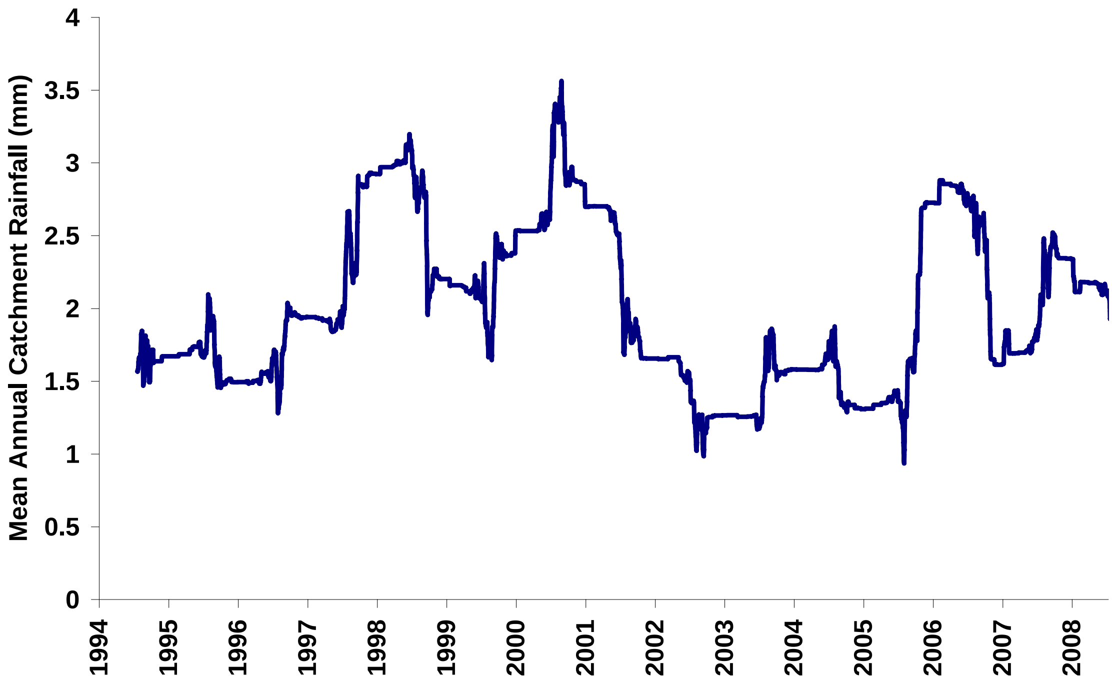

Figure 5 (A) Annual water flow for the Norman River (megalitres; November-October) recorded at Glenore Weir (B) Annual running average rainfall (mm) for the Norman River catchment area*

(Source: (A) Natural Resources Mines and Water, 2008, (B) Bureau of Meteorology, 2008)

* The catchment area rainfall was a sum of rainfall records at Normanton Airport, Normanton Post Office, Escott, Mundjuro, Numil Downs, Blackbull, Karumba Airport, Iffley, Millungera, Esmerelda and Arizona.

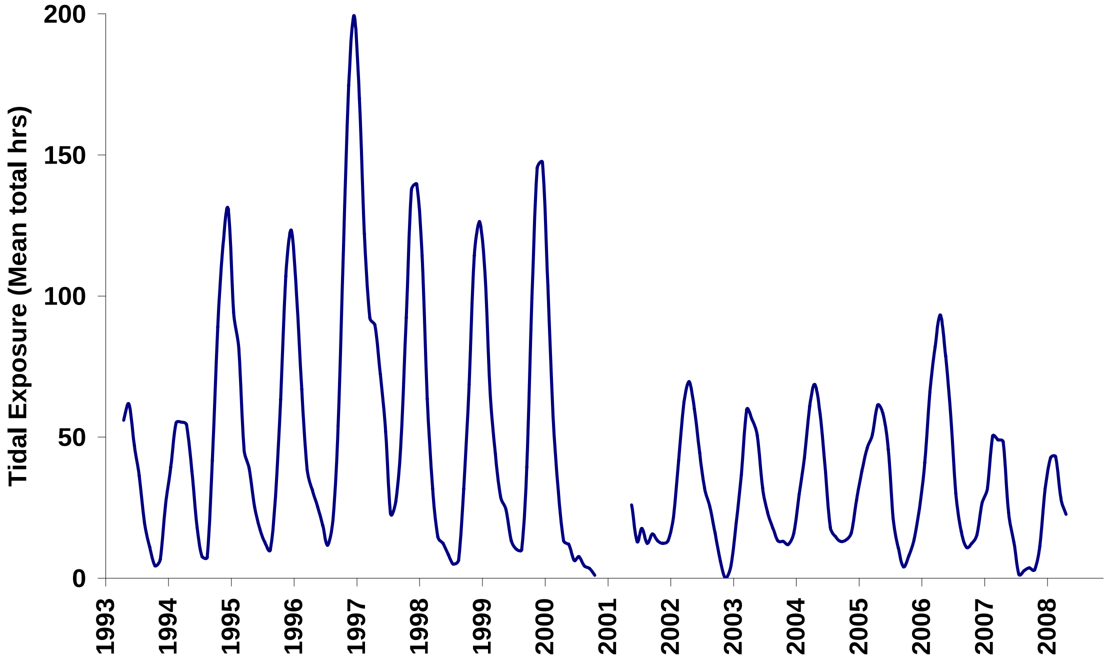

Figure 6 Total monthly daytime exposure (hours)* of seagrass meadows on Alligator Bank, Karumba from October 1993 to October 2008 (note – data missing between November 2000 and June 2001).

* Assumes intertidal banks become exposed at a tide height of 0.9m above Lowest Astronomical Tide.

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APPENDIX

Results of inter-annual one-way ANOVA for mean above ground biomass versus year for the Core and Fringing monitoring meadows at Karumba - 1994 to 2008.

	Source	DF	SS	F	P
Core Meadow	Between years	14	38.2	70.1	P<0.001
	Within years	769	29.9		
	Total	783	68.1		
Fringing Meadow	Between years	14	5.6	4.3	P<0.001
	Within years	494	46		
	Total	508	51.7		

Results of inter-annual least squares difference pairwise comparisons of mean above ground biomass (g DW m^{-2}) for the Core meadow. Each group represents inter-annual comparisons that are not significantly different (P<0.05).

Group A	Biomass
2008	14.23
2006	17.26

Group B	Biomass
1998	9.8
1996	9.6

Group C	Biomass
2007	6.94
2005	6.05
2004	6.43
2000	7.49
1997	6.5
1994	6.2

Group D	Biomass
2007	6.94
2005	6.05
2004	6.43
2001	5.57
1997	6.5
1994	6.2

Group E	Biomass
2001	5.57
1999	4.65
1995	5.11