Department of **Employment, Economic Development and Innovation**

Long Term Seagrass Monitoring in the Port of Mourilyan

November 2009

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On 26 March 2009, the Department of Primary Industries and Fisheries was amalgamated with other government departments to form the Department of Employment, Economic Development and Innovation.

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EXECUTIVE SUMMARY

This report details results from the October/November 2009 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.

In 2009 seagrasses in Mourilyan Harbour were in an extremely vulnerable state. Three of the five monitoring meadows were no longer present and the two remaining meadows had significant declines. These losses 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. The causes of seagrass declines were potentially related to catchment water quality issues compounded by carry over impacts from Cyclone Larry in 2006. 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 seagrasses extra caution should be applied to future port activities or other developments that have the potential to impact on seagrass communities.

Further investigation into water quality within the Port of Mourilyan 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. Such enhancements are out of the scope of the current seagrass monitoring program and Ports North and Fisheries Queensland will be investigating funding and collaboration opportunities to address these additional information needs.

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. 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 for 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 and identified widespread declines in subtidal seagrass from 1997 levels that were likely due to flooding of the Moresby River (Thomas and Rasheed 2001). Since 2000, annual surveys have found changes to seagrass meadows 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 2009.

Objectives

The objectives of the 2009 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 2008, and compare results with the long term monitoring dataset.

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 periodic 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 2009 survey.

Seagrass surveys were conducted using two field techniques: intertidal aerial and sub-tidal boat surveys. Intertidal seagrasses were surveyed using a helicopter at low tide on October 15th 2009 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 including Bradshaw, Lily, Seaforth Edge and Seaforth Bank. Subtidal seagrasses in the Channel meadow and some deeper sites of Seaforth Bank and Seaforth Edge were surveyed from a boat on November 25th and 26th 2009 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.

This survey targeted the five monitoring meadows and an aerial reconnaissance of seagrasses outside of the monitoring meadows was also conducted at the time of the monitoring survey.

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 2009.

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 2009.

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 ± 5 m 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 2009.

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 (in the channel) entirely subtidal. Relatively high density of survey sites. Recent aerial photography aided in mapping.

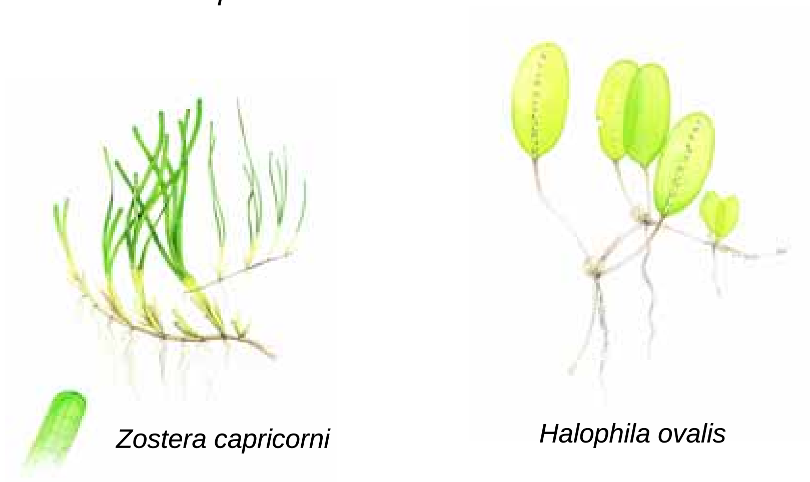
RESULTS

Seagrass Species, Distribution and Abundance

Two seagrass species (from two families) were present in the monitoring meadows in October/November 2009 (Figure 1) (for a full description of species and distribution refer to baseline survey McKenzie *et al.* 1996):

Family HYDROCHARITACEAE Jussieu:
Halophila ovalis (R. Br.) Hook. F.

Family ZOSTERACEAE Drummortier:
Zostera capricorni Aschers.



Zostera capricorni *Halophila ovalis*

Figure 1. Seagrass species present in the Port of Mourilyan monitoring meadows 2009.

Long Term Seagrass Monitoring Survey

Of the 247 sites (61 subtidal and 186 intertidal) surveyed in October/November 2009, 20% contained seagrass, which was isolated to two of the five monitoring meadows, Bradshaw (1) and Lily (2) (Map 1). Total area of seagrass habitat in these meadows was 2.8 ± 0.7 ha (Table 5), while mean above-ground biomass was 0.04 ± 0.02 g DW m^{-2} for Lily and 15.5 ± 2.9 g DW m^{-2} for Bradshaw (Table 5). The large difference in biomass is largely due to the distinct species composition in these meadows (Table 4). Both meadows were characterised as light in cover based on the mean biomass for the species present (Table 4, Map 1).

Table 4 Community type, seagrass cover and species present in the five Mourilyan Harbour monitoring meadows October/November 2009.

Monitoring Meadow	No. of sites	Community Type	Species Present
Bradshaw	34	Light *Z. capricorni*	*Z. capricorni*
Lily	13	Light *H. ovalis*	*H. ovalis*
Seaforth Bank	n/a	Meadow not present	No seagrass present
Seaforth Edge	n/a	Meadow not present	No seagrass present
Channel	n/a	Meadow not present	No seagrass present

Comparison with previous monitoring surveys

In 2009 seagrasses in Mourilyan Harbour were dramatically reduced compared to the 2008 survey and remain well below their historical peak densities (biomass) and distribution (area) (Table 5; Figures 2a & b; Map 2; Appendix 1). Only two of the five monitoring meadows (Bradshaw and Lily) remained. The Bradshaw meadow decreased in density and area but remained dominated by *Zostera capricorni*. The Lily Meadow continued recent declining trends and consisted of isolated patches of *Halophila ovalis*. The large, subtidal Channel meadow completely disappeared and the Seaforth Bank and Seaforth Edge meadows continued declining trends with no seagrass present in 2009. As a consequence of the meadow losses two species normally present in the harbour were lost, *Halophila decipiens* and *Halodule uninervis* (Table 5; Figures 2a & b).

The Channel meadow has been highly variable from year to year throughout the monitoring program, although complete loss of seagrass for the meadow has only occurred on one previous occasion in 2000. The 2009 survey failed to find any evidence of seagrass despite an increase recorded from 2007 to 2008 (Table 5; Map 2, Figure 2b).

The small Lily meadow recorded its lowest biomass and area since the monitoring program began. Previously this meadow had been dominated by *Zostera capricorni* but in 2009, a complete species shift occurred to the pioneering *Halophila ovalis* with no *Zostera capricorni* recorded (Table 5; Map 2, Figure 2a). This meadow has been declining in area for the last three years with biomass substantially lower from 2005 to 2009 than earlier in the monitoring program.

The larger higher biomass Bradshaw *Zostera capricorni* meadow has remained the most consistent meadow throughout the long term monitoring program, with meadow area remaining similar between surveys (Table 5; Figure 2a). However this meadow also experienced a significant decline in biomass in 2009 decreasing 46% from the 2008 survey and resulted in the lowest density and area recorded since the monitoring program began (Table 5; Map 2; Appendix 1).

In 2009, 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. For example, in 2000 & 2006, the Seaforth Edge meadow had completely declined to the point where no above-ground structures remained (Table 5; Figures 2a & 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 very isolated patches of light seagrass for the last 7 years with no seagrass recorded in 2009 (Table 5; Map 2; Figure 2b).

Area of seagrass in the Seaforth Bank meadow has been declining since 2006. In 2009 no seagrass was recorded. 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 throughout the entire monitoring program, to a dominance by *Halodule uninervis* (narrow) to no seagrass present in 2009. This meadow was also previously not present in 2003 (Table 4; Map 1; Figure 2a).

Map 1. Port of Mourilyan seagrass distribution and community types October/November 2009.

Legend

Community Type

Light *Zostera capricorni*

Light *Halophila ovalis*

Monitoring Meadows 2009

1. Bradshaw
2. Lily

Monitoring Sites 2009

(No seagrass

(Seagrass present

Source: Sankey, T.L. and Rasheed, M.A. (2010). Long term seagrass monitoring in the Port of Mourilyan - November 2009. © Ports North and the State of Queensland through Department of Employment, Economic Development and Innovation. Produced by the Marine Ecology Group, Fisheries Queensland, 2010.(Aerial photograph courtesy Beach Protection Authority, 1:25000; 1/07/2000).

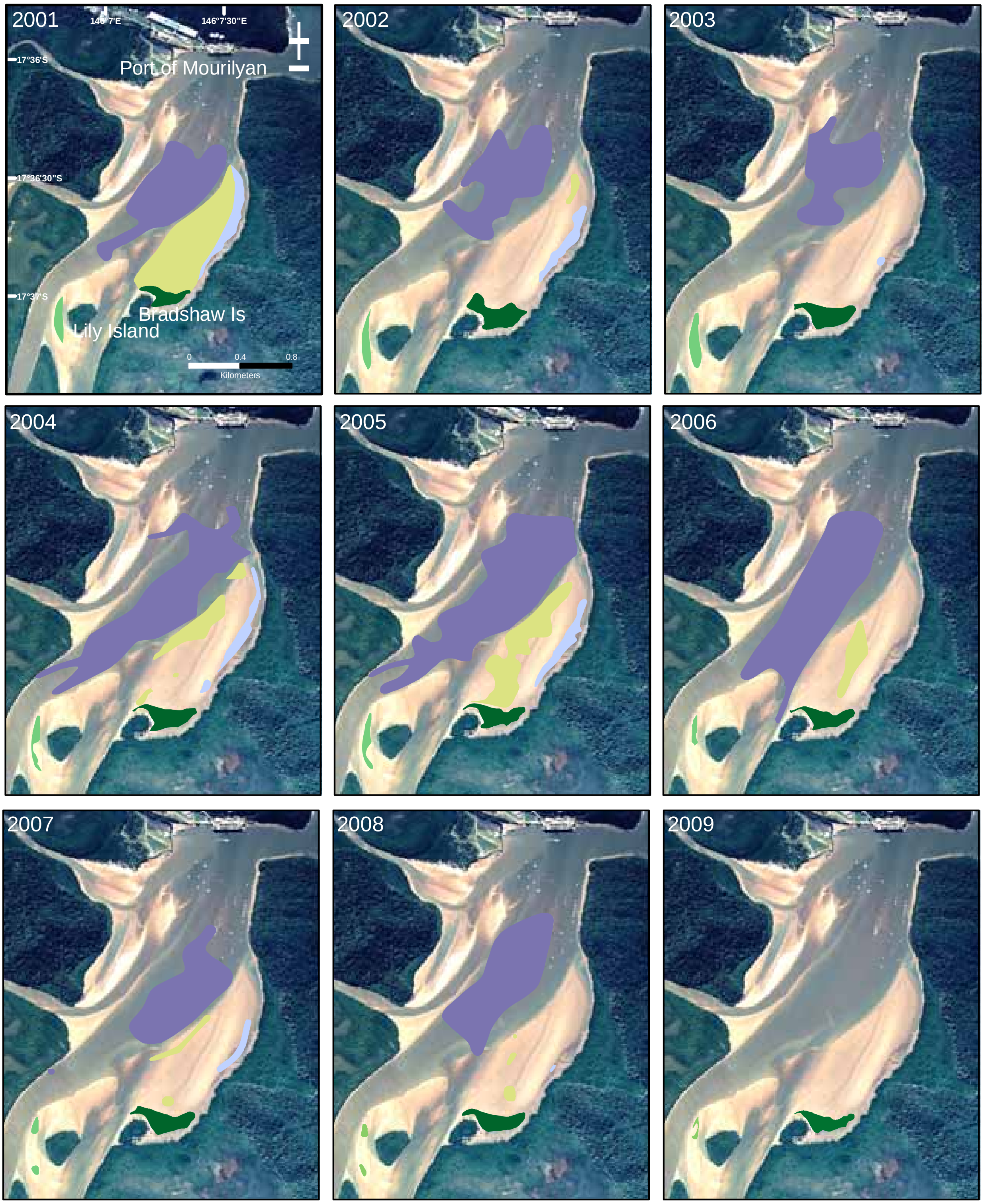
Table 5. Area and mean above ground biomass for Mourilyan Harbour monitoring meadows from December 1993 to November 2009.

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**
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)
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)
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
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
Channel (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
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)

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**
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 + 34.6%	15.5 ± 2.9 - 46.1%
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 - 0.1%	0.04 ± 0.02 - 98.5%
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
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
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 - 40.0 %	*NP

**NR (Not recorded) signifies seagrass present but too sparse to record biomass; *NP signifies 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 2009.



Legend

Seagrass Meadow ID

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

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Source: Sankey, T.L. and Rasheed, M.A. (2010). Long term seagrass monitoring in the Port of Mourilyan - November 2009. © Ports North and the State of Queensland through Department of Employment, Economic Development and Innovation. Produced by the Marine Ecology Group, Fisheries Queensland, 2010. (Aerial photograph courtesy Beach Protection Authority, 1:25000; 1/07/2000).

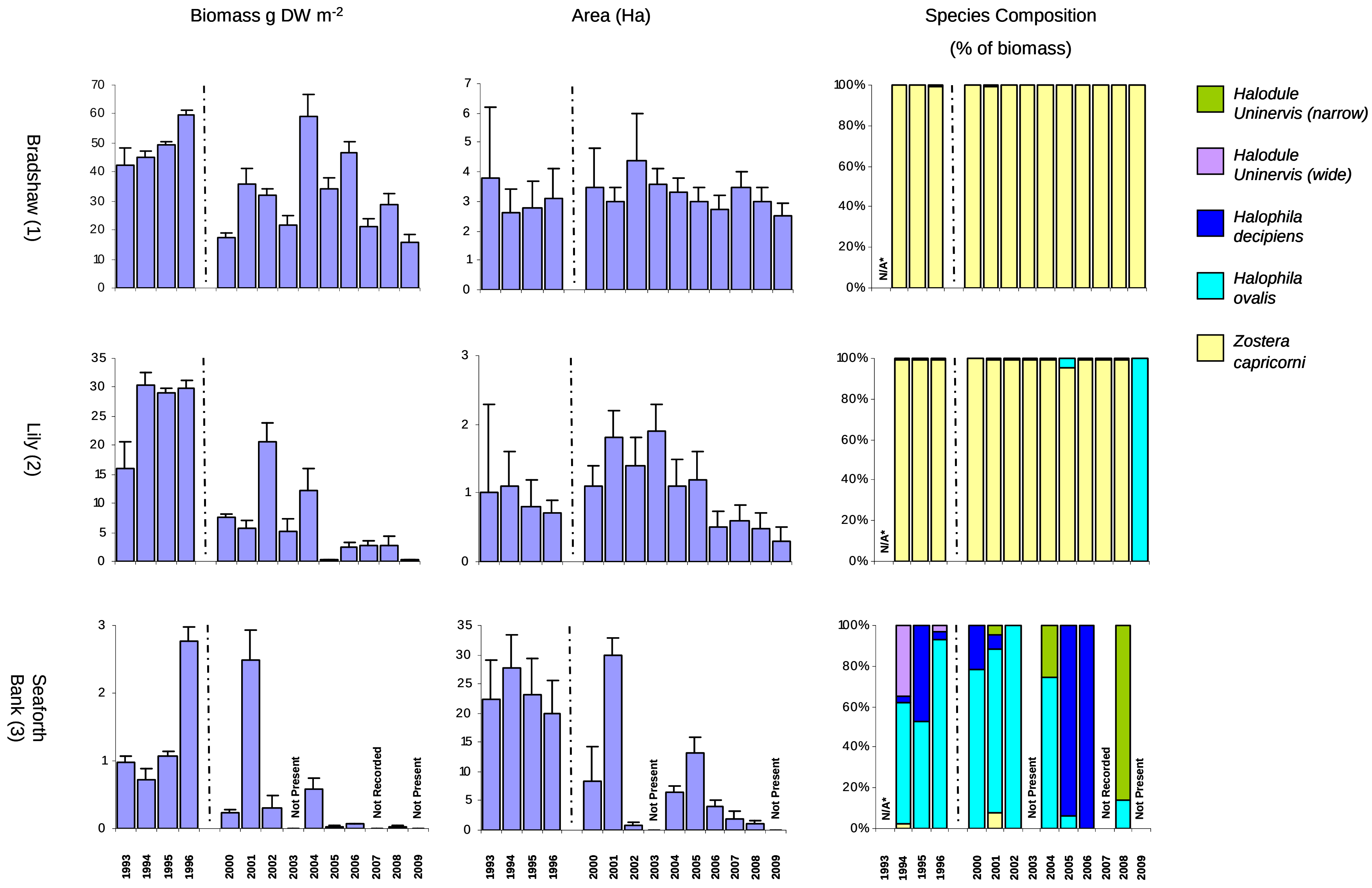


Figure 2a Changes in biomass, area and species composition for monitoring meadows from 1993 to 2009 (Biomass error bars = SE; Area error bars = "R" reliability estimate) (dashed line designates a four-year gap between surveys; N/A* = % composition of biomass not available; Not Recorded signifies seagrass present but too sparse to record biomass; Not Present signifies seagrass not present).

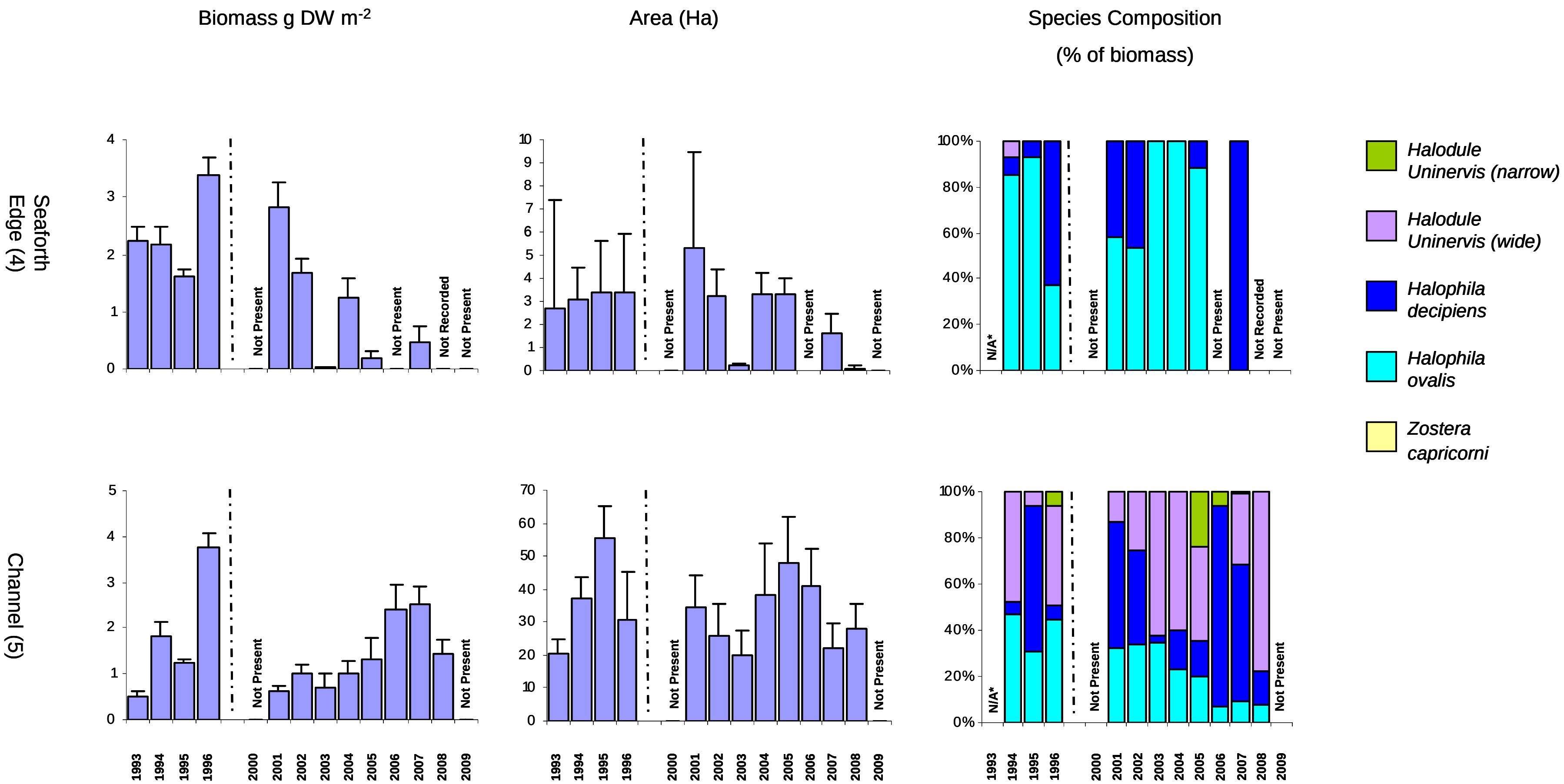


Figure 2b Changes in biomass, area and species composition for monitoring meadows from 1993 to 2009 (Biomass error bars = SE; Area error bars = "R" reliability estimate) (dashed line designates a four-year gap between surveys; N/A* = % composition of biomass not available; Not Recorded signifies seagrass present but too sparse to record biomass; Not Present signifies seagrass not present).

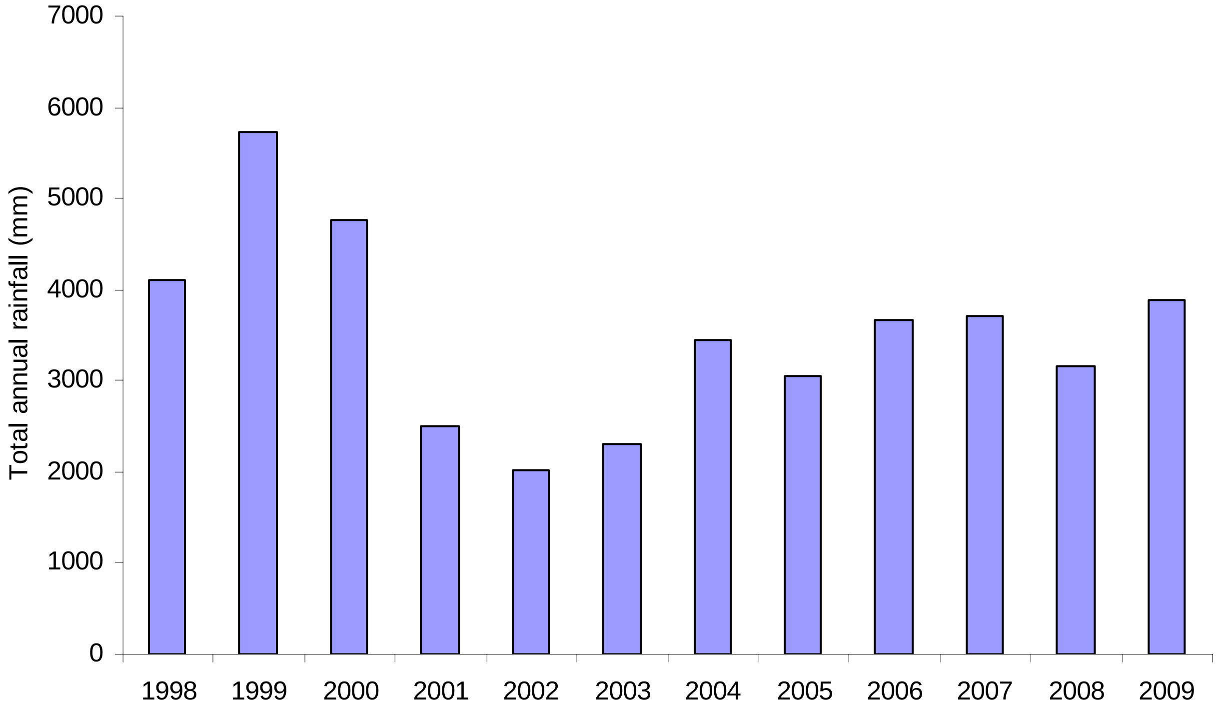
Mourilyan Climate Data

Total annual rainfall in Mourilyan Harbour during 2009 was 3875 mm with the majority of this recorded during the wet season early in the year (Figure 3a). This was above the 15 year average of 3467 ± 241 mm and had been preceded by three years of additional above average rainfall in 2008, 2007 and 2006 (Figures 3a & b).

The average maximum daily temperature in 2009 was 28.5°C. This was below the 15 year average of 28.8 ± 0.4°C (Figure 3b).

The level of tidal exposure in 2009 was somewhat lower than the past few years (Figures 4 & 5). Low exposure compounded with reduced temperatures may indicate lower thermal and desiccation stress during 2009.

A



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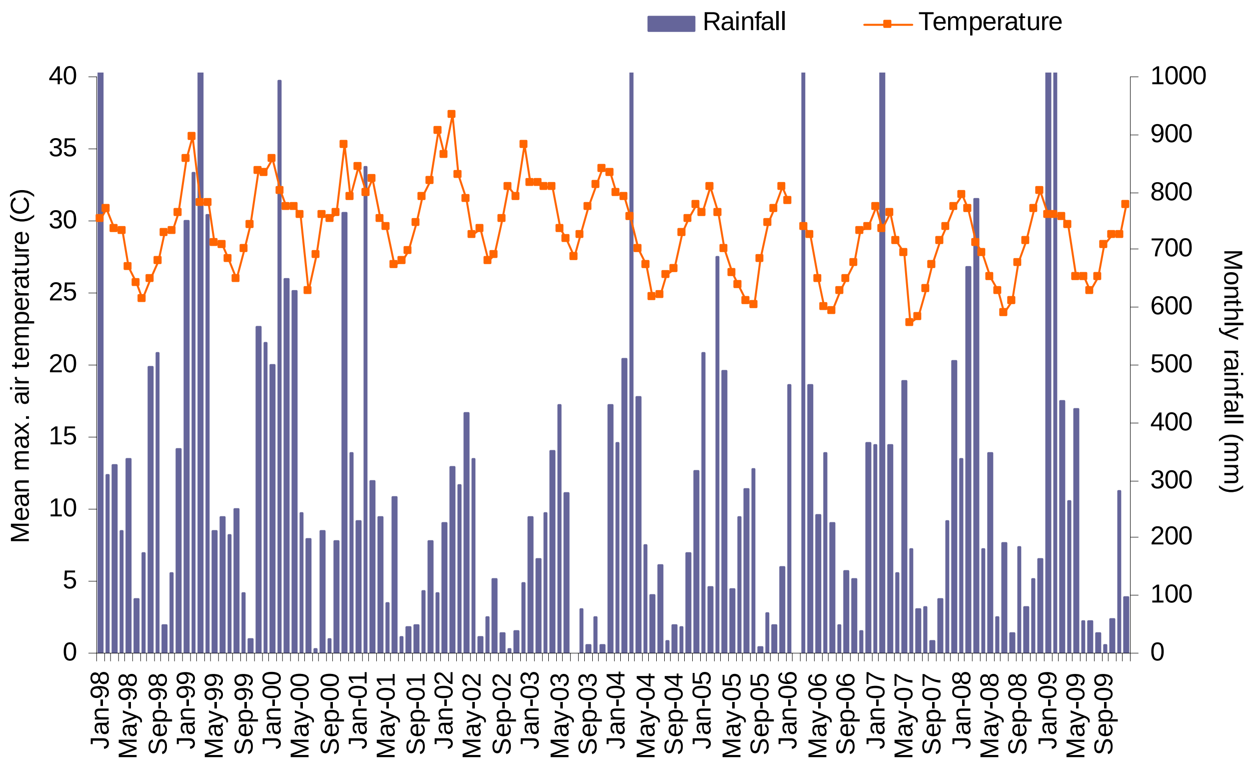

Figure 3 (A) Total annual rainfall recorded at Mourilyan Harbour from 1998 to 2009; (B) Mourilyan Harbour mean monthly maximum temperature and total monthly rainfall (Source: Australian Bureau of Meteorology, 2009).

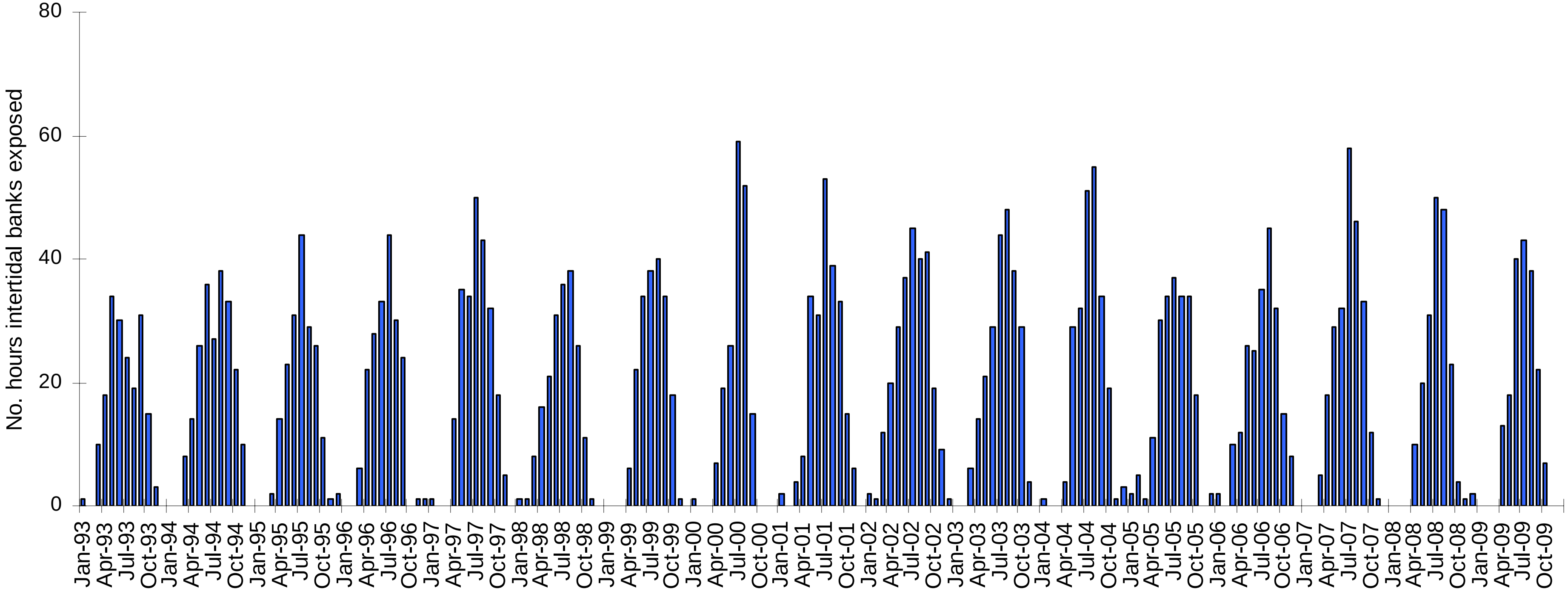

Figure 4 The total number of daylight hours per month that intertidal banks were exposed, recorded from 1993 to 2009 (Source: Maritime Safety Queensland, 2010).

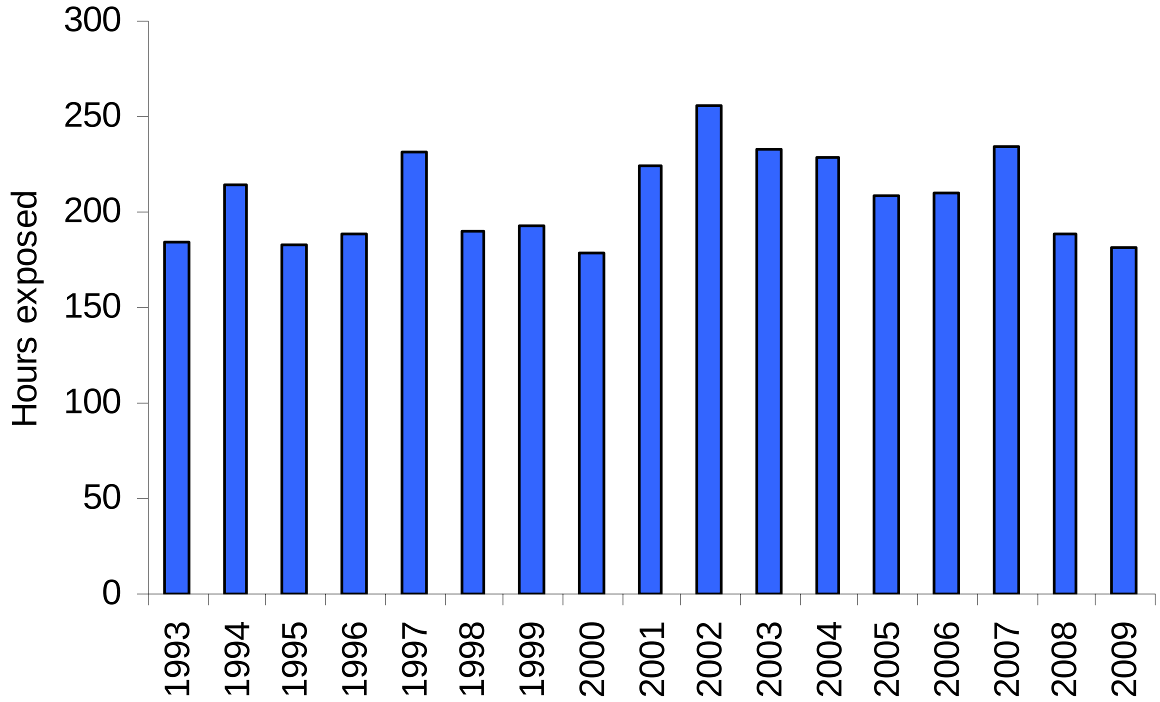

Figure 5 Total annual hours of daytime exposure of intertidal banks recorded from 1993 to 2009 (Source: Maritime Safety Queensland, 2010).

DISCUSSION

In 2009 seagrasses in Mourilyan Harbour were in an extremely vulnerable state. Three of the five monitoring meadows were no longer present and the two remaining meadows had significant declines. These losses 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. The causes of seagrass declines were potentially related to catchment water quality issues compounded by carry over impacts from Cyclone Larry in 2006. 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 or requirements for capital dredging that have occurred in recent years. However due to the fragile condition of seagrasses extra caution should be applied to future port activities or other developments that have the potential to impact on seagrass communities.

The only seagrass meadow that remained in a relatively robust state was the intertidal *Zostera capricorni* meadow (Bradshaw), however even this meadow had declined significantly in 2009. The meadow had been relatively stable and healthy throughout the monitoring program until the 46% decline in biomass from 2008 to 2009. It now consists of light seagrass cover compared to previous moderate/dense coverage. The only other monitoring meadow that remained (intertidal Lily) declined by 98.5% in biomass and consisted of isolated patches of *Halophila ovalis* scattered across the northern portion of the old meadow extent. There was very little seagrass remaining in the meadow and species had changed from *Zostera capricorni* to the pioneering *Halophila ovalis.*

All three of the monitoring meadows that were absent in 2009 have previously been absent in the monitoring program, but not at the same time. The loss of the Seaforth Edge meadow followed several years of declining trends in biomass and area. In 2008, only one sparse patch of *Halophila ovalis* was found. This meadow had re-established in small isolated patches in 2007 after disappearing in 2006 following Tropical Cyclone Larry. The Seaforth Edge meadow was also absent in 2000 coinciding with high rainfall and flooding in Mourilyan Harbour (Thomas and Rasheed 2001). The adjacent Seaforth Bank meadow was absent in 2003 and the subtidal Channel meadow had also disappeared in 2000 (Thomas and Rasheed 2001). The disappearance and reappearance of seagrasses in these meadows indicates that they may be highly susceptible to water quality issues and disturbance associated with high rainfall and flood events.

In 2009 annual rainfall was the highest recorded in Mourilyan Harbour since 2000. Previous analysis of change in Mourilyan Harbour seagrass meadows has been correlated with climate, flood and storm events (McKenna *et al.* 2008). High rainfall events in 2000 coincided with a massive decline in seagrasses in Mourilyan Harbour that year. High rainfall and flooding events can produce high sediment loads and increased run-off from local catchment activities. Effects of local catchment use, however, have not been quantified and may potentially explain much of the seagrass change observed in the harbour (Thomas and Rasheed 2004; Thomas *et al*. 2006, Lewis *et al*. 2009). In 2006, Tropical Cyclone Larry had a major impact on many of the harbour's seagrass meadows. These meadows, although initially showing signs of recovery during the subsequent annual survey, have continued to decline since disturbance from the cyclone. Climate factors apart from rainfall and flooding between 2007 and 2009 were generally favourable for seagrass growth. Maximum air temperature, solar irradiance and tidal exposure remained relatively low (Figures 3, 4 & 5). These conditions would tend to reduce the risk of thermal stress and desiccation at low tide to intertidal seagrasses.

The differences in survival of monitoring meadows in 2009 may be partly attributed to meadow position within the harbour and their vulnerability to impacts associated with flooding and catchment run-off (herbicides, suspended sediments and nutrients and changes to salinity). For instance, although 2009 showed a 46% decrease in biomass in the Bradshaw meadow, it was the only meadow to maintain a relatively healthy biomass. This meadow is positioned in a protected corner of the harbour not directly in the path of heavy river flows (Map 1) which may also be favourable to greater tidal flushing compared to the more upstream Lily meadow. The Lily meadow, with a 98.5% decrease in biomass and located furthest upstream, may receive greater exposure to catchment runoff including potential negative effects of higher turbidity, shear stress, herbicide residues, and changes to salinity. The species shift in the Lily meadow from a previously dominated *Zostera capricorni* meadow to being solely composed of *Halophila ovalis* in 2009 may be a response to the substantially higher 2009 rainfall (Figure 3). *Halophila ovalis* has a lower minimum light requirement than most species allowing them to persist in areas with high turbidity during high rainfall and flooding periods (Kenworthy *et al*. 1989; Birch & Birch 1984). Additionally the Bradshaw meadow was the highest biomass meadow in the harbour and was likely to have a higher resilience to impacts due to greater stores of energy within the plants.

Water quality issues associated with agricultural practices may explain some of the observed changes to seagrasses and may be exacerbated by flooding events. Agricultural land use comprises 43% of the Mourilyan (Moresby River) catchment area and has impacted the marine environment in the past (Russell *et al*. 1996). Elevated herbicide concentrations associated with agriculture have been recorded in waterways of the Great Barrier Reef catchment area including in intertidal and subtidal sediments (Duke *et. al*. 2005, Haynes *et. al.* 2000, Ham 2007). The herbicides diuron, atrazine, hexazinone and ametryn have been frequently detected in relatively high concentrations at sites draining sugar cane in North Queensland catchment areas, with the highest concentrations of diuron recorded in the Tully-Murray region during a recent water quality study (Lewis *et. al.* 2009). These herbicides have been shown to inhibit photosystem II in plants (Jones *et. al*. 2003; Muller *et. al.* 2003). Currently there are no direct measures of water quality collected in Mourilyan Harbour to determine whether catchment and agricultural runoff are the drivers of seagrass change. A mixture of herbicide residues following river discharge events have the capacity to produce cumulative chronic effects on seagrasses (Lewis *et. al.* 2009) and potentially adjust seagrass community structure. Seagrasses in Mourilyan Harbour are continuing to decline with further substantial reductions in seagrass biomass and cover in 2009. Water quality investigations along with sedimentary herbicide analysis in Mourilyan would help to strengthen the possible links between seagrass condition and catchment issues and assist in developing mitigation strategies to encourage their recovery and protection.

The losses recorded in the monitoring meadows in Mourilyan represented a harbour wide loss of seagrasses. 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. Additionally aerial reconnaissance at the time of the monitoring survey indicated that seagrasses outside of the monitoring meadows were also absent in 2009. The absence of the majority of meadows, including the complete absence of some species is likely to have substantially impacted on the ability of seagrasses to recover should conditions become more favourable for seagrass growth. With the absence of adult plants for most meadows recovery 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 and recovery that have occurred over the last few years (McKenna *et. al.* 2007). Potentially seagrasses may struggle to re-establish in Mourilyan in the short to medium term, particularly if further losses of the remaining seagrasses occur during the 2009/2010 wet season.

The highly vulnerable state of seagrasses in Mourilyan Harbour in 2009 means that measures to reduce further impacts to their health and resilience and additional investigations and monitoring measures may be required to assist in their longer term protection and recovery. Such measures could include:

- Continuing seagrass monitoring to assess the long term viability and potential for recovery.
- An examination and monitoring of water quality within Mourilyan Harbour to determine the impact of land-based run off.
- Applying extra caution and management measures to future port activities or other developments that have the potential to impact on seagrass communities.
- Adding enhancements to existing monitoring such as assessments of seed banks and examinations of seagrass stress indicators such as an examination of tissue nutrients and herbicides in seagrasses.

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 be investigating options for such collaborations leading up to the next scheduled annual monitoring event in November 2010.

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APPENDIX

Appendix 1. Statistical Analysis

Results of one-way ANOVA for mean above-ground biomass versus year for the Mourilyan Harbour monitoring meadows, 1993 to 2009

Bradshaw (1) [a]	**DF**	**SS**	**MS**	**F**	**P**
Between years	13	71818.1	5524.47	12.52	**<0.001**
Within years	347	153136	441.315		
Total	360	224955			
Lily (2) [a]					
Between years	13	101668	7820.60	45.65	**<0.001**
Within years	347	59444.3	171.309		
Total	360	161112			
Seaforth Bank (3) [b]					
Between years	10	284.9	28.5	13.2	**<0.001**
Within years	275	592.6	2.2		
Total	285	877.5			
Seaforth Edge (4) [c]					
Between years	n/a				
Within years					
Total					
Channel (5) [d#]					
Between years	11	20.6	1.87	4.52	**<0.001**
Within years	332	137.4	0.41		
Total	343	158.0			

[a] 1993 has been omitted from analyses due to low number of replicates

[b] Meadow was not present in 2003 and 2009; 2007 has been omitted from analyses due to low number of replicates

[c] Meadow was not present in 2000, 2006 and 2009; 2008 has been omitted from analyses due to low number of replicates

[d] Meadow was not present in 2000 and 2009 ; [#] One-way ANOVA using log+1 transformed data

Results of Least Significant Difference (LSD) pair-wise comparisons of mean above-ground biomass (g DW m^{-2}) for the Mourilyan Harbour monitoring meadows. Means that share a common letter for each meadow are not significantly different ($P < 0.05$)

Year	Mean Biomass (g DW m^{-2})				
	Bradshaw	Lily	Seaforth Bank	Seaforth Edge	Channel #
1993	n/a	n/a	1.0 ab	2.2 ab	0.5 a
1994	45.1 b	30.5 b	0.7 a	2.2 ab	1.8 ab
1995	49.3 b	29.1 b	1.1 abc	1.6 ab	1.4 ab
1996	59.5 b	29.8 b	2.8 c	3.4 b	2.8 ab
2000	17.6 a	7.7 a	0.2 a	n/a	n/a
2001	35.9 b	5.6 a	2.5 bc	2.8 b	0.6 a
2002	32.1 b	20.7 b	0.3 a	1.6 ab	1.0 ab
2003	21.6 a	5.1 a	n/a	n/a	0.7 a
2004	59.3 b	12.3 b	0.6 a	1.2 ab	1.0 a
2005	34.1 b	0.2 a	0.03 a	0.2 a	1.3 a
2006	46.5 b	2.4 a	0.06 a	n/a	2.4 ab
2007	21.4 a	2.8 a	n/a	n/a	2.5 b
2008	28.0 b	1.5 a	0.06 a	n/a	0.6 a
2009	15.5 a	0.04 a	n/a	n/a	n/a

One-way ANOVA using log+1 transformed data