Department of Employment, Economic Development and Innovation

Long-Term Seagrass Monitoring in the Port of Mourilyan

November 2010

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EXECUTIVE SUMMARY

This report details results from the October/November 2010 seagrass monitoring for the Port of Mourilyan, conducted as part of the annual long-term monitoring program. The program was developed following a baseline survey in December 1993 and examines selected representative seagrass meadows in Mourilyan Harbour. Total area of each monitoring meadow, species composition and seagrass density (above-ground biomass) were measured for comparison with previous surveys. The program is used to assess the marine environmental health of the port and as a tool to ensure that port operations and maintenance do not have an adverse effect on the marine environment and forms a key location in the assessment of the health of Queensland's seagrass and fisheries habitats.

In 2010 seagrasses in Mourilyan Harbour had declined to a critical level. Three of the five monitoring meadows were no longer present and the two remaining meadows only consisted of isolated remnant patches. These losses have added to declining trends for seagrasses in Mourilyan that have occurred over recent years, resulting in seagrasses reaching their lowest area and abundance recorded in the monitoring program. Of greatest concern is the complete loss of the previously dense and highly productive *Zostera capricorni* seagrass meadow that has been a permanent feature of Mourilyan Harbour during the 17 years of monitoring. The causes of the continued seagrass declines were potentially related to another season of high rainfall and catchment water quality issues. However, in the absence of any local water quality monitoring information, it is difficult to define the exact causes of decline. It is highly unlikely that port activities were behind the seagrass changes as there have been no significant changes in port operations in recent years. However, due to the fragile condition of seagrass in Mourilyan Harbour extra caution should be applied to future activities that have the potential to impact on seagrass communities.

The highly vulnerable state of seagrasses in Mourilyan Harbour in 2010 means that measures to reduce further impacts to their health and resilience may be required to assist in their longer term protection and recovery. The relationships observed between seagrass biomass and climate variability are indicative only, and the monitoring program would be enhanced in the long-term with additional investigations and monitoring measures. Further investigation into water quality within the Port of Mourilyan for example would greatly assist in determining whether land-based run-off is influencing the decline of seagrasses within the port. Given the fragile state of seagrasses, continued monitoring as well as further investigations of the drivers of seagrass change, capacity for recovery and indicators of stress are recommended to ensure their longer term recovery and to effectively manage these marine habitats.

INTRODUCTION

Background

Seagrass forms an ecologically valuable component of Mourilyan Harbour's marine environment (Thomas et al. 2006). Seagrasses also show measurable growth responses to a broad range of water quality parameters that make them good "indicators" of water quality conditions (Dennison et al. 1993) and overall marine environmental health. In recognition of this importance, Ports North in conjunction with Fisheries Queensland has developed a long-term seagrass monitoring program for the Port of Mourilyan that began in 1993. This program aims to monitor the health of Mourilyan Harbour's marine environment and fisheries habitats while providing for the ecologically sustainable use and development of the associated port and shipping facilities. Port activity at Mourilyan includes export of live cattle and bulk raw sugar on a regular basis. The port is also utilised by a small commercial fishing fleet and recreational vessels. Port maintenance includes an annual bed levelling campaign of short duration to maintain navigable depth in the berth areas.

Seagrass baseline surveys and a three year monitoring program in the Port of Mourilyan from December 1993 to July 1997 established seasonal and inter-annual variation in seagrass distribution and abundance (McKenzie et al. 1996). The current annual monitoring program commenced in 2000. These annual surveys have found that changes to seagrass meadows are likely linked to local and regional climate conditions or non-point source inputs in the broader Moresby River catchment (Thomas and Rasheed 2003; 2004; McKenna et al. 2005).

This report details the results of the ninth annual long-term seagrass monitoring survey conducted in October/November 2010.

Objectives

The objectives of the 2010 seagrass monitoring survey were to:

1. Map seagrass distribution and abundance of long-term monitoring meadows in the Port of Mourilyan.

2. Assess changes in these monitoring meadows since November 2009, and compare results with the long-term monitoring dataset and other monitoring programs throughout Queensland.

3. Incorporate results into the Ports North Geographic Information System (GIS) database for the Port of Mourilyan.

METHODS

Five seagrass meadows have been the subject of annual monitoring at Mourilyan Harbour since baseline surveys of the entire port limits in 1993 (see McKenzie et al. 1998). The five meadows were selected on the basis that they represent the range of seagrass species and habitats within the port limits. These five meadows were again targeted for the 2010 survey. In addition, an aerial reconnaissance of seagrasses outside of the monitoring meadows was also conducted at the time of the monitoring survey.

Seagrass surveys were conducted using two field techniques: intertidal aerial and subtidal boat surveys. Intertidal seagrasses were surveyed using a helicopter at low tide on October 6th 2010 when these habitats were exposed. Helicopter surveys are an effective and efficient means to survey large areas of intertidal seagrass habitat. Four of the five monitoring meadows were intertidal and surveyed using this technique; the Bradshaw, Lily, Seaforth Edge and Seaforth Bank monitoring meadows. Subtidal seagrasses in the Channel meadow and some deeper sites of Seaforth Bank and Seaforth Edge were surveyed from a boat on November 18th 2010 using a real-time underwater video camera and a Van Veen sediment grab. This camera technique provides an image of the sea floor from which visual estimates of above-ground biomass were made. A detailed description of methodology and survey techniques can be found in McKenzie et al. (1998) and Thomas and Rasheed (2001). The Van Veen grab was used to confirm seagrass species and to determine sediment composition.

Geographic Information System

Spatial data from the field surveys were incorporated into the Geographic Information System (GIS) established for Mourilyan Harbour. This database includes data from all previous baseline and monitoring surveys. Two GIS layers were created for this survey:

- **Site data** - contains above-ground biomass (for each species present), depth below mean sea level (dbMSL) (for subtidal meadows), sediment type, time, Global Positioning System (GPS) fixes (± 5 m) 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 (Thomas and Rasheed 2003) (Table 1). Abundance categories (light, moderate, dense) were assigned to community types according to above-ground biomass of the dominant species (Table 2).

Table 1 Nomenclature for community types in Mourilyan Harbour, October/November 2010.

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 in Mourilyan Harbour, October/November 2010.

Density	Mean above-ground biomass (g DW m^{-2})			
	Halodule uninervis (narrow)	*Halophila ovalis/ Halophila decipiens*	*Halodule uninervis* (wide)	*Zostera capricorni*
Light	< 1	< 1	< 5	< 20
Moderate	1 - 4	1 - 5	5 - 25	20 – 60
Dense	> 4	> 5	> 25	> 60

Each meadow was assigned a mapping precision estimate (in metres) based on mapping methodology utilised for that meadow (Table 3). Mapping precision ranged from ± 5m for the intertidal meadows to ± 30 m for the subtidal Channel meadow (Table 3). 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 in Mourilyan Harbour, October/November 2010.

Mapping precision	Mapping methodology
± 5 m	Meadow boundaries mapped in detail by dGPS from helicopter. Intertidal meadows completely exposed or visible at low tide. Relatively high density of mapping and survey sites. Recent aerial photography aided in mapping.
± 10 m	Some intertidal meadow boundaries mapped in detail by dGPS from helicopter. Most meadow boundaries determined by camera survey sites. Reliability based on distance between survey sites.
± 30 m	Meadow boundary interpreted from camera surveys. Meadow entirely subtidal. Relatively high density of survey sites. Recent aerial photography aided in mapping.

RESULTS

Seagrass Species, Distribution and Abundance

Two seagrass species (from one family) were present in the monitoring meadows in October/November 2010 (for a full description of species and distribution refer to baseline survey McKenzie *et al.* 1996):

Family	Species			
HYDROCHARITACEAE Jussieu	*Halophila decipiens* Ostenfield		*Halophila ovalis* (R. Br.) Hook. F.	

Of the 187 sites (57 subtidal and 130 intertidal) surveyed in October/November 2010, 20.5% contained seagrass, which was isolated to two of the five monitoring meadows; the Channel (5) and Lily (2) meadows (Map 1). Total area of seagrass habitat in these meadows was 0.52 ± 0.89 ha (Table 5a). Mean above-ground biomass was 0.57 ± 0.62 g DW m^{-2} for the Lily (2) meadow while the Channel meadow only had one site that had seagrass present and therefore a mean biomass was not obtainable (Table 5b). Both meadows were characterised as light in cover based on the mean biomass for the most dominant species present (Table 4, Map 1).

Table 4 Description of the five Mourilyan Harbour monitoring meadows from the October /November 2010 monitoring survey.

Monitoring Meadow	No. of sites	Community Type	Habitat type	Meadow cover	Species Present
Bradshaw	n/a	Meadow not present	Intertidal	Meadow not present	No seagrass present
Lily	10	Light *H. ovalis*	Intertidal	Isolated patches	*H. ovalis*
Seaforth Bank	n/a	Meadow not present	Intertidal/Subtidal	Meadow not present	No seagrass present
Seaforth Edge	n/a	Meadow not present	Intertidal	Meadow not present	No seagrass present
Channel	1	Light *H.decipiens*	Subtidal	Isolated patch	*H.decipiens*

n/a – no sites that had seagrass present

Comparison with previous monitoring surveys

In 2010 seagrasses in Mourilyan Harbour were further reduced compared to the 2009 survey and remain well below their historical peak densities and distribution (Table 5; Figures 1a & b; Map 2; Appendix 1). Only two of the five monitoring meadows (Lily and Channel) remained in 2010 and these consisted of only small isolated patches of pioneering *Halophila* species. The previously stable Bradshaw meadow was completely absent for the first time since surveys began in 1993, while the Seaforth Bank and Seaforth Edge meadows have been absent since 2008, when only remnant patches were found in the area. *Zostera capricorni,* a species that has always been found in Mourilyan harbour was not found at all in 2010, while *Halodule uninervis* has not been present for the last two years (Table 5; Figures 1a & b).

The previously large, subtidal Channel (5) meadow contained only one isolated patch of *Halophila decipiens* in 2010. This meadow has been variable from year to year throughout the monitoring program, with complete loss of seagrass in 2000 and 2009. The 2010 survey found a small isolated patch of *Halophila decipiens* at the northern end of the meadow (Table 5; Map 2, Figure 1b).

The small Lily meadow remained as only remanent patches of *Halophila* in 2010. The peak area for this meadow of 1.9 ha was recorded in 2003. The pioneering seagrass species *Halophila ovalis* continues to prevail in this meadow with no evidence of the previously dominant *Zostera capricorni* (Table 5; Map 2, Figure 1a).

The Bradshaw *Zostera capricorni* meadow has been the most stable and consistent meadow throughout the long-term monitoring program. Meadow area has remained similar throughout the length of the program while biomass has been variable but never absent (Table 5; Figure 1a). There was a significant 46% decline in biomass from 2008 to 2009 and subsequently the meadow completely disappeared in the 2010 (Table 5; Map 2; Appendix 1).

In 2010, survey results showed no seagrass present in the intertidal *Halophila* meadows (Seaforth Bank and Seaforth Edge). In recent years these meadows have been highly variable. In 2000 & 2006, the Seaforth Edge meadow had declined to the point where no above-ground structures remained (Table 5; Figures 1a & b). This meadow showed initial signs of recovery in November 2007 following Cyclone Larry but significantly declined again in 2008 with only a small remnant patch of *Halophila ovalis* remaining. The Seaforth Edge meadow has been comprised of isolated patches of light seagrass for the last 8 years however no seagrass was recorded in 2010 (Table 5; Map 2; Figure 1b).

The distribution of seagrass in the Seaforth Bank meadow has been declining since 2006 with seagrass absent for the last two years. The Seaforth Bank meadow had contracted in area to a collection of small isolated patches in 2008 (Map 1) and had one of the lowest recorded areas in the monitoring program. A species change occurred in the Seaforth Bank meadow in 2008 from being previously dominated by *Halophila* species to being dominated by *Halodule uninervis* (narrow), however, no seagrass has been present in both 2009 and 2010. This meadow was also absent in 2003 (Table 4; Map 1; Figure 1a).

Map 1. Port of Mourilyan seagrass distribution and community types, November 2010.

Legend

Community Type

Light *Halophila decipiens*

Light *Halophila ovalis*

Monitoring Meadows Present in 2010

5. Channel

2. Lily

Monitoring Sites 2010

No seagrass

Seagrass present

Source: Fairweather, C.L., McKenna, S.A. and Rasheed, M.A. (2011). Long term seagrass monitoring in the Port of Mourilyan - November 2010. © Ports North and the State of Queensland through Department of Employment, Economic Development and Innovation. Produced by the Marine Ecology Group, Fisheries Queensland, 2011. (Aerial photograph courtesy Beach Protection Authority, 1:25000; 1/07/2000).

Table 5a. Area (ha) for Mourilyan Harbour monitoring meadows from December 1993 to October/November 2010 (values in brackets represent reliability estimate range).

Meadow	Area (ha) (R)														
	Dec 1993	**Dec 1994**	**Dec 1995**	**Dec 1996**	**Dec 2000**	**Dec 2001**	**Dec 2002**	**Dec 2003**	**Nov 2004**	**Nov 2005**	**Nov 2006**	**Nov 2007**	**Nov 2008**	**Nov 2009**	**Nov 2010**
Bradshaw (1)	3.8 (1.9-6.2)	2.6 (1.8-3.4)	2.8 (2.0-3.7)	3.1 (2.1-4.1)	3.5 (2.2-4.8)	3.0 (2.5-3.5)	4.2 (3.7-4.7)	3.6 (3.1-4.1)	3.3 (2.8-3.8)	3.0 (2.5-3.5)	2.7 (2.2-3.3)	3.5 (3-4)	3.0 (2.5-3.5)	2.5 (2.0-3.0)	NP
Lily (2)	1.0 (0.1-2.3)	1.1 (0.7-1.6)	0.8 (0.6-1.2)	0.7 (0.5-0.9)	1.1 (0.9-1.4)	1.8 (1.4-2.2)	1.4 (1.0-1.8)	1.9 (1.5-2.3)	1.1 (0.7-1.5)	1.2 (0.8-1.6)	0.5 (0.3-0.7)	0.6 (0.4-0.8)	0.5 (0.3-0.7)	0.3 (0.09-0.5)	0.4 (0.15-0.65)
Seaforth Bank (3)	22.3 (16.0-29.0)	27.7 (22.4-33.3)	23.2 (17.5-29.3)	19.9 (14.1-25.7)	8.4 (2.5-14.3)	30.0 (27.2-32.8)	0.8 (0.3-1.3)	NP	6.5 (5.4-7.6)	13.1 (10.4-15.8)	4.1 (2.9-5.2)	2.0 (0.7-3.3)	1.0 (0.3-1.4)	NP	NP
Seaforth Edge (4)	2.7 (2.6-7.4)	3.1 (1.8-4.5)	3.4 (1.5-5.6)	3.4 (0.9-5.9)	NP	5.3 (1.1-9.5)	3.0 (1.7-4.3)	0.2 (0.1-0.3)	3.3 (2.4-4.2)	3.3 (2.6-4.0)	NP	1.6 (0.7-2.4)	0.1 (0-0.2)	NP	NP
hannel (5)	20.2 (15.9-24.8)	37.3 (31.1-43.7)	55.7 (46.7-64.9)	30.5 (15.5-45.5)	NP	34.3 (24.4-44.2)	24.4 (15.5-33.3)	20.1 (12.5-27.7)	38.5 (23.2-53.8)	47.9 (34.0-61.8)	40.9 (29.7-52.1)	22.0 (14.3-29.7)	27.8 (20.2-35.4)	NP	0.11 (0.001-0.75)
Total (ha) COMBINED	49.9 (36.6-69.7)	71.6 (57.3-85.6)	85.9 (68.2-104.6)	57.6 (33.2-82.0)	13.0 (6.3-19.7)	74.4 (56.6-92.2)	35.4 (23.1-47.7)	25.8 (17.2-34.4)	52.7 (34.5-70.9)	68.5 (50.3-86.7)	48.2 (35.1-61.3)	29.7 (19.1-40.2)	32.3 (23.3-41.2)	2.8 (2.1-4.5)	0.52 (0.001-1.41)

NP signifies seagrass not present.

Note: no data collected in 1997, 1998 and 1999.

Table 5b. Seagrass mean above-ground biomass (g DW m^{-2}) and standard error for Mourilyan Harbour monitoring meadows from December 1993 to October/November 2010.

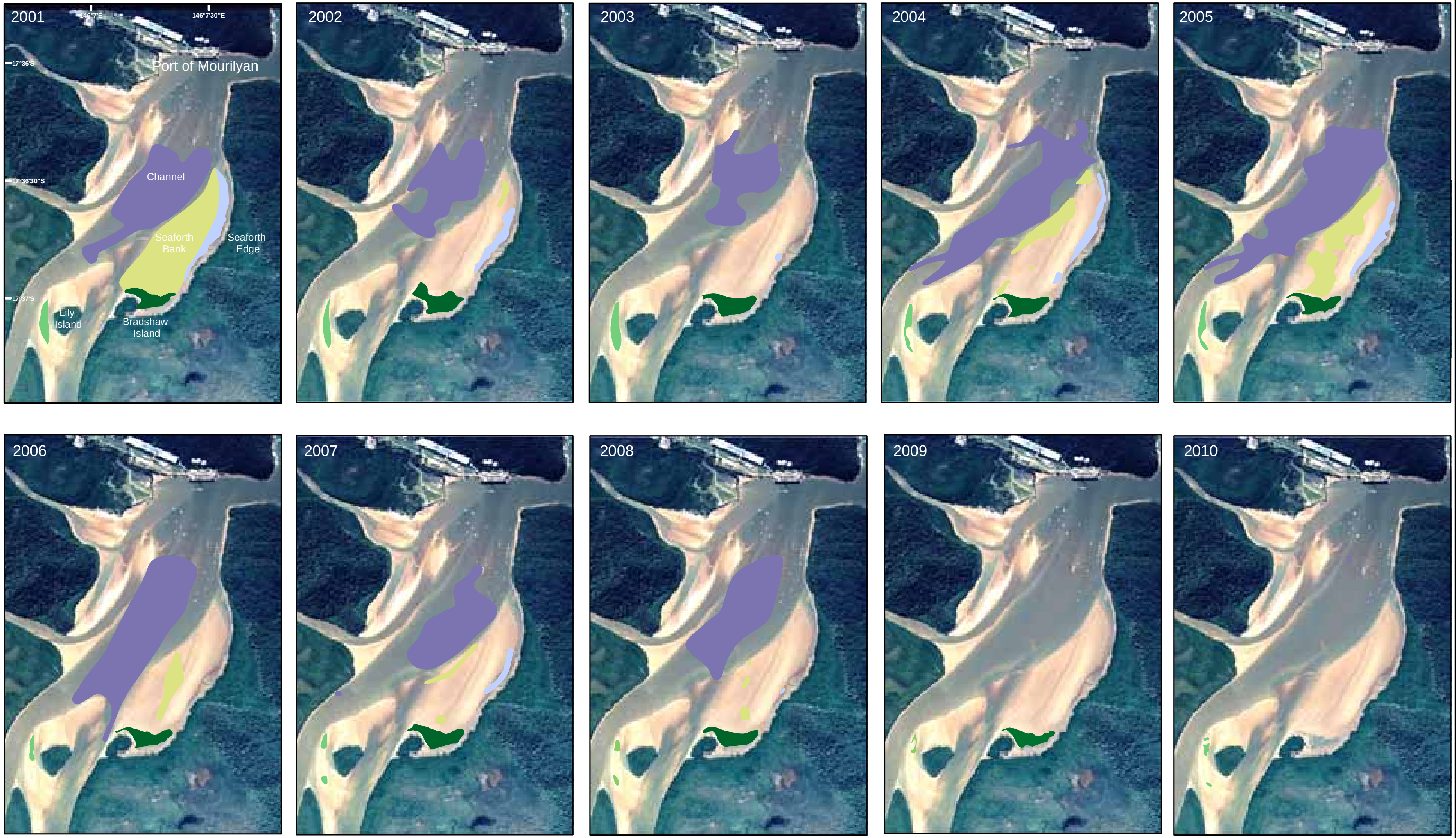
Meadow	Mean biomass ± SE (g DW m^{-2})														
	Dec 1993	**Dec 1994**	**Dec 1995**	**Dec 1996**	**Dec 2000**	**Dec 2001**	**Dec 2002**	**Dec 2003**	**Nov 2004**	**Nov 2005**	**Nov 2006**	**Nov 2007**	**Nov 2008**	**Nov 2009**	**Nov 2010**
Bradshaw (1)	42.2 ± 6.0	45.1 ± 2.1	49.3 ± 1.3	59.5 ± 2.0	17.6 ± 1.3	35.9 ± 5.4	32.1 ± 2.0	21.6 ± 3.4	59.3 ± 7.2	34.1 ± 3.7	46.5 ± 4.2	21.4 ± 2.4	28.8 ± 3.5	15.5 ± 2.9	NP
Lily (2)	16.1 ± 4.4	30.5 ± 2.2	29.1 ± 0.9	29.8 ± 1.5	7.7 ± 0.6	5.6 ± 1.6	20.7 ± 3.1	5.1 ± 2.4	12.3 ± 3.6	0.2 ± 0.1	2.4 ± 0.9	2.8 ± 0.6	2.6 ± 1.8	0.04 ± 0.02	0.56 ± 0.62
Seaforth Bank (3)	1.0 ± 0.1	0.7 ± 0.2	1.1 ± 0.1	2.8 ± 0.2	0.2 ± 0.04	2.5 ± 0.5	0.3 ± 0.2	NP	0.6 ± 0.2	0.03 ± 0.01	0.06 ± 0.02	NR	0.03 ± 0.01	NP	NP
Seaforth Edge (4)	2.2 ± 0.3	2.2 ± 0.3	1.6 ± 0.1	3.4 ± 0.3	NP	2.8 ± 0.4	1.6 ± 0.3	0.02 ± 0.02	1.2 ± 0.4	0.2 ± 0.1	*NP	0.5 ± 0.3	NR	NP	NP
Channel (5)	0.5 ± 0.1	1.8 ± 0.3	1.3 ± 0.1	3.8 ± 0.3	NP	0.6 ± 0.1	1.0 ± 0.2	0.7 ± 0.3	1.0 ± 0.3	1.3 ± 0.5	2.4 ± 0.6	2.5 ± 0.4	1.5 ± 0.3	NP	NR

NR (Not recorded) - seagrass present but too sparse to record biomass;

NP - seagrass not present.

Note: no data collected in 1997, 1998 and 1999.

Map 2. Port of Mourilyan seagrass monitoring meadows from December 2001 to November 2010.



Legend

Seagrass Meadow ID

- Seaforth Edge
- Seaforth Bank
- Channel
- Lily
- Bradshaw

0 0.4 0.8
Kilometers

MARINE ECOLOGY GROUP

Ports North

Queensland Government

Source: Fairweather, C.L., McKenna, S.A. and Rasheed, M.A. (2011).
Long term seagrass monitoring in the Port of Mourilyan - November 2010. © Ports North and the State of Queensland through Department of Employment, Economic Development and Innovation. Produced by the Marine Ecology Group, Fisheries Queensland, 2011.(Aerial photograph courtesy Beach Protection Authority, 1:25000; 1/07/2000).

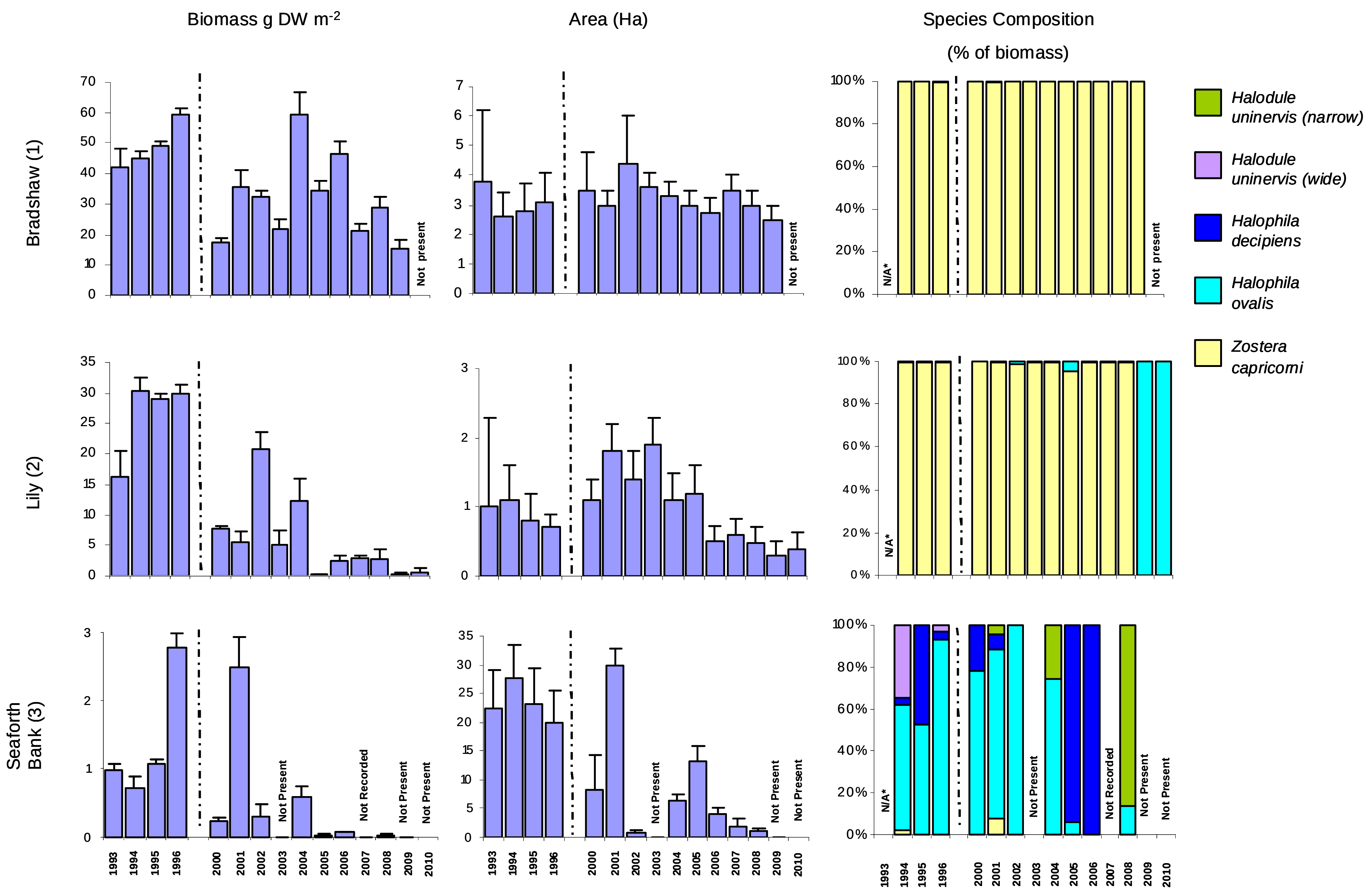


Figure 1a Changes in biomass, area and species composition for monitoring meadows from 1993 to 20010 (Biomass error bars = SE; Area error bars = "R" reliability estimate) (dashed line = four-year gap between surveys; Not Recorded = seagrass present but too sparse to record biomass; Not Present = seagrass not present).

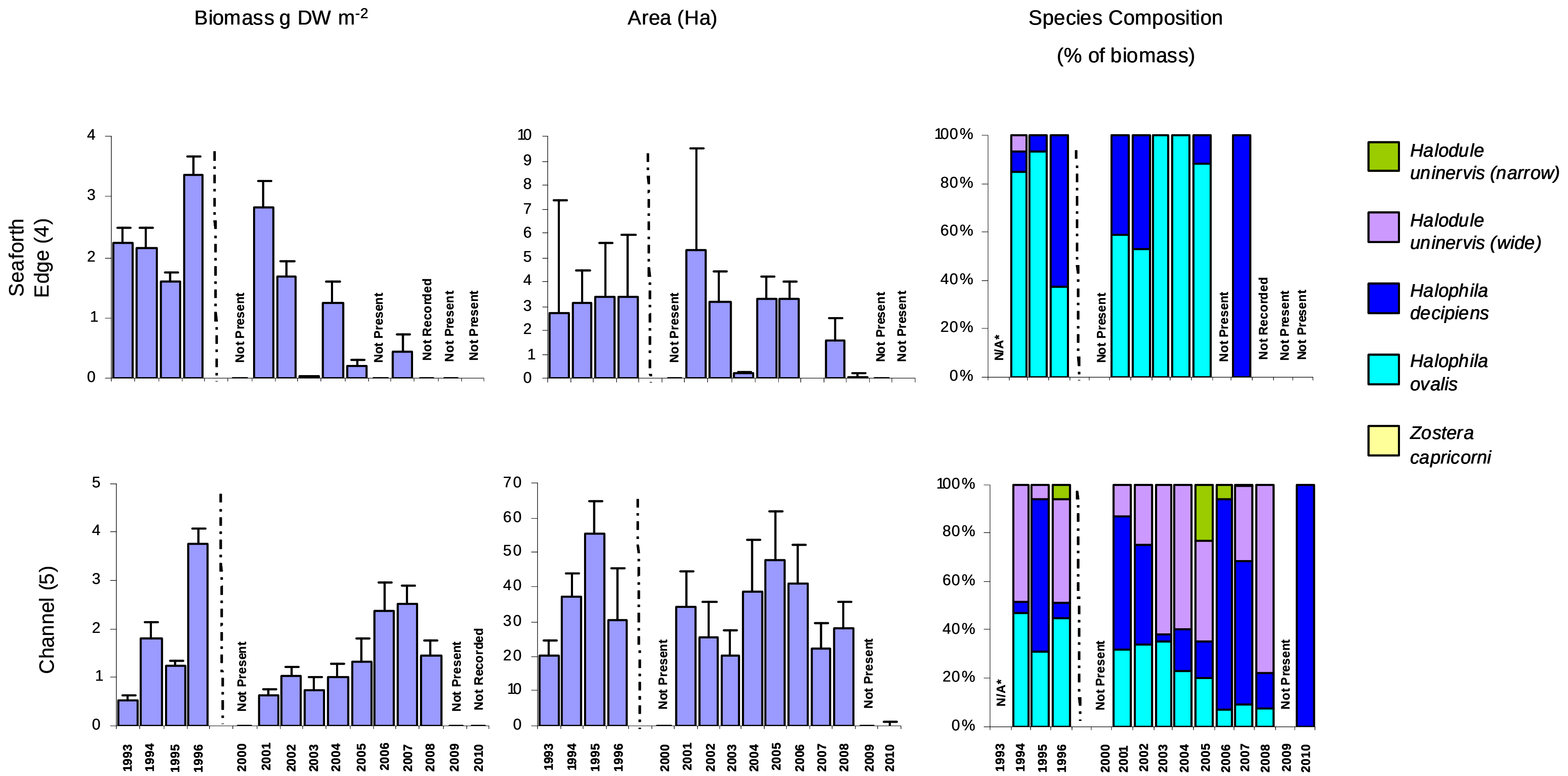


Figure 1b Changes in biomass, area and species composition for monitoring meadows from 1993 to 2010 (Biomass error bars = SE; Area error bars = "R" reliability estimate) (dashed line = a four-year gap between surveys; N/A* = % composition of biomass not available; Not Recorded = seagrass present but too sparse to record biomass; Not Present = seagrass not present).

Mourilyan Climate Data

Total annual rainfall in Mourilyan Harbour during 2010 was 3962mm with the majority of this recorded during the wet season early in the year (Figure 2a). This was above the 25 year average of 3551mm and is the highest annual rainfall since 2001 (Figures 2a & b).

The average maximum daily temperature in 2010 was 28.2°C. This was above the 30 year average of 27.9 °C (Figure 2a).

The amount of tidal exposure in 2010 was considerably lower than previous years with only 83 hours of exposure recorded, the lowest on record in the dataset (Figures 3 & 4). Low exposure compounded with reduced temperatures may indicate lower thermal and desiccation stress during 2010 but also a reduced light environment for seagrass meadows.

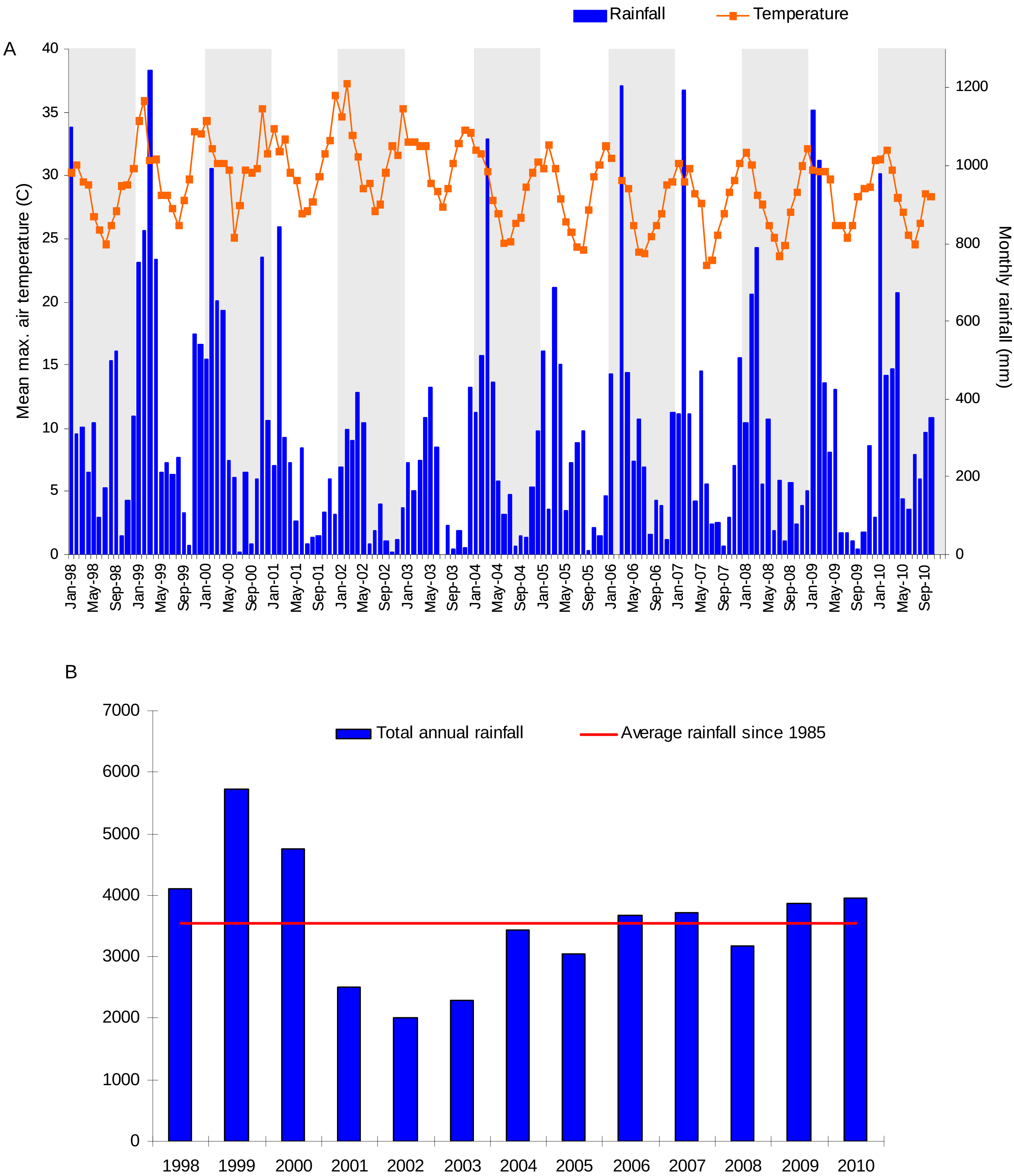


Figure 2 (A) Mourilyan Harbour mean monthly maximum temperature and total monthly rainfall (B) Total annual rainfall recorded at Mourilyan Harbour from 1998 to 2010 (Source: Australian Bureau of Meteorology, 2010).

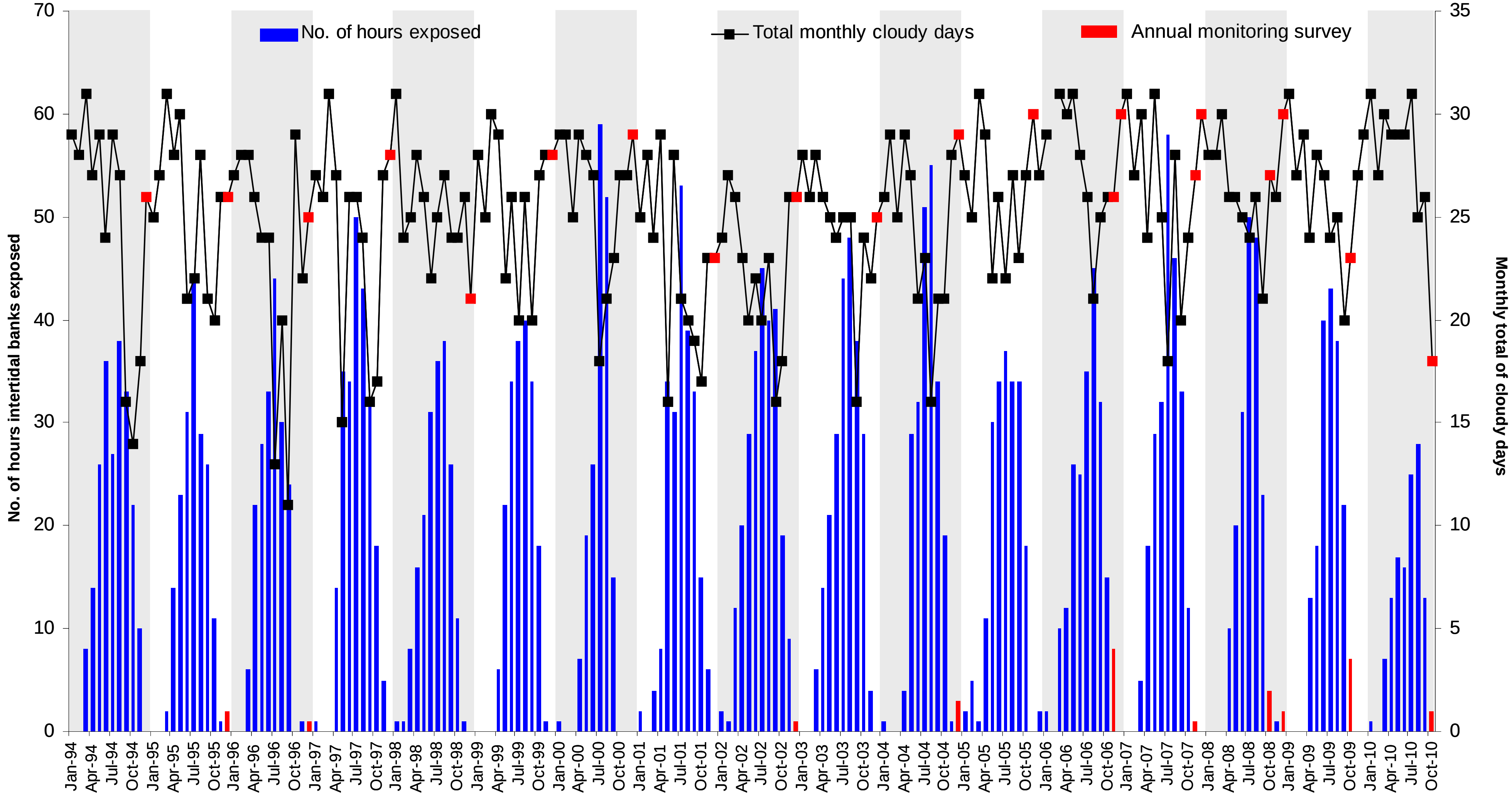


Figure 3 The total number of daylight hours per month that intertidal banks were exposed (<0.8m tidal height) with number of cloudy days per month, recorded from 1994 to 2010 (Source: Maritime Safety Queensland, 2010 and Bureau of Meteorology 2010).

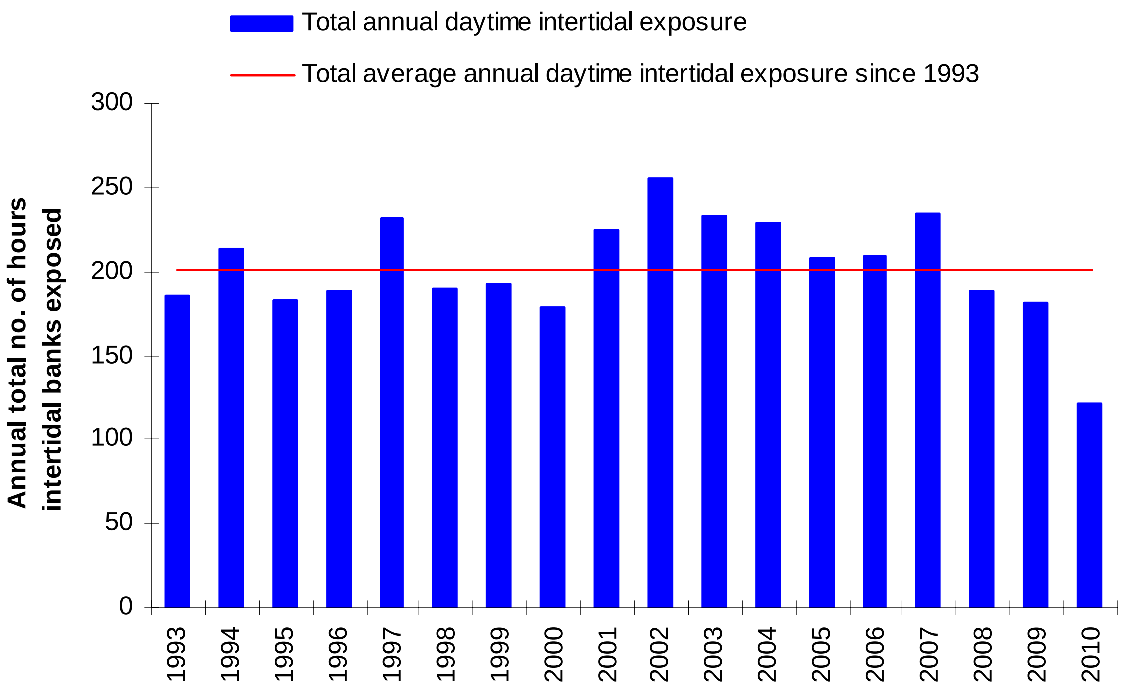


Figure 4 Total annual hours of daytime exposure of intertidal banks (<0.8m tidal height) recorded from 1993 to 2010 (Source: Maritime Safety Queensland, 2010).

DISCUSSION

In 2010 seagrasses in Mourilyan had reduced to critical levels. Only small patches of colonising species remained with the previously stable and highly productive *Zostera capricorni* meadows now completely absent. Prior to 2010 seagrasses in Mourilyan were already in a highly reduced and vulnerable condition and a further year of significantly above average rainfall and land based runoff into the catchment was the most likely cause of this further decline. The loss of the previously robust *Zostera capricorni* Bradshaw meadow and the complete loss of *Zostera capricorni* from the harbour is of particular concern. With the complete absence of this species recovery may take a substantial time even in the presence of favourable growing conditions.

The declines of Mourilyan Harbour seagrass meadows have been attributed to atypical regional climate conditions, particularly storm events and floods (Thomas and Rasheed 2003, McKenna et al. 2008, Sankey and Rasheed 2010). High rainfall in 2000 coincided with massive declines in seagrasses in Mourilyan Harbour that year, while in 2006 Cyclone Larry also had major impacts on most of the meadows; only the Bradshaw meadow remained after the cyclone (McKenna et al. 2007). In 2009 and 2010 annual rainfall in Mourilyan Harbour and the Moresby catchment was the highest recorded since 2000 and above the annual average. The disappearance and reappearance of seagrasses throughout Mourilyan Harbour may indicate that they may be highly susceptible to water quality issues and disturbance associated with high rainfall and flood events.

Significant losses of intertidal and shallow subtidal seagrass habitat have also occurred in other areas of Queensland in 2010. Cairns, Townsville, Gladstone and Abbot Point have all experienced major declines in seagrass abundance and distribution (Fairweather et al. 2011; Taylor and Rasheed, In press; Chartrand et al. 2011). The La Nina events that affected the state in 2010 have likely contributed to the major declines of seagrass habitat seen on the east coast through significant flooding and storm events. These events can result in lowered salinity, high sediment loading leading to burial, reduced light availability and high nutrient doses and the effects of increased run-off from local catchment activities, which can all negatively affect seagrasses (Campbell and McKenzie 2004, Chartrand et al. 2010, Waycott et al. 2007). Other climate factors apart from rainfall and flooding between 2008 and 2010 have been generally favourable for seagrass growth. Maximum air temperature and tidal exposure have remained relatively low. These conditions would tend to reduce the risk of thermal stress and desiccation at low tide to intertidal seagrasses.

Water quality issues associated with agricultural land use practices may also explain some of the declines in seagrass throughout Mourilyan Harbour (Thomas and Rasheed 2004; Thomas et al. 2006, Lewis et al. 2009). Agricultural land use practices may exacerbate the effects of flooding on seagrasses and have impacted the marine environment in the past (Russell et al. 1996). Agricultural land use practices was suspected of contributing to the loss of seagrasses in Hervey Bay in 1992 (McKenzie et al. 2000). The effects of sediment and runoff as well as local catchment use, however, have not been examined in Mourilyan Harbour.

While flooding has been demonstrated to lead to seagrass loss in Queensland, tropical seagrass meadows have previously shown a good capacity for recovery. In most areas where decreases in seagrass habitat have occurred due to acute impacts, seagrasses have recovered within 4 months to 5 years (McKenzie et al. 2000, Unsworth et al. 2010). However, propagules and established seed banks from which recovery can occur must be present and locally available (Rasheed 1999; 2000, Inglis 2000, McKenzie and Unsworth 2009). Studies in Cairns Harbour found that recovery of *Zostera capricorni* was almost exclusively reliant on asexual colonisation through rhizome extension from nearby plants with the seed bank being absent and playing no role in recovery (Rasheed 1999). Under these conditions if all adult plants were lost from the meadow, as is the case in Mourilyan Harbour, then recovery could only occur through dispersal from elsewhere. There are few other areas however, from which propagules could easily be transported. Hinchinbrook channel and the Cairns Harbour are the next closest substantial areas of productive *Zostera* seagrass habitat from which recruitment could occur (Coles et al. 1993). These plants are poorly adapted for long distance dispersal and this combined with the narrow entrance to Mourilyan Harbour would decrease the probability of effective natural dispersal and recruitment. There may potentially be seeds stored in the sediment (seed bank) in Mourilyan from which recovery could occur, but there has been no seed assessment conducted to confirm this.

The loss of seagrass habitat in Mourilyan Harbour may have implications to local fisheries. Studies conducted in 1993-1994 found commercially important tiger prawns (*Penaeus esculentus* and *P. semisulcatus*) and endeavour prawns (*Metapenaeus endeavouri*) in Mourilyan seagrass meadows (McKenzie et al. 1996). The Bradshaw Island meadow produced the highest abundances and largest sizes of these prawns. The commercially targeted brown tiger prawn (*Penaeus esculentus*) was only found at the Bradshaw site. Juvenile tiger prawns are considered to be almost entirely dependant on shallow, coastal, seagrass meadows for growth and survival, and what were once densely vegetated *Zostera capricorni* and *Halophila* meadows in Mourilyan Harbour provide typical habitat for these species. There are few other areas between the Hinchinbrook channel and the Port of Cairns that contain productive nursery habitat (Coles et al. 1993).

The absence of the majority of seagrass meadows, including the complete absence of some species, is likely to have substantially impacted the ability of seagrasses to recover should conditions become more favourable for seagrass growth. With the absence of adult plants, the recovery of most meadows would be reliant on germination of seeds either stored in the seed bank or recruited via dispersal from other locations. These seed banks are likely to have been already substantially reduced due to the repeated declines that have occurred over the last few years. Seagrasses may potentially struggle to re-establish in Mourilyan in the short to medium term, particularly if further losses of the remaining remnant patches of seagrasses occur during the 2010/2011 wet season.

The highly vulnerable state of seagrasses in Mourilyan Harbour in 2010 means that measures to reduce further impacts to their health and resilience may be required to assist in their longer term protection and recovery. Although the monitoring program does not examine all seagrasses in Mourilyan Harbour, the selected monitoring meadows encompass the vast majority of seagrasses that have been mapped in previous baseline surveys. Aerial reconnaissance at the time of the monitoring survey indicated that seagrasses outside of the monitoring meadows were also absent in 2010.

The relationships observed between seagrass biomass and climate variability are indicative only, and the monitoring program would be enhanced in the long-term with additional investigations and monitoring measures. This will allow for the more complete separation of natural and anthropogenic influences upon seagrass meadows in Mourilyan Harbour. Such measures could include:

1. *Continuing the seagrass monitoring program at Mourilyan Harbour to assess the long-term viability and potential for recovery.*

2. *Investigations and monitoring of water quality within Mourilyan Harbour to determine the impact of land-based run off to strengthen the possible links between seagrass conditions and catchment issues.*

3. *Assessing light and temperature at the individual meadow level (in situ loggers)*

Light and temperature are two of the major factors that have been linked to changes in seagrasses. The use of light and temperature data loggers within monitoring meadows at other monitoring locations has enabled an evaluation of changes occurring at the meadow scale (Chartrand et al. 2009; 2010). This provides direct information on what conditions seagrasses are experiencing rather than inferring them from regional climate information. Where installed, these loggers have shown that meadows of similar species composition and location may experience different physical conditions and different outcomes in density and distribution over time (Chartrand et al. 2009; 2010).

4. Examining reproductive and recovery capacity of the meadows

The capacity for meadows to reproduce, including the density of seeds stored as a "seed-bank", are critical components of the resilience of seagrass meadows and their ability to recover from impacts. Assessments of seed bank status have been used in other monitoring locations (e.g. Karumba) to assess meadow vulnerability (McKenna and Rasheed 2011).

5. Assessing seagrass stress indicators such as examining tissue nutrients and herbicides in seagrasses.

Analysis of tissue nutrient data is 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 (McKenzie and Unsworth 2009). For example changing C:N ratios have been found to be related to light levels (Abal et al. 1994; Collier et al. 2009)

6. Applying extra caution and management measures to future port activities or other developments that have the potential to impact on seagrass communities.

Introducing these measures would require additional resources beyond the scope of the current Ports North/Fisheries Queensland seagrass monitoring program. This would require a collaborative approach with other agencies and research organisations. Ports North and Fisheries Queensland will investigate options for such collaborations leading up to the next scheduled annual monitoring event in November 2011.

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APPENDIX

Appendix 1. Statistical Analysis

Results of one-way ANOVA for mean above-ground biomass versus year for the Lily meadow in Mourilyan Harbour, 1994 to 2010. ANOVA was unable to be carried out on the Channel meadow as there was only one site, while the Bradshaw and Seaforth meadows were absent in 2010. Pair-wise comparison of means was unable to be carried out on the Lily meadow due to low numbers of replicates in 2009 and 2010.

Lily (2) *	**DF**	**SS**	**MS**	**F**	**P**
Between years	13	34793.1	2676.39	24.71	**<0.001**
Within years	254	27515.4	108.328		
Total	267	62308.5			

* 1993 was omitted from analyses due to low number of replicates