Smart State smart fishing

Port of Karumba Long Term Seagrass Monitoring

October 2006

Kara Dew
Michael Rasheed
Helen Taylor
Tonia Sankey

Department of Primary Industries and Fisheries
Marine Ecology Group
Northern Fisheries Centre

Queensland Government
Department of Primary Industries and Fisheries

PCQ Ports Corporation of Queensland

Reef & Rainforest Research Centre

Port of Karumba Long Term Seagrass Monitoring

October 2006

DPI&F Publication PR07-2670

Report to:
Ports Corporation of Queensland
GPO Box 409 Brisbane
Queensland 4001

Authors:
Kara Dew
Michael Rasheed
Helen Taylor
Tonia Sankey

Marine Ecology Group
Department of Primary Industries and Fisheries
Northern Fisheries Centre
PO Box 5396 Cairns Qld 4870

ACKNOWLEDGMENTS

This project was funded by the Ports Corporation of Queensland and the Queensland Department of Primary Industries and Fisheries. The Marine Ecology Group is partially funded through the Reef and Rainforest Research Centre

The correct citation of the following document is:

Dew, K.R., Rasheed, M.A., Taylor, H.A. and Sankey, T.L. (2007). Port of Karumba Long Term Seagrass Monitoring, October 2006. DPI&F Publication PR07-2670 (DPI&F, Northern Fisheries Centre, Cairns) 15 pp.

TABLE of CONTENTS

ACKNOWLEDGMENTS i

EXECUTIVE SUMMARY...iii

1. INTRODUCTION 1

1.1. Consultancy Brief 1

2. BACKGROUND AND METHODOLOGY 1

3. RESULTS...3

3.1. Seagrass Distribution and Abundance 3
3.2. Comparison with Previous Monitoring Surveys 6

4. DISCUSSION & CONCLUSIONS 11

5. REFERENCES 13

EXECUTIVE SUMMARY

This report details results of the October 2006 seagrass survey which forms part of the established annual long term seagrass monitoring program for Karumba. Seagrass abundance was the highest on record in 2006 and seagrass meadows covered one of the largest areas since monitoring began in 1994. Total biomass of the monitoring meadows increased by 123% between October 2005 and October 2006 surveys, while total seagrass meadow area remained similar.

The dramatic increase in seagrass biomass was most likely a result of local and catchment climate conditions. Lower than average temperatures, higher rainfall and increased cloud cover in Karumba, combined with an increase in the catchment area rainfall and water flow from the Norman River may all have contributed to the observed increase. The 12 months leading up to the October 2006 survey saw the first substantial flows of the Norman River in more than five years. This increased river flow was likely to have provided the first flush of nutrients from the catchment to the river mouth for several years.

The higher biomass and area of seagrass were likely to have positive effects on their value as a fish nursery habitat and provide a more abundant food source for dugong utilising the region. 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.

1. INTRODUCTION

1.1. Consultancy Brief

The Ports Corporation of Queensland (PCQ) is the port authority for the Port of Karumba. PCQ has identified seagrass meadows as an important component in 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 project lead and zinc export facility, 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 strategy for the Port of Karumba was developed. This current survey is the sixth of the planned annual LTSM events funded by the PCQ and Department of Primary Industries and Fisheries. For this 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 are used by PCQ to help identify any possible detrimental effects of port operations and developments (eg. 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.

2. BACKGROUND AND METHODOLOGY

A survey of seagrass monitoring meadows in the Port of Karumba was conducted between 30th – 31st October 2006. 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).

The boundaries of seagrass meadows were interpreted from aerial (helicopter) surveys conducted at low tide when seagrass meadows were exposed using a differential global positioning system (dGPS) and 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 Goedetic Datum of

Australia (GDA 94) coordinates. Estimates of meadow boundary mapping reliability were calculated for each meadow area, based on accuracy of site fixes and distances between mapping sites. These have been set at between ±10 - 15m for this survey.

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 the results of the baseline surveys described in Rasheed *et al.* (1996). Seagrass habitat characteristics, including seagrass species composition, above-ground biomass, percent algae cover, sediment type and dGPS 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 described by Mellors (1991). This technique involves an observer ranking seagrass biomass in the field of a number of random placements of a $0.25m^2$ quadrat while referring to a series of quadrat photographs of similar seagrass habitats for which the above-ground biomass has been measured. The relative proportion of each seagrass species within each survey quadrat was also recorded. The seagrass within each of the quadrats was harvested and dried, and then converted into above-ground biomass in g DW m^{-2}. A linear regression was calculated and applied for the ranks and calibrated for each observer.

Sampling of the seagrass seed bank (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 collected however as their small size would allow them to pass through the sieve mesh.

3. RESULTS

3.1. Seagrass Distribution and Abundance

1280 ± 55ha 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 986 ± 19ha, and the fringing monitoring meadow covered 294 ± 36ha (Map 1, Table 1). 83 sites were randomly sampled within the seagrass meadows, 72 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*.

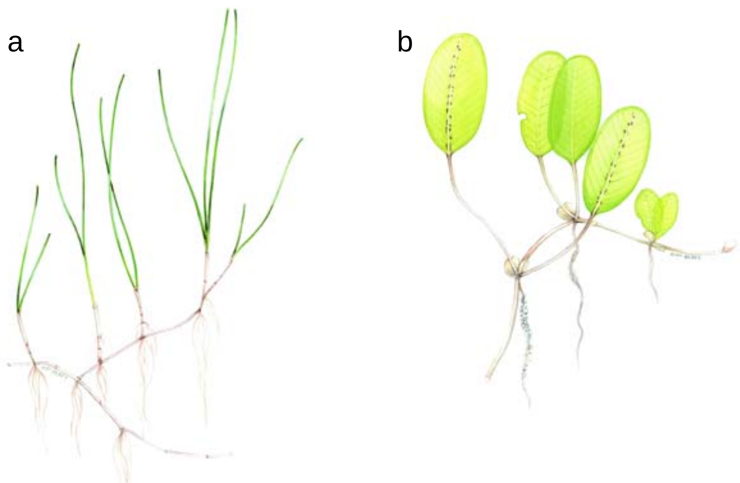
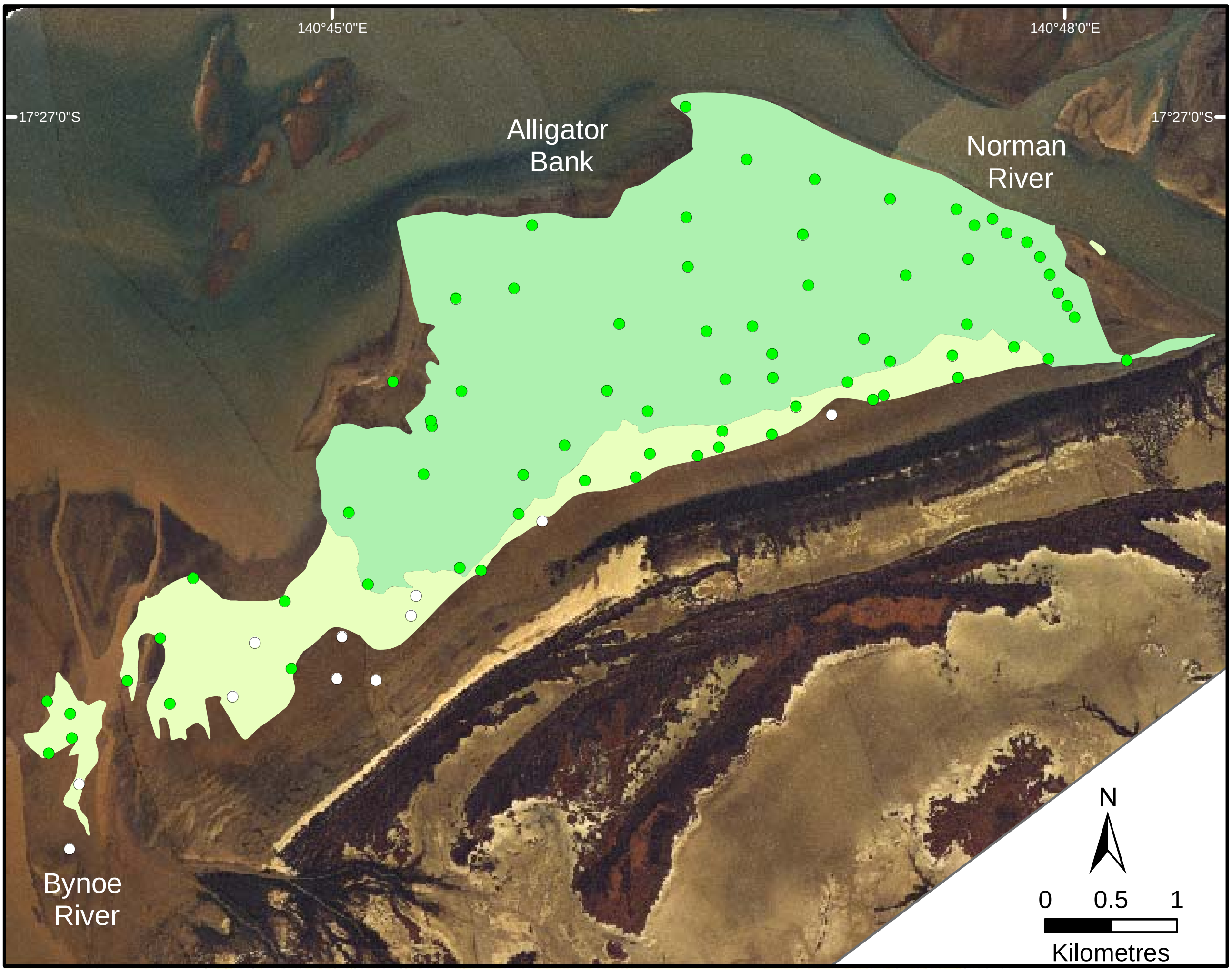


Plate 1 Seagrass species found in Karumba: *Halodule uninervis* (narrow leaf form) (a); *Halophila ovalis* (b).

Halodule uninervis (narrow leaf form) was the dominant species in both monitoring meadows (Figure 1). Average above-ground seagrass biomass was higher in the Core meadow (Alligator Bank 1) (17.26 ± 0.93 g dw m^{-2}) than the Fringing meadow (Alligator Bank 2) (2.63 ± 0.67 g dw m^{-2}) (Table 1). Seagrass occurred predominantly on mud sediment.

Seed sampling was conducted at 17 sites on Alligator Bank (Map 2). *Halodule uninervis* seeds and pieces of seed pericarp (outer casing of seeds) were predominantly found in the north of the meadow (Map 2). Mean *Halodule uninervis* seed density for the meadow was 26 ± 9.8 seeds m^{-2} and density of pericarp pieces was 20 ± 5.9 pieces m^{-2}. *Halophila ovalis* fruits were also found throughout the meadow. Mean *Halophila ovalis* fruit density was 31 ± 13.0 fruits m^{-2} (Table 2).

Map 1. Seagrass monitoring meadows and location of seagrass habitat characterisation sites in the Port of Karumba, October 2006.



LEGEND

Seagrass characterisation sites

- Seagrass not present
- Seagrass present
- Core Meadow - Dense *Halodule uninervis*
- Fringing Meadow - Moderate *Halodule uninervis*

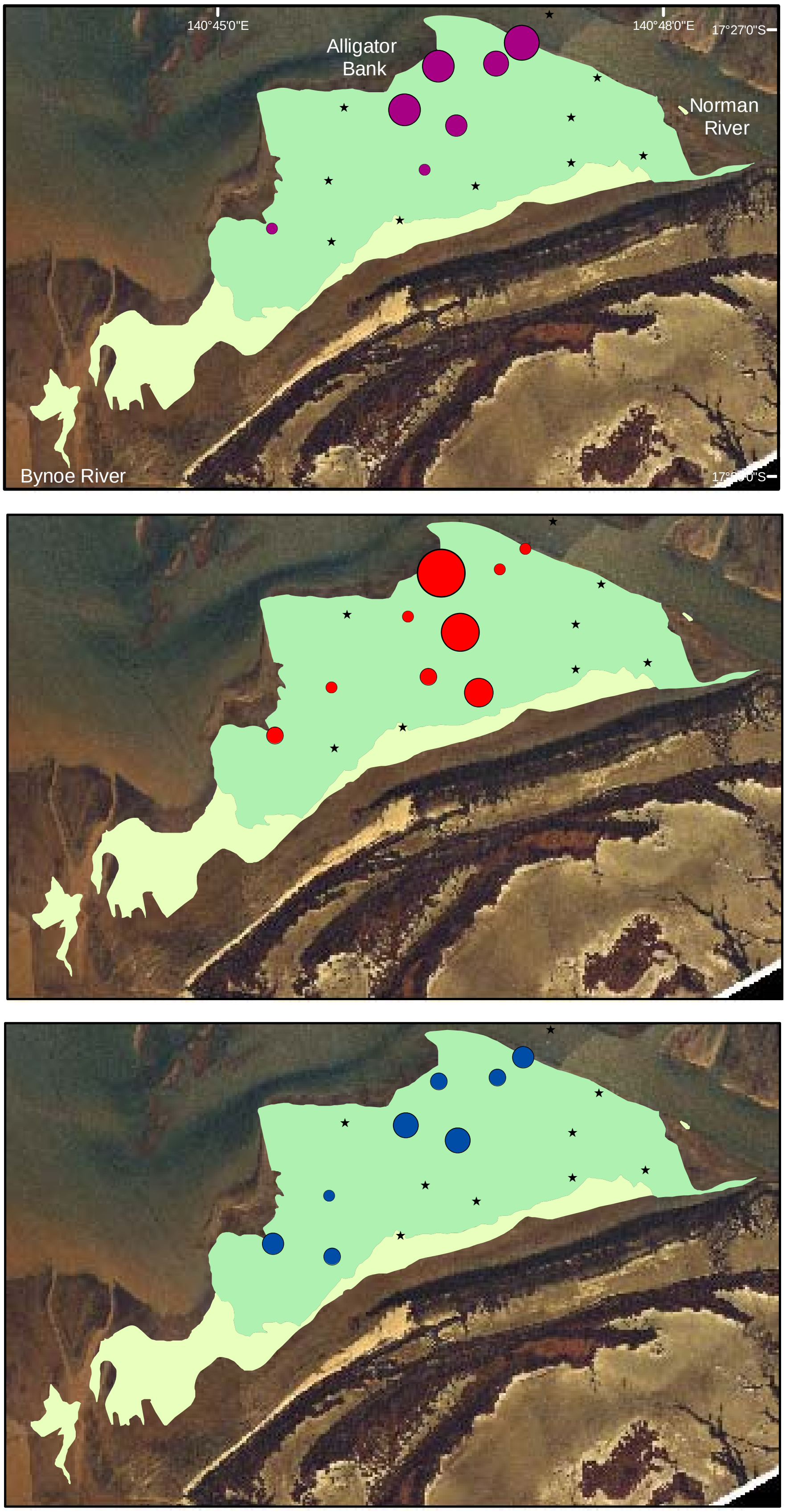
Source:
Dew, K.R., Rasheed, M.A., Taylor, H.A. and Sankey, T.L. (2007). Port of Karumba Long Term Seagrass Monitoring, October 2006. DPI&F Publication PR07-2670, (DPI&F, NFC, Cairns).

Funded by Ports Corporation Queensland and CRC Reef Research Centre.

Produced by the Marine Ecology Group, Queensland Department of Primary Industries and Fisheries, Northern Fisheries Centre, Cairns, 2007.

Sampling Dates: 30-31st October 2006
Aerial photo: 15/9/1994 1:25,000

Map 2. Density of *Halodule uninervis* seeds, broken pericarp pieces and *Halophila ovalis* fruits on Alligator Bank in the Port of Karumba, October 2006.



LEGEND

- Core meadow - Dense *Halodule uninervis*
- Fringing meadow - Moderate *Halodule uninervis*
- ★ Seed / Fruit sampling site

Density of *Halophila ovalis* fruits
Fruits per square metre
10
50
100

Density of *Halodule uninervis* seeds
Seeds per square metre
10
50
100

Density of pericarp seeds
Pieces per square metre
10
50
100

N

0 1 2
Kilometres

Source:
Dew, K.R., Rasheed, M.A., Taylor, H.A. and Sankey, T.L. (2007). Port of Karumba Long Term Seagrass Monitoring, October 2006. DPI&F Publication PR07-2670, (DPI&F, NFC, Cairns).

Funded by Ports Corporation Queensland and CRC Reef Research Centre.

Produced by the Marine Ecology Group, Queensland Department of Primary Industries and Fisheries, Northern Fisheries Centre, Cairns, 2007.

Sampling Dates: 30-31st October 2006
Aerial photo: 15/9/1994 1:25,000

3.2. Comparison with Previous Monitoring Surveys

Seagrass abundance was the highest on record in 2006 and seagrass meadows covered one of the largest areas since monitoring began. Total biomass of the monitoring meadows increased by 123% between October 2005 and October 2006 surveys, while total meadow area remained similar (Table 1).

The increased biomass resulted in the leaves of the dominant species, *Halodule uninervis,* becoming substantially longer and wider than in previous surveys, to the point where they were on the cusp of changing from the narrow leaf to wide leaf morphology of the species (Plate 1).

Plate 1. Long and "wider" leaf morphology of *Halodule uninervis* (narrow) that occurred in Karumba in 2006.

The Core meadow experienced the largest recorded increase in seagrass biomass. The mean biomass of 17.26 ± 0.93 g DW m^{-2} was almost double that of the previous biomass record of 9.80 ± 0.57 g DW m^{-2} observed in 1998 (Table 1; Figure 2). Meadow area in the Core meadow remained one of the highest throughout the monitoring period (986 ha; Table 1; Figure 3; Map 1 & 3).

The fringing meadow had decreased in area by 46% and biomass by 13% between 2005 and 2006 due to a decline near the Bynoe River mouth (Table 1; Figure 2 & 3; Map 1 & 3). Despite this decline, the fringing meadow maintained one of the highest areas over 13 years of monitoring (Table 1).

Species composition of the monitoring meadows has remained relatively constant since monitoring began in 1994, with *Halodule uninervis* (narrow) remaining the dominant species in both the Fringing and Core meadows. In 2006, *Halophila ovalis* had decreased to 4% of the total biomass in the Core meadow, its lowest level since 1997 (Figure 1). This difference was more a result of the substantial increase in the biomass of *Halodule uninervis* in the meadow rather than an actual reduction in the amount of *Halophila ovalis* present. Despite this there was a decline in the amount of *Halophila ovalis* in both the Core and Fringing meadows, from the unusually high levels of 2005.

After four years of sampling, there continued to be relatively stable numbers of *Halodule* seeds and pericarps in the Core meadow (Table 2). The exception was in 2004 when substantial meadow recovery had occurred presumably as a result from germination of seeds stored in the seed-bank. Density of *Halophila ovalis* fruits had declined by 59% from 2005 and was the lowest recorded density since sampling began in 2004 (Table 2; Map 2).

There has been consistent evidence of dugong activity on the Karumba seagrass meadows throughout the monitoring program. Field observations in 2006 indicated a high level of dugong activity with feeding trails present in at least 25% of seagrass meadow sites surveyed.

Table 1. Area and mean above-ground biomass for Karumba seagrass meadows from October 1994 to October 2006.

(Values in brackets for area are the estimate of reliability (R) (Rasheed *et al* 2001) and biomass is % change since the previous dry-season (October) survey. TOTAL is all sites pooled).

Meadow	Area (ha)												
	Oct-94	**Oct-95**	**Oct-96**	**Oct-97**	**Oct-98**	**Oct-99**	**Oct-00**	**Oct-01**	**Oct-02**	**Oct-03**	**Oct-04**	**Oct-05**	**Oct-06**
Core (1)	963 (952-974)	1072 (1058-1086)	922 (906-938)	964 (947-981)	879 (862-896)	759 (741-777)	948 (932-964)	966 (948-984)	537 (522-552)	899 (882-916)	954 (937-970)	1029 (1013-1045)	986 (967-1005)
Fringing (2)	302 (285-319)	229 (207-252)	368 (352-384)	150 (135-165)	100 (88-112)	195 (177-213)	248 (222-274)	281 (262-300)	576 (555-597)	191 (172-210)	339 (311-368)	430 (397-463)	294 (258-330)
TOTAL monitoring meadows	1265 (1246-1284)	1301 (1279-1323)	1290 (1274-1306)	1114 (1092-1136)	979 (964-994)	954 (938-970)	1196 (1169-1223)	1247 (1229-1265)	1113 (1089-1137)	1090 (1067-1113)	1293 (1248-1338)	1459 (1410-1508)	1280 (1225-1335)
Meadow	**Mean Biomass ± Standard Error (g dw m^{-2})**												
	Oct-94	**Oct-95**	**Oct-96**	**Oct-97**	**Oct-98**	**Oct-99**	**Oct-00**	**Oct-01**	**Oct-02**	**Oct-03**	**Oct-04**	**Oct-05**	**Oct-06**
Core (1)	6.20 ± 0.21	5.11 ± 0.25 (-15%)	9.60 ± 0.21 (+79%)	6.60 ± 0.49 (-29%)	9.80 ± 0.57 (+46%)	4.65 ± 0.24 (-53%)	7.49 ± 0.46 (+61%)	5.57 ± 0.29 (-26%)	1.2 ± 0.17 (-78%)	1.7 ± 0.17 (+42%)	6.43 ± 0.36 (+278%)	6.05 ± 0.33 (-5.9%)	17.26 ± 0.93 (+185%)
Fringing (2)	1.07 ± 0.24	0.80 ± 0.17 (-35%)	2.97 ± 0.53 (+234%)	2.04 ± 0.34 (no change)	2.41 ± 0.51 (+14%)	1.86 ± 0.29 (-23%)	1.94 ± 0.38 (+4%)	1.35 ± 0.30 (-39%)	0.56 ± 0.07 (-49%)	0.37 ± 0.11 (-33%)	1.03 ± 0.26 (+157%)	3.04 ± 0.55 (+195%)	2.63 ± 0.67 (-13%)
TOTAL monitoring meadows	5.0 ± 0.25	4.22 ± 0.26 (-18%)	6.13 ± 0.47 (+29%)	4.73 ± 0.4 (-12%)	7.25 ± 0.56 (+54%)	3.12 ± 0.25 (-54%)	4.6 ± 0.44 (+38%)	3.49 ± 0.33 (-26%)	0.85 ± 0.09 (- 75%)	1.3 ± 0.14 (+41%)	3.91 ± 0.38 (+226%)	4.88 ± 0.33 (+25%)	10.87 ± 1.01 (+123%)

Table 2. Mean density ± standard error 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}	*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

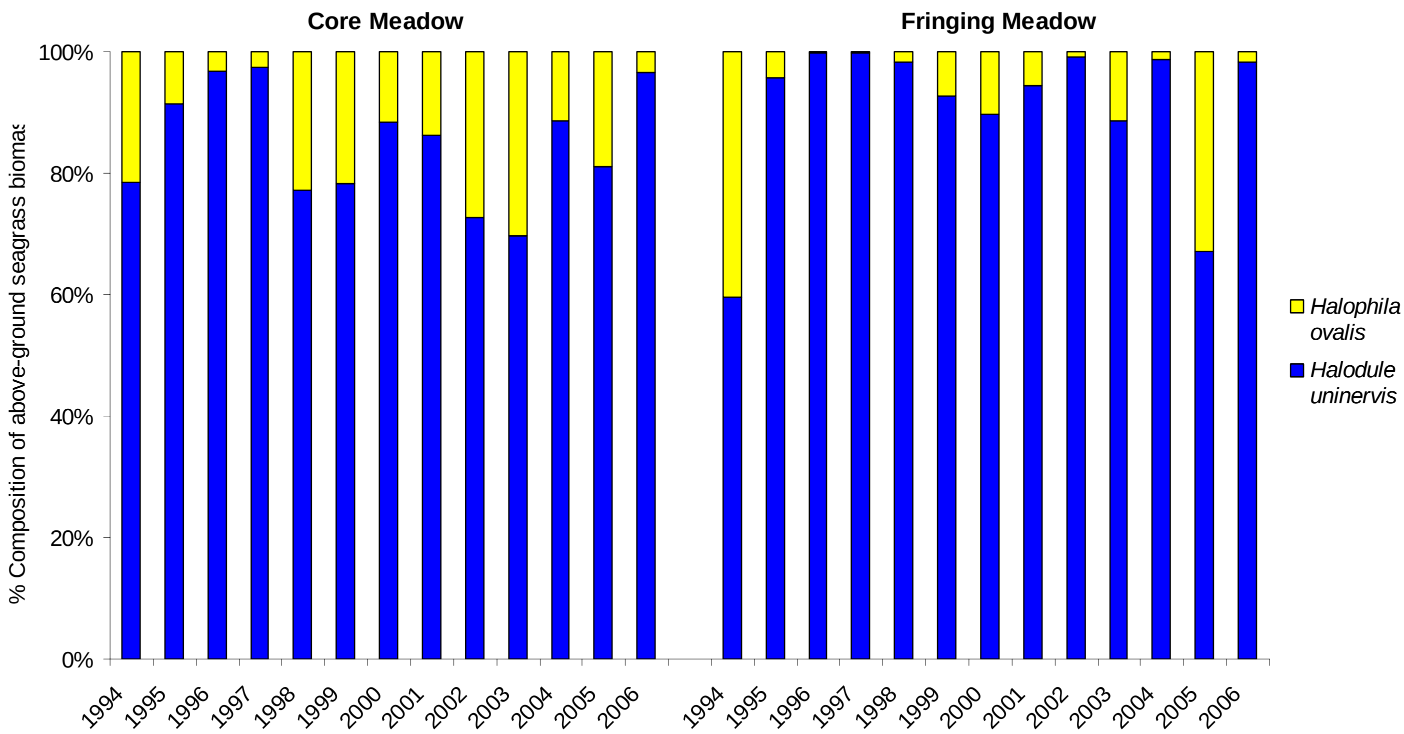


Figure 1. Percent composition of above ground biomass for seagrass species at each monitoring meadow from October 1994 to October 2006.

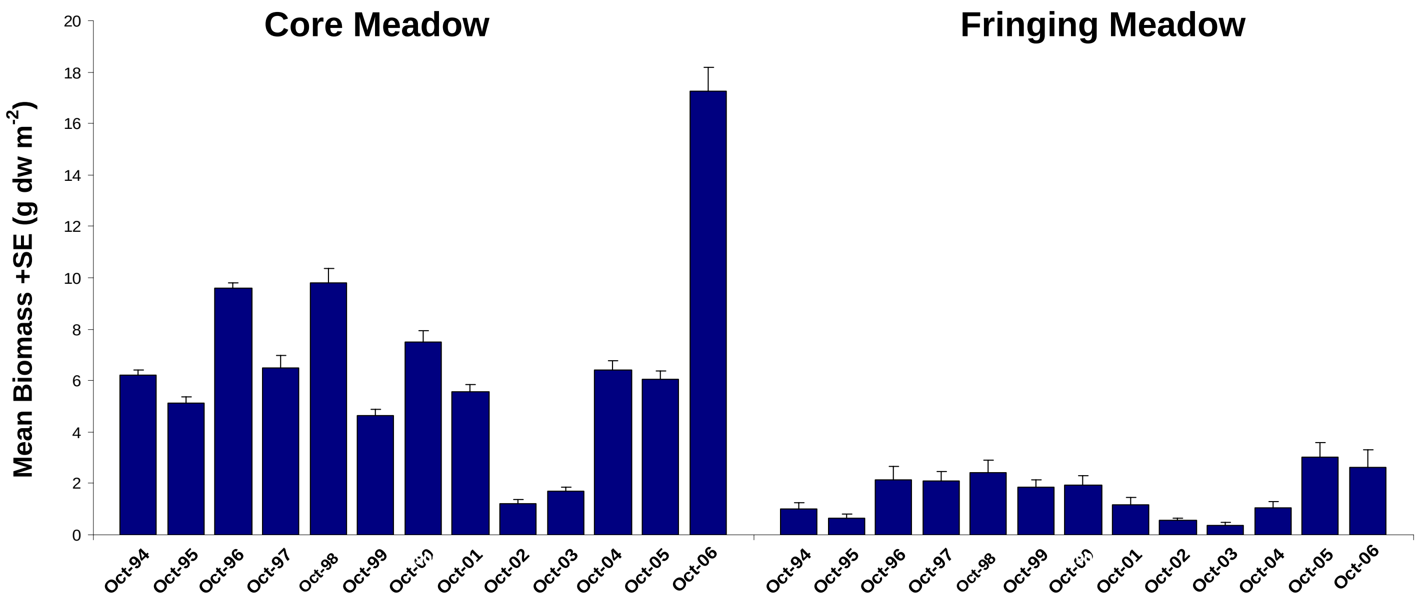


Figure 2. Mean above ground biomass of monitoring meadows (+ SE) for each October seagrass survey of Karumba.

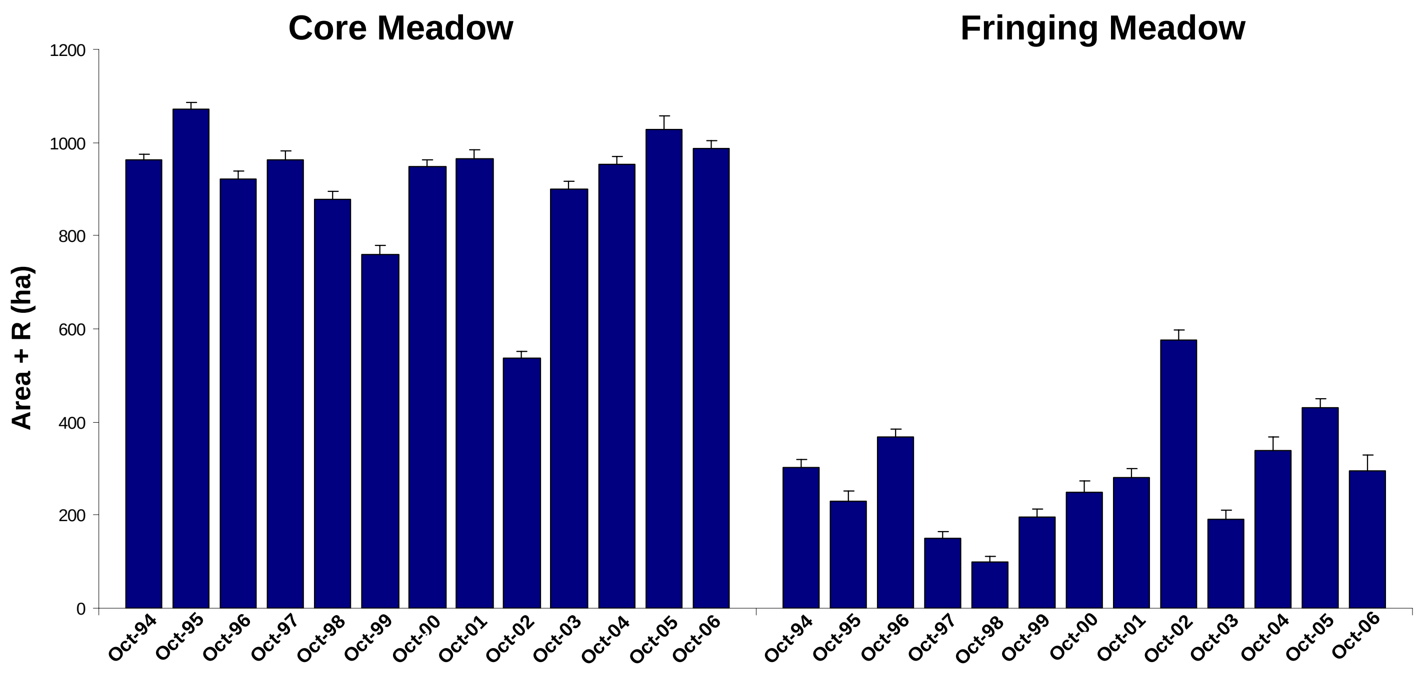
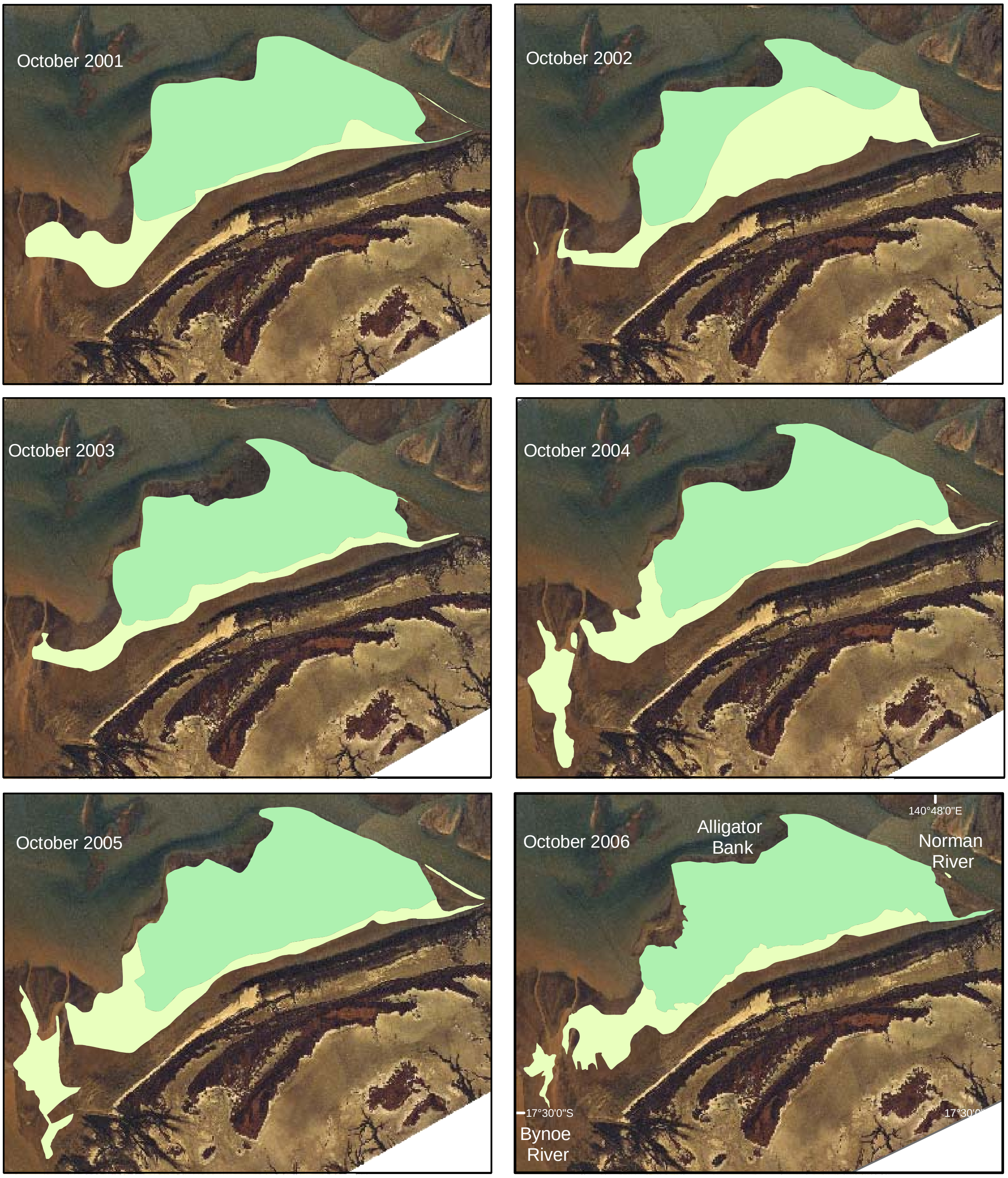


Figure 3. Area of monitoring meadows (+ estimate of reliability (R) for each October seagrass survey of Karumba.

Map 3. Changes in the Port of Karumba seagrass monitoring meadows in the past six years, October 2001 to October 2006.



LEGEND

Core monitoring meadow

Fringing monitoring meadow

N

0 1 2

Kilometres

Sampling Dates: 30-31st October 2006
Aerial photo: 15/9/1994 1:25,000

Source:
Dew, K.R., Rasheed, M.A., Taylor, H.A. and Sankey, T.L. (2007). Port of Karumba Long Term Seagrass Monitoring, October 2006. DPI&F Publication PR07-2670, (DPI&F, NFC, Cairns).

Funded by Ports Corporation Queensland and CRC Reef Research Centre.

Produced by the Marine Ecology Group, Queensland Department of Primary Industries and Fisheries, Northern Fisheries Centre, Cairns, 2007.

4. DISCUSSION

Seagrass density (biomass) had increased to the highest levels on record in 2006. The total area of the seagrass meadows was also among the largest observed during the 13 years of monitoring despite a small decline from 2005.

The dramatic increase in seagrass biomass was most likely a result of regional and local climate conditions. Lower than average temperatures, higher rainfall and increased cloud cover in Karumba, combined with an increase in the catchment area rainfall and water flow from the Norman River may all have contributed to the observed increase (Figures 4 & 5). The 12 months leading up to the October 2006 survey saw the first substantial flows of the Norman River in more than five years (Figure 5). This increased river flow was likely to have provided the first flush of nutrients from the catchment to the river mouth for several years. In tropical areas the addition of nutrients has been shown to benefit seagrass growth particularly in areas where nutrients are limited (Brodie 1995; Udy *et al.* 1999). While extreme flood events have the potential to add excessive nutrients and high sediment loads leading to eutrophication and decline in seagrasses (McKenzie 1994; Carruthers *et al.* 2002). However the relatively low flow levels for Karumba leading up to the 2006 survey were not likely to have produced these extreme flood effects.

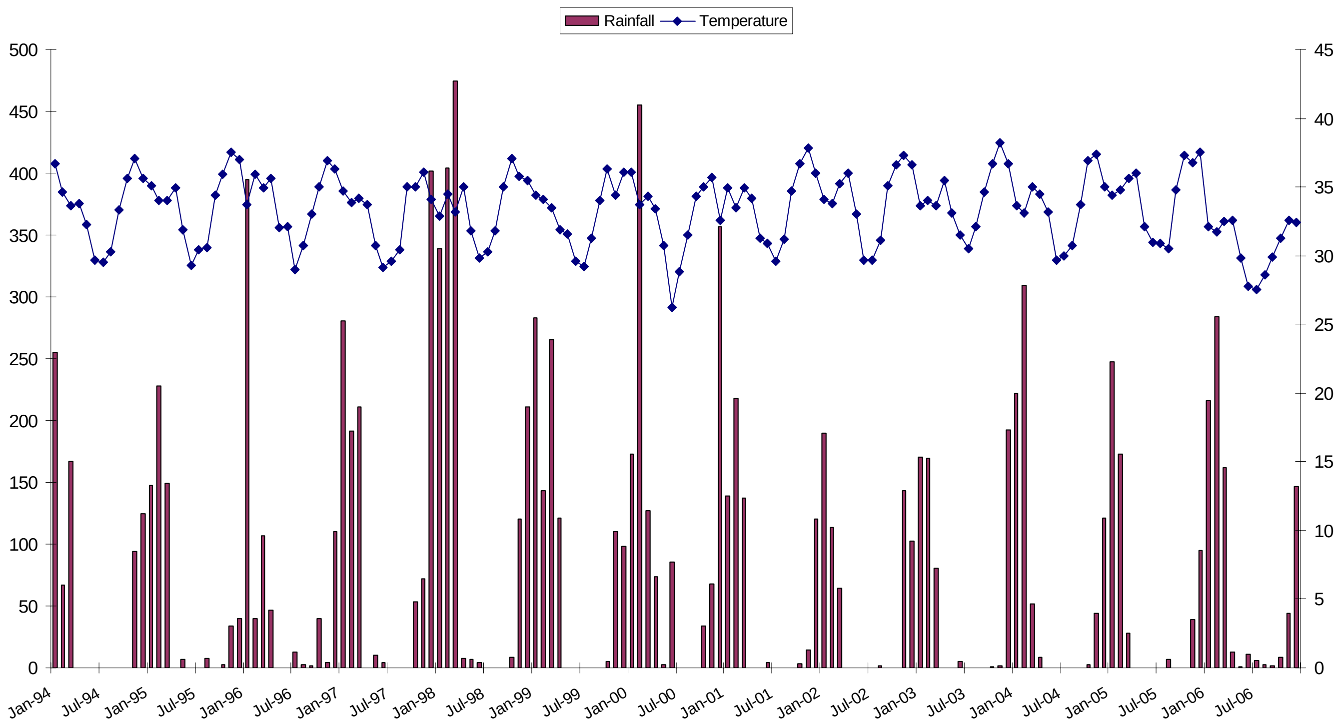
In previous years adverse climate conditions resulting in thermal stress and desiccation of intertidal seagrasses were thought to have led to seagrass decline in areas of the Gulf of Carpentaria, including Karumba and Weipa (Rasheed and Thomas 2003; Roelofs et al 2006). In 2006 Karumba experienced lower temperatures and increased cloud cover (decreased solar irradiance) compared with recent years (Figure 5). As all seagrasses in Karumba are intertidal they are particularly susceptible to exposure related stress, and these more “benign” conditions were likely to have contributed to the recorded increase in seagrass health.

The increases in seagrass biomass in Karumba may have been localised to the Karumba area, and not part of a greater regional trend. Similar seagrass meadows in Weipa in the northern Gulf of Carpentaria did not show the same increases in biomass (Taylor *et al.* 2007). Unlike Karumba the Weipa area continued to have “drought” conditions during 2006, with intertidal meadows likely to be under continued thermal stress.

The displacement of *Halophila ovalis* by *Halodule uninervis* (narrow) in Karumba was a typical successional change for tropical seagrass communities (Rasheed 2004). The expansion of meadow area in 2005 largely occurred through *Halophila ovalis*, a known colonising species that is often displaced by other slower growing species in Queensland (Rasheed 2004; Birch & Birch 1984). Additionally the majority of the small loss in meadow area from 2005 to 2006 occurred in this newly colonised area (near the Bynoe River) that had been dominated by *Halophila ovalis.*

Karumba’s seagrass meadows in 2006 were in the healthiest condition recorded since the commencement of monitoring in 1994. The higher biomass and area of seagrass were likely to have positive effects on their value as a nursery habitat and provide a more abundant food source for dugong utilising the region. 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.

(A)



(B)

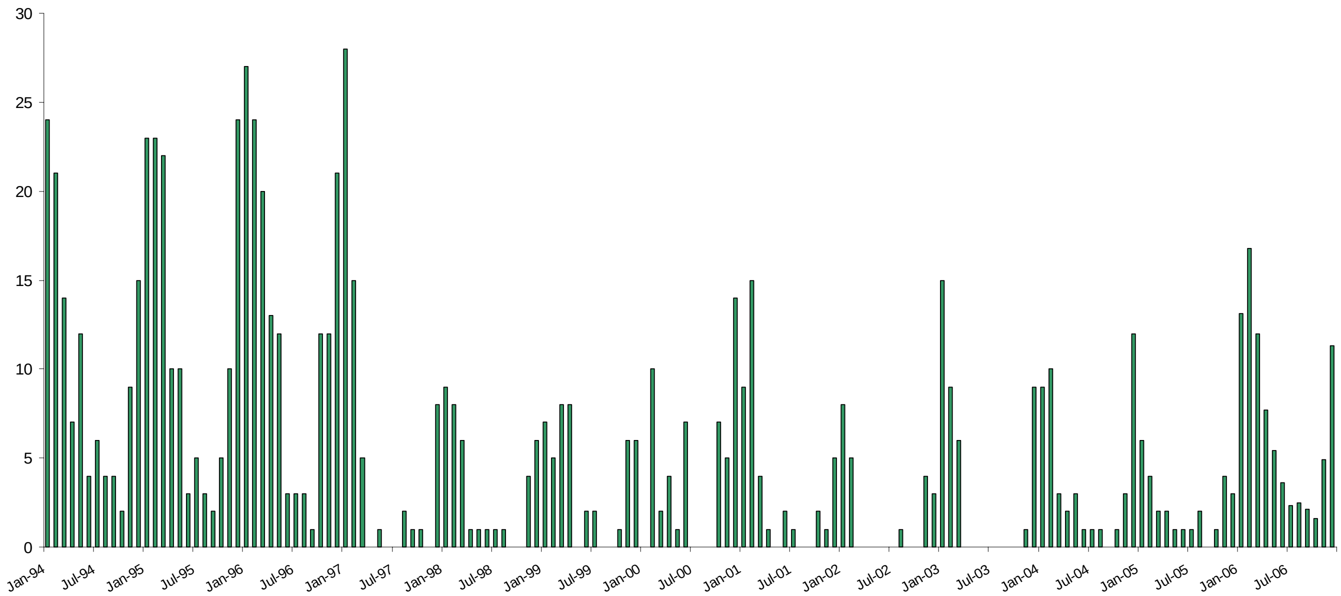
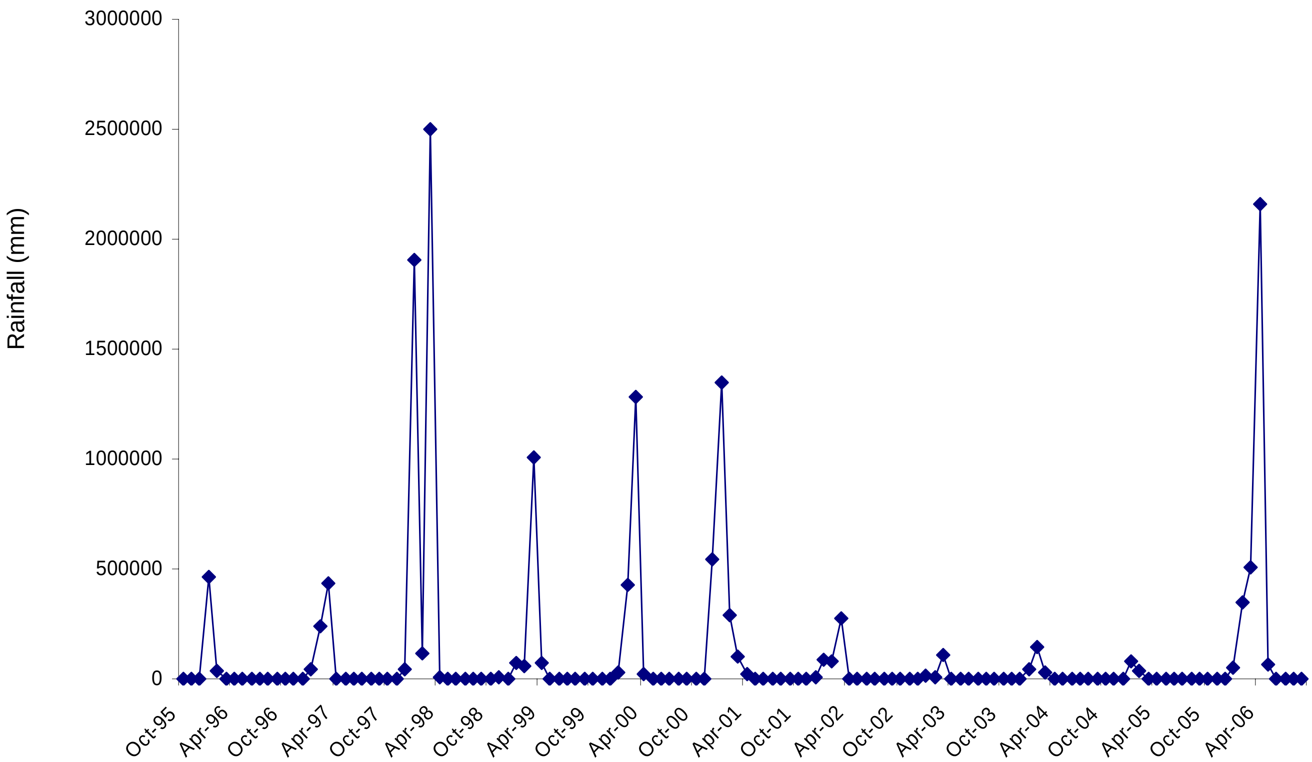


Figure 4. (A) Average monthly rainfall (mm) for Karumba and average maximum air temperature (°C) at Normanton from January 1994 to December 2006, (B) Monthly number of cloudy days at Normanton (Source: Bureau of Meteorology, 2006).

(A)



(B)

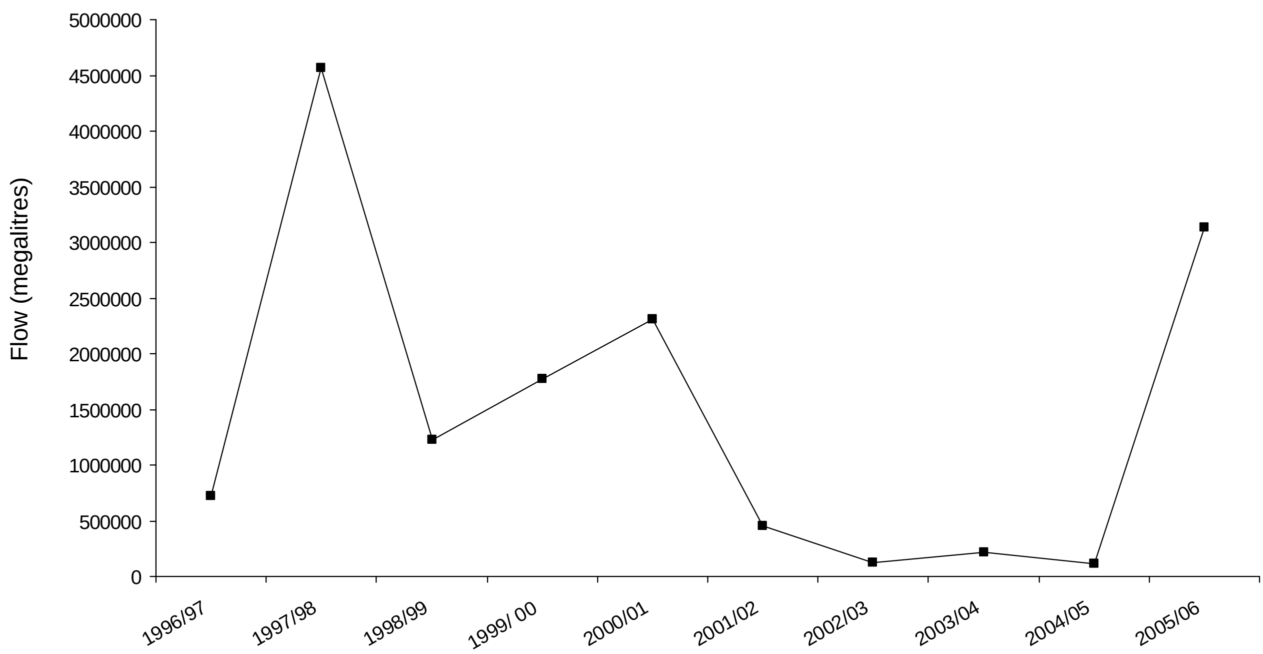


Figure 5. (A) Monthly rainfall (mm) for the Norman River catchment area* from January 1995 to December 2006, (B) Annual water flow for the Norman River (megalitres) from October 1969 to December 2006 recorded at Glenore Weir (Source: (A) Bureau of Meterology, 2006 (B) Natural Resources Mines and Water, 2006).

* The catchment area data was recorded at Normanton, Croydon, Iffley, Millungera and Esmerelda and was averaged across all locations.

5. REFERENCES

Birch, W.R. and Birch, M. (1984). Succession and pattern of tropical intertidal seagrasses in Cockle Bay, Queensland, Australia: a decade of observations. *Aquatic Botany* **19**, 343-367.

Brodie, J. (1995). The problems of nutrients and eutrophication in the Australian marine environment. *In* Zann, L.P. and Sutton, D, (eds) *State of the marine environment report for Australia: Pollution - Technical Annex 2.* (Department of the Environment Sport and Territories, Canberra).

Carruthers, T.J.B, Dennison, W.C., Longstaff, B.J., Waycott, M., Abal, E.G., McKenzie, L.J., Lee Long, W.J. (2002). Seagrass habitats of northeast Australia: Models of key processes and controls. *Bulletin of Marine Science* **71**, 1153-1169.

Mellors, J.E. (1991). An evaluation of a rapid visual technique for estimating seagrass biomass. *Aquatic Botany* **42**, 67-73.

McKenzie, L., 1994. Seasonal changes in biomass and shoot characteristics of a Zostera capricorni Aschers. dominant meadow in Cairns Harbour, Northern Queensland. *Australian Journal of Marine and Freshwater Research* **45**, 1337-1352.

Rasheed, M.A. (2004). Recovery and succession in a multi-species tropical seagrass meadow following experimental disturbance: the role of sexual and asexual reproduction. *Journal of Experimental Marine Biology and Ecology* **310**, 13 - 45.

Rasheed, M.A. and Thomas, R. (2003). 'Port of Karumba Long Term Seagrass Monitoring, Progress Report - October 2002. Report to the Ports Corporation of Queensland. (Queensland Department of Primary Industries: Northern Fisheries Centre, Cairns) 10 pp.

Rasheed, M.A., Roelofs, A.J., Thomas, R. and Coles, R.G. (2001). 'Port of Karumba Seagrass Monitoring - First 6 Years.' EcoPorts Monograph Series No. 20 (Ports Corporation of Queensland, Brisbane) 38pp.

Rasheed, M.A., Lee Long, W.J., McKenzie, L.J., Roder, C.A., Roelofs, A.J. and Coles, R.G. (1996). Port of Karumba Seagrass Monitoring, Baseline Surveys - Dry Season (October) 1994 and Wet Season (March) 1995. 'EcoPorts Monograph Series No. 4 (Ports Corporation of Queensland, Brisbane) 47pp.

Roelofs, A.J., Rasheed, M.A., Thomas, R., McKenna, S. and Taylor, H.A. (2006). Port of Weipa Long-Term Seagrass Monitoring, 2003 - 2005. Ecoports Monograph Series (in prep).

Taylor, H.A., Rasheed, M.A., Sankey, T.L. and Roelofs, A.J. (2007). Port of Weipa Long Term Seagrass Monitoring, August 2006. DPI&F Publication PR07-2671 (DPI&F, Northern Fisheries Centre, Cairns), 20 pp.

Udy, J.W., Dennison, W.C.. Lee Long, W. and McKenzie, L.J., 1999. Responses of seagrass to nutrients in the Great Barrier Reef, Australia. Marine Ecology Progress Series **185**, 257-271.

6. APPENDIX 1

Results of one-way ANOVA for mean above ground biomass versus year for the Core Monitoring (meadow 1) at Karumba 1994 to 2006.

Core Monitoring Meadow	DF	MS	F	P
Between Years	12	768.835	90.53	< 0.0001
Within Years	673	8.493		
Total	685			

Results of Least Significant Difference (LSD) pairwise comparisons of mean above ground biomass (g DW m^{-2}) for the core monitoring meadow. Means that share the same letter group are not significantly different.

Year	Mean biomass
1994	6.20 a
1995	5.12 be
1996	9.60 c
1997	6.60 ad
1998	9.80 c
1999	4.65 e
2000	7.49 d
2001	5.57 abe
2002	1.19 f
2003	1.67 f
2004	6.43 ad
2005	6.05 ab
2006	17.26 g