Port of Mourilyan Seagrass Monitoring

CRC Reef Research Centre

DPI QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES

First Four Years

Summer 1993 – 1996, Winter 1994 – 1997

McKenzie, L.J., Lee Long, W.J., Roelofs, A.J., Roder, C.A., & Coles, R.G.

PORTS CORPORATION QUEENSLAND

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Cover Image
Port of Mourilyan

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Executive Summary

1. This report presents data from 8 surveys (4 Summer and 4 Winter) conducted over 4 years at the Port of Mourilyan.

2. The area of seagrass meadows in Mourilyan Harbour increased between Summer surveys (65 ±21 ha December 1993 to 71 ±33 ha December 1996), and decreased between Winter surveys (68 ±21 ha July 1994 to 47 ±22 ha July 1997), however these changes are within the estimated ranges of mapping error, indicating no measurable change in overall distribution.

3. Meadows in Mourilyan Harbour in both Summer and Winter were mostly low-biomass *Halophila*-dominated found along shallow banks within the harbour, and the periphery of Armit and Walter creeks. High biomass *Halophila*-dominated meadows were found along the Seaforth Valley mangrove fringe, the sand banks between Armit and Walter Creek mouths and adjacent to Lily Island. High-biomass *Zostera capricorni*-dominated meadows were found adjacent to Bradshaw Island and between Lily and Maizie Island. An extensive *Halodule/ Halophila*-dominated meadow was found within the main channel in the harbour.

4. Mean above-ground biomass for all seagrass meadows pooled within Mourilyan Harbour was greater in December 1996 compared to the Summer baseline (December 1993), and lower in July 1997 than the Winter baseline (July 1994).

5. Mean depth of *Zostera capricorni* was shallower and *Halophila decipiens* deeper, in later surveys than in the initial Summer baseline (December 1993). Mean depth for all other seagrass species found within Mourilyan Harbour has remained constant.

6. *Enhalus acoroides* occurred in a small patch (0.04 ha) in Armit Creek, and as individual plants in other parts of Mourilyan Harbour. Distribution of this seagrass species has remained patchy in surveys and as this species is close to its southern geographical limits of distribution, the survival of these plants are important to seagrass biodiversity in this part of Australia.

7. The area of the seagrass meadows selected for monitoring varied throughout the monitoring period, however these changes were within the estimated ranges of reliability (error), indicating no measurable change in overall distribution.

8. Above-ground seagrass biomass in the meadows selected for monitoring, either remained stable or significantly increased between Summer surveys. In Winter these meadows varied significantly in biomass between surveys, with no apparent trend. These changes appear to be within the range of variation documented for other tropical Australian seagrass meadows.

9. Species composition of the *Zostera*-dominated meadows remained stable between surveys, however minor changes occurred in all other meadows selected for monitoring.

10. Meadows selected for monitoring extended into deeper waters in the Summer months compared to Winter. Mean depth of meadows either remained stable or decreased within seasons.

11. Algal cover was highly variable between surveys, but algae was generally less common in Winter months than in Summer for most meadows selected for monitoring. The most common algal types recorded in Mourilyan Harbour were “benthic algal turf” and filamentous green algae.

12. The trends observed over the Summer events at Mourilyan Harbour indicate a need to investigate further the causes for changes in the Channel, Seaforth Bank and Bradshaw meadows, eg., possible shallowing, or changes in light availability and nutrient levels.

13. Monitoring of selected meadows in Mourilyan Harbour has been successful and appears the most accurate method for monitoring changes in seagrass habitats in tropical estuaries. Changes occurring in the meadows selected for monitoring reflect changes occurring within the entire harbour. The present study also demonstrates the importance of monitoring individual meadows (seagrass habitats) to detect change; stable *Zostera* habitats are best for determining significant change/impact, however highly variable subtidal *Halophila* habitats are useful indicators of less-significant changes requiring further investigation.

14. The present study provides the best available measure of year-to-year change in seagrasses for any north Queensland estuarine location. To obtain a reliable measure of the range of natural variability requires a longer-term monitoring strategy, which we suggest would include remapping the entire harbour at least every 3 years and immediately after major climatic or anthropogenic impact events.

15. It appears that during the 4 year monitoring period, impacts on Mourilyan Harbour seagrasses from natural events, port developments/operations, and other land-use practices in the Moresby catchment were not large enough to be of ecological importance. Ongoing, long term monitoring would be prudent.

Introduction

1.1. Consultancy Brief

The Ports Corporation of Queensland (PCQ) is the port authority for the Port of Mourilyan. As part of its strategic planning process PCQ developed an environmental management plan (EMP) for the port. This EMP included contracting the Queensland Department of Primary Industries (QDPI) Northern Fisheries Centre (NFC) to conduct seagrass monitoring within Mourilyan Harbour. Initial baseline surveys in December 1993 and July 1994 established that seagrasses and their associated faunal communities comprised an important component of Mourilyan Harbour's marine environment and were suitable for monitoring the condition of the port's environment (McKenzie *et al*.1996).

As seagrasses have marked seasonal differences in their distribution and abundance it was decided that two surveys a year, Summer and Winter, would be performed and a 3 year monitoring program comparing seagrasses within seasons (ie Summer/Summer or Winter/Winter) was developed. This report presents the results of surveys conducted in the first 4 years (baseline and monitoring). For these surveys the following objectives were set:

- *Monitor the areal extent of seagrass meadows (identified as suitable for monitoring during the baseline surveys) in both Summer and Winter;*

- *Monitor change in above-ground seagrass biomass and species composition for the selected meadows;*

This report summaries the results of the following surveys:

- Summer baseline (December 1993) (McKenzie *et al*. 1996)
- Winter baseline (July 1994) (McKenzie *et al*. 1996)
- Interim progress (January 1995)
- Interim progress (July 1995)
- Interim progress (December 1995)
- Interim progress (July 1996)
- Summer final (December 1996)
- Winter final (July 1997)

PCQ will use the results of seagrass monitoring to help identify any possible detrimental effects of port operations and developments on seagrasses and assist in formulating management measures for the port.

1.2. Site Description

Mourilyan Harbour is an estuary of the lower reaches of the Moresby River on the north-eastern coast of Queensland. The Moresby River catchment covers approximately 12 600 ha (Eyre 1993). The catchment has no major secondary industries and no sewage treatment plants. Large areas of the catchment are under sugar cane production and there are 2 aquaculture operations. Mourilyan Harbour is a port for sugar export and a small number of fishing and recreational vessels.

The region has a tropical monsoon rainfall pattern, with a dry season between April and November (average 200 mm per month, 24-28°C) and a wet season from December to March (average 800 mm per month, 30-34°C).

1.3. General Seagrass Ecology

The importance of seagrass meadows as structural components of coastal ecosystems is well recognised. These marine angiosperms are important for stabilising coastal sediments; providing food and shelter for diverse organisms; as a nursery ground for many prawn and fish of commercial importance; and for nutrient trapping and recycling (Short 1987; Larkum *et al.* 1989; Edgar and Kirkman 1989).

Seagrass/algae beds are rated the 3rd most valuable ecosystem globally (on a per hectare basis), only preceded by estuaries and swamps/flood-plains (Costanza *et al.* 1997). The average global value of seagrasses for their nutrient cycling services and the raw product they provide has been estimated at ^{1994}US$ 19,004 ha^{-1} yr^{-1} (Costanza *et al.* 1997). This value would be significantly greater if the habitat/refuge and food production services of seagrasses were included. Watson *et al*. (1993) for example, estimated that the landed value of the three major commercial penaeid prawns (*Penaeus esculentus, P. semisulcatus* and *Metapenaeus endeavouri*) averaged ^{1992}A$3,687 ha^{-1} yr^{-1} from seagrasses meadows in western Cairns Harbour.

Seagrasses are unique amongst flowering plants in that they can live entirely immersed in seawater. Several species are found at depths of down to fifty metres (den Hartog 1977; Coles *et al.* 1995) but tropical species are most common in less than ten metres below mean sea level (MSL) (Lee Long *et al.* 1993). Adaptation to a marine environment imposes major constraints on morphology and structure. The restriction to seawater may have also influenced their geographic distribution and speciation.

Seagrass meadows in northern Queensland play a critical ecological role as a support for commercial species of penaeid prawns and fish (Coles and Lee Long 1985; Coles *et al*. 1993). Seagrasses are also essential food for dugong, *Dugong dugon* (Miller), and green sea turtles, *Chelonia mydas* (Linnaeus) (Lanyon *et al.* 1989).

The growth of seagrasses depends on several factors including the availability of light (Dennison 1987; Williams and Dennison 1990), nutrients (Orth 1977; Erftemeijer 1994) and water temperature (Bulthuis 1987). Seagrasses show measurable growth responses to changes in ambient water quality conditions and can therefore be used as effective ecological indicators of environmental impact (Dennison *et al*. 1993).

Tropical seagrass meadows vary seasonally and between years (Mellors *et al*. 1993; McKenzie 1994). The potential for widespread seagrass loss has been well documented. The causes of loss can be natural such as cyclones and floods (Poiner *et al.* 1989), or due to human influences such as dredging (Onuf 1994), agricultural runoff (Preen *et al*. 1995), industrial runoff (Shepherd *et al*. 1989) or oil spills (Jackson *et al.* 1989).

Destruction or loss of seagrasses has been reported from most parts of the world, often from natural causes, eg "wasting disease" (den Hartog 1987), or high energy storms (Patriquin 1975; Poiner *et al.* 1989). More commonly destruction has resulted from human activities, eg. as a consequence of eutrophication (Bulthuis 1983; Orth and Moore 1983; Cambridge and McComb 1984) or land reclamation and changes in land use (Kemp 1983). Anthropogenic impacts on seagrass meadows are continuing to destroy or degrade coastal ecosystems and decrease their yield of natural resources (Walker 1989).

1.4. Mourilyan Harbour Seagrasses

The Moresby River catchment which flows into Mourilyan Harbour is subjected to existing anthropogenic influences. Future development of the port and agriculture in the catchment may add to this. A seagrass monitoring program was established by PCQ and QDPI to assist with management to minimise potential impacts of future developments.

Mourilyan Harbour seagrass meadows were first mapped in October 1987 (Coles *et al*. 1992) as part of a broad scale survey of the region. Results from beam trawl samples indicated high abundance and species richness of juvenile prawns and fish when compared to other meadows in the region (Coles *et al*. 1992; McKenzie *et al*. 1996). A seagrass survey by WBM Oceanics in August 1993 (WBM Oceanics Aust. 1993) was of insufficient scope and intensity to detect all major areas of seagrass habitat in the harbour for comparison.

As seagrass abundance and distribution has been shown to vary significantly between seasons at other locations (Mellors *et al.* 1993; McKenzie 1994), it was considered important to establish both Winter and Summer baselines for Mourilyan Harbour seagrasses, for future monitoring.

➪ 2. METHODS

2.1. Design of Seagrass Monitoring Program

A cost effective monitoring program based on the levels of significance and assurance was designed from the results of the Summer (December 1993) and Winter (July 1994) baseline surveys. A complete background and description of the monitoring program and detailed methodology is presented in McKenzie *et al.* (1996).

Monitoring of individual seagrass meadows, rather than considering seagrasses in Mourilyan Harbour as a whole, was decided as this allowed detection of finer changes in seagrass biomass and more detailed information on seagrass species composition changes within the available budget. Many of the meadows mapped in the baseline surveys were expected to be naturally ephemeral based on prior knowledge of species present and the environmental conditions under which they exist. Excluding suspected ephemeral meadows, five *primary* or *monitoring meadows* were selected for monitoring in Summer and four in Winter. These were meadows 3 (Channel), 4 (Seaforth bank - *Summer only*), 5 (Seaforth edge), 23 (Bradshaw Island) and 26 (Lily Island).

The appropriate sampling strategy for each monitoring meadow depended on the overall size of the meadow, the number of sites possible (dependent on available time) and the number of quadrats required per site. The monitoring program could detect 30 - 75% change in Summer and 75 - 100% change in Winter (depending on meadow) such that change in the mean would be detected at the 90% level (i.e. Type I error of 10%) with 90% assurance of detecting a true difference of this size (i.e. Type II error of 10%).

Monitoring of the selected *primary* seagrass meadows in Mourilyan Harbour was conducted between January 1995 and July 1997 (Table 1). The initial Summer and Winter baseline surveys detected no seagrass beyond the northward limit of Walter Creek mouth or south of Maizie Island, which were thus set as the northern and southern limits for subsequent surveys, respectively.

2.2. Seagrass Distribution and Abundance

The sampling approach was based on the need to monitor changes in the above-ground biomass and areal extent of seagrass within Mourilyan Harbour. Survey sites (10 m radius) were haphazardly sampled within specified monitoring meadows at predetermined frequencies (Table 2). Estimates of above-ground seagrass biomass (3 - 10 replicates of a 0.25 m^2 quadrat), seagrass species composition, % cover of algae and sediment characteristics were recorded at each site. The relative proportion of biomass for each seagrass species within each quadrat was also recorded.

Above-ground biomass was determined by a “visual estimates of biomass” technique described by Mellors (1991). At each site, divers recorded an estimated rank of seagrass biomass. To calculate above-ground biomass estimates each diver’s rank of seagrass biomass was calibrated against a set of quadrats which were harvested and the above-ground dry biomass measured (g DW. m^{-2}).

Seagrass species were identified according to Kuo and McComb (1989). Specimens of seagrass were collected for later taxonomic verification where necessary. Sediment characteristics were described at each site using visual estimates of grain size: shell grit, rock gravel, coarse sand, sand, fine sand and mud.

A differential global positioning system (dGPS) was used to locate each survey site (latitude and longitude) accurate to within 5 m. A depth sounder was used to measure water depth. Depth below mean sea level (MSL) was calculated for each survey site by reference to tide times.

The presence or absence of seagrass is defined by the above-ground biomass. Where above-ground biomass was absent, the presence of rhizome/root and seed bank material was not reported. Survey sites with no seagrass can be found within meadows because seagrass cover within meadows is not always uniform.

2.3. Geographic Information System

All data from each survey were entered onto a Geographic Information System (GIS). A GIS base map using aerial photographic images (courtesy Beach

Protection Authority: 28/8/1992, 4410 m; 17/7/1996, 1830m) was rectified to AMG zone 55 co-ordinates.

Boundaries of seagrass meadows were determined in the field by divers, based on the GPS fix at each survey site, by surface observation from a vessel where possible and where available on information from aerial photograph interpretation. The accuracy of this boundary method depends largely on the GPS accuracy, plus biologist interpretation of meadow boundaries/edge (ie. considering depth, sand bank position, sediment, etc.), aerial photograph resolution, and rectified GIS map. Taking these factors into account we have provided an 'estimate of reliability' (R) of the areal extent (ha) of each monitoring meadow within Mourilyan Harbour. For each meadow we accounted for these sources of error when estimating a reliability value. For example, for some meadows the main source of error was GPS data (eg. ±25 m for the Channel meadow in December 1993 (see (McKenzie *et al.* 1996)), or aerial photograph interpretation (eg. ±7.5 m Lily meadow). The estimate of reliability (R) was determined from the MapInfo® computer program.

When comparing post-1994 surveys with the baseline surveys (December 1993 and July 1994), the conclusions should be treated with caution. This is because the baseline surveys were essentially pilot studies, in which methodology was still being refined. Also, the baseline surveys used normal GPS (error for site positions ±25 m), while the monitoring surveys used differential GPS (error for site positions ±5 m). This makes direct comparisons difficult.

2.4. Analysis

Standard parametric tests were used for analysis of data (Sokal and Rohlf 1987). All divers had significant linear regressions and r^2 >0.84 when calibrating above-ground biomass estimates against a set of harvested quadrats (Appendix 1, Table 5). As the baseline surveys inadequately sampled variances for above-ground biomass and depth, they were not included in statistical analysis. Comparisons with the baseline, were only made by visually comparing means and 95% confidence limits.

⇘ 3. RESULTS

3.1. Mourilyan Harbour Seagrass Species

Five species, 3 families, of seagrasses were found within the survey area of Mourilyan Harbour:

Family Cymodoceaceae
Halodule uninervis (wide & narrow leaf) (Forsk.) Aschers. in Boissier

Family Hydrocharitaceae
Enhalus acoroides (L.*f*.) Royle
Halophila decipiens Ostenfeld
Halophila ovalis (R. Br.) Hook.*f*.

Family Zosteraceae
Zostera capricorni Aschers.

3.2. Mourilyan Harbour Seagrass Distribution and Abundance

Seagrass meadows in Mourilyan Harbour are present in the estuary downstream/north of Maizie Island (survey sites upstream/south of Maizie Island not included in Map 1). Seagrass meadows were found within the harbour channel north of Lily Island, on banks and along the mangrove fringe north of Bradshaw Island. Isolated patches of seagrass were found near the mouths and to 1 km up Armit and Walter Creeks (Map 1).

3.2.1 Entire Harbour

The number of individual seagrass meadows in Mourilyan Harbour increased from 22 to 24 between Summer surveys (December 1993 to December 1996), and 10 to 21 between Winter surveys (July 1994 to July 1997) (Map 1). This is partly because more extensive surveys in December 1996 (Table 3) and July 1997 (Table 4) identified several small isolated patches and thin strips of seagrass within the harbour and along the harbour banks, which were not sampled pre-1995 (Map 1).

The area of seagrass in Mourilyan Harbour increased between Summer surveys, December 1993 to December 1996 (Table 3), and decreased between Winter surveys, July 1994 to July 1997 (Table 4), however these changes were within the estimated ranges of mapping error, indicating no measurable change in overall distribution.

Meadows in Mourilyan Harbour were mostly low biomass *Halophila*-dominated (12 out of 24 meadows in December 1996 were <3 g DW. m^{-2} above-ground biomass and 3 out of 21 meadows in July 1997 were >1 g DW. m^{-2} above-ground biomass). Low-biomass *Halophila*-dominated meadows were found along shallow banks within the harbour, and the periphery of Armit and Walter creeks (Map 1). High-biomass *Halophila*-dominated meadows were found along the Seaforth Valley mangrove fringe, the sand banks between Armit and Walter Creek mouths and adjacent to Lily Island (Map 1). *Zostera capricorni*-dominated meadows were found adjacent to Bradshaw Island and between Lily and Maizie Islands (Map 1). An extensive *Halodule/ Halophila* meadow was found in the main channel in the harbour (Map 1). Although mean above-ground seagrass biomass within Mourilyan Harbour (all meadows pooled) was greater in December 1996 than in the Summer baseline (December 1993) (5.8 ±0.7 g DW. m^{-2} to 4.0 ±0.5 g DW. m^{-2} respectively) (Table 3), it was lower in July 1997 than in the Winter baseline (July 1994) (4.0 ±0.6 g DW. m^{-2} to 5.1 ±0.7 g DW. m^{-2} respectively).

Depth ranges for all seagrass species were below Mean Sea Level (MSL) (Figure 1). *Zostera capricorni* occurred the shallowest on average (0.37 ±0.02 m below MSL), and *Halodule uninervis* (wide leaf) had the greatest mean depth of 2.93 ±0.23 m below MSL (Figure 1). With the exception of *Zostera capricorni* and *Halophila decipiens,* mean depth for individual seagrass species found within Mourilyan Harbour has remained constant since the initial Summer survey of December 1993, (Figure 1). Mean depth of *Zostera capricorni* was shallower in December 1996 (0.37 m below MSL) than first recorded in December 1993 (0.55 m below MSL). *Halophila decipiens* occurred at a greater depth in December 1996 and July 1997 than in both Summer and Winter baselines (Figure 1).

A small (0.04 ha), but dense, patch of *Enhalus acoroides* was found for the first time in December 1996, in a previously unsurveyed part of Armit Creek (Map 1). This species was previously found only as individual plants in other parts of the survey area.

Seagrass occurred mainly on mud or mud/sand substrates, with some shell included in Channel substrates.

3.2.2 Meadows Selected for Monitoring

Meadow Area

The area of the seagrass meadows selected for monitoring (all combined) varied greatly throughout the monitoring period (Map 2), however these changes are within the estimates of reliability (Tables 3 & 4), so there was no measurable change in overall distribution.

The degree of variation in meadow area differed between meadow type (seagrass community) and season. The Channel meadow changed the most throughout the monitoring period of all the meadows (selected for monitoring), and because it was subtidal, mapping was less accurate. The Channel meadow has continued to increase in area between Summer surveys (Table 3), although the area has decreased in each subsequent Winter survey (Figure 2). The Seaforth Bank meadow increased in area in January 1995, but has since continued to decrease in area over the past two Summers (Figure 2). The area of the Bradshaw Island, Lily Island and Seaforth Edge meadows remained stable throughout both Summer and Winter monitoring events (Map 2).

Above-ground Biomass

Above-ground biomass was consistently high in the *Zostera capricorni*-dominated monitoring meadows at Bradshaw Island and Lily Island, compared to the *Halophila*-dominated meadows, throughout the monitoring period (Tables 3 & 4).

Above-ground biomasses, for all meadows monitored, were lower, and more variable in Winter than in Summer. Between Summer surveys, average above-ground seagrass biomass of Bradshaw Island, Seaforth Edge, Seaforth Bank and the Channel monitoring meadows significantly increased (Figure 2, Tables 3 & 6). Between Winter surveys however, above-ground seagrass biomass either significantly decreased (Seaforth Edge) or increased (Channel) (Figure 2, Tables 4 & 7). Average above-ground biomass of the Lily Island monitoring meadow has remained relatively stable between Summer surveys, but there was a non-significant progressive increase between Winter surveys (Figure 2, Tables 3, 4, 6 & 7).

Species Composition

Halophila ovalis was present in all meadows selected for monitoring (Figure 3). Lily Island and Bradshaw Island meadows were dominated by *Zostera capricorni*. Seaforth Bank meadow was dominated by *Halophila ovalis,* Seaforth Edge meadow was dominated by *Halophila decipiens,* while the Channel meadow contained a mixture of *Halophila ovalis, Halodule uninervis* (wide leaf), *Halophila decipiens* and *Halodule uninervis* (narrow leaf) (Figure 3).

Species composition for the Bradshaw Island and Lily Island monitoring meadows remained stable between surveys (Figure 3a & 4b), with only small amounts of *Halophila ovalis* in the Summer months. Species composition in all other meadows selected for monitoring has changed during the monitoring period.

Halophila decipiens has displaced *Halophila ovalis* as the dominant species within the Seaforth Edge meadow and the amount of *Halodule uninervis* has diminished greatly (Figure 3c). *Halophila ovalis* continued to dominate the Seaforth Bank meadow, although the amount of *Halophila decipiens* has varied over the monitoring period (Figure 3d).

In the Channel meadow, *Halodule uninervis* increased, displacing *Halophila* as the most abundant species (Figure 3e). Also, narrow-leaf *Halodule uninervis* appeared in December 1996, while in previous Summer surveys only the wide-leaf *Halodule uninervis* was found in the Channel meadow (Figure 3e).

Depth

The depth distribution of the meadows selected for monitoring in Mourilyan Harbour ranged between 0.1 - 4.4 m below MSL in Summer and 0.3 - 2.8 m below MSL in Winter (Figure 4).

Average meadow depth was shallowest for the Bradshaw and Lily Island *Zostera*-dominated meadows and deepest in the Channel meadow (Figure 4). Average depths for all meadows selected for monitoring were generally deeper in the Summer months than in Winter.

Mean depth of the Channel meadow decreased significantly from 3.2 m to 2.5 m below MSL over the Summer monitoring period (Figure 4a, Tables 8). During Winter months however, the Channel meadow depth decreased significantly in July 1996, but has since increased to 2.6 m below MSL in July 1997.

Depth of the Seaforth Bank meadow has significantly decreased over the past 3 Summer monitoring events (Figure 4a, Table 8). Mean depths for the Seaforth Edge and Lily Island meadows have remained constant between Summer surveys (Figure 4a, Table 8), however they have significantly decreased between Winter surveys (Figure 4b, Table 9). Mean depth of the Bradshaw Island meadow remained relatively constant over the monitoring period (Figure 4b, Table 9).

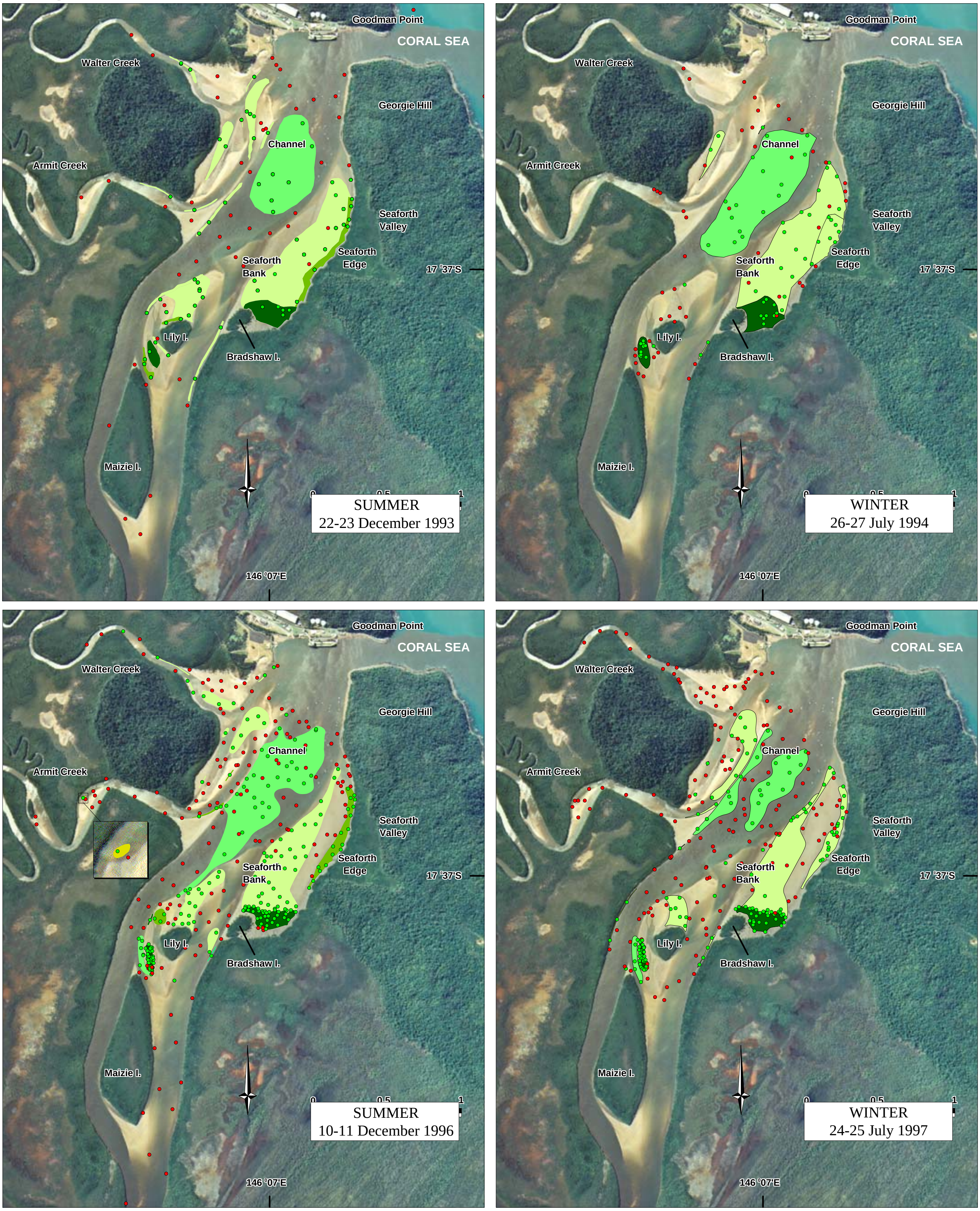
3.3. Mourilyan Harbour Algae.

The most common algal types recorded in Mourilyan Harbour were “benthic algal turf” and filamentous green algae. Algal cover was highly variable between surveys, but algae was generally less common in Winter months than in Summer for most meadows selected for monitoring (Figure 5). Benthic algal turf and filamentous green algae were most common on the Seaforth Bank and Edge meadows. In early surveys, only algae in patches of low cover (<10%) was present in the *Zostera capricorni* meadows.

The composition of algae in the channel has changed from mainly “benthic algal turf” and filamentous green algae in 1995, to macro brown algae and *Udotea* spp. in 1996, to predominantly red algae in 1997. Also, isolated plants of *Caulerpa* spp. were recorded sporadically in the harbour in later surveys.

MAP 1.

Seagrasses of Mourilyan Harbour - entire harbour surveys.



LEGEND

- Seagrass present
- Seagrass absent
- *Zostera capricorni*
- High biomass *Halophila*
- Low biomass *Halophila*
- *Halodule/Halophila*
- *Enhalus acoroides*

Source:
L.J. McKenzie, W.J. Lee Long, A.J. Roelofs, C.A. Roder and R.G. Coles. (1998).
'Port of Mourilyan Seagrass Monitoring - First 4 Years.'
EcoPorts Monograph Series No 15. (Ports Corporation of Queensland, Brisbane) 34 pp.

Maps pre 1995: L.J. McKenzie, M.A. Rasheed, W.J. Lee Long and R.G. Coles. (1996).
'Port of Mourilyan Seagrass Monitoring - Baseline Surveys-Summer (December) 1993 and Winter (July) 1994.'
EcoPorts Monograph Series No 2. (PCQ, Brisbane) 52 pp.

Aerial photo: 28/8/92 1:25,000, courtesy Beach Protection Authority.

Produced by the Seagrass Ecology Group, QDPI, Northern Fisheries Centre, Cairns, 1998.

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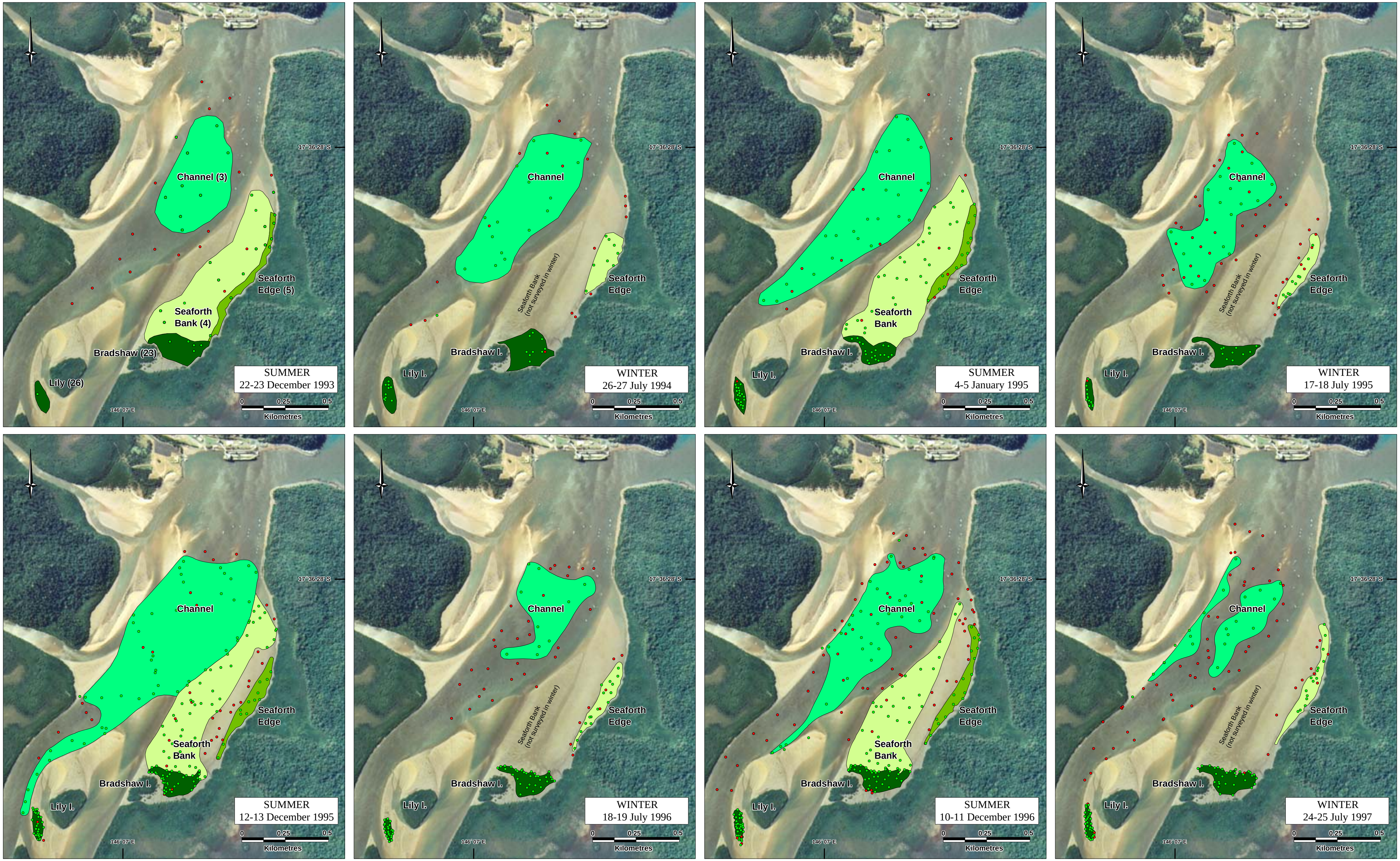
MAP 2.
Changes in Mourilyan Harbour seagrasses - meadows selected for monitoring only.



LEGEND

- Seagrass present
- Seagrass absent
- *Zostera capricorni*
- High biomass *Halophila*
- *Halodule/Halophila*
- Low biomass *Halophila*

Source: L.J. McKenzie, W.J. Lee Long, A.J. Roelofs, C.A. Roder and R.G. Coles. (1998). 'Port of Mourilyan Seagrass Monitoring - First 4 Years.' *EcoPorts Monograph Series No 15.* (Ports Corporation of Queensland, Brisbane) 34 pp.

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PORTS CORPORATION QUEENSLAND

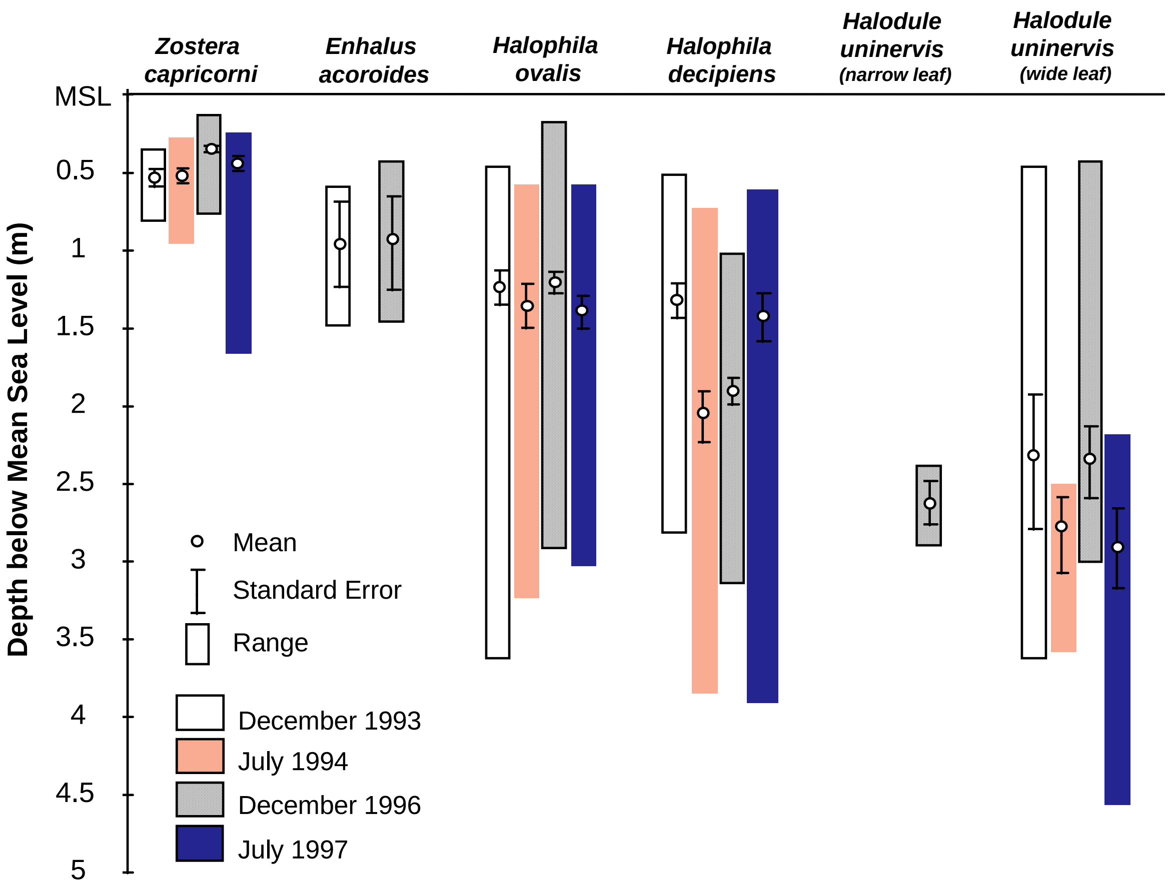

Figure 1. Means, ranges and standard error of the depth distribution of seagrasses (all sites pooled) in Mourilyan Harbour in Summer and Winter surveys of the entire harbour.

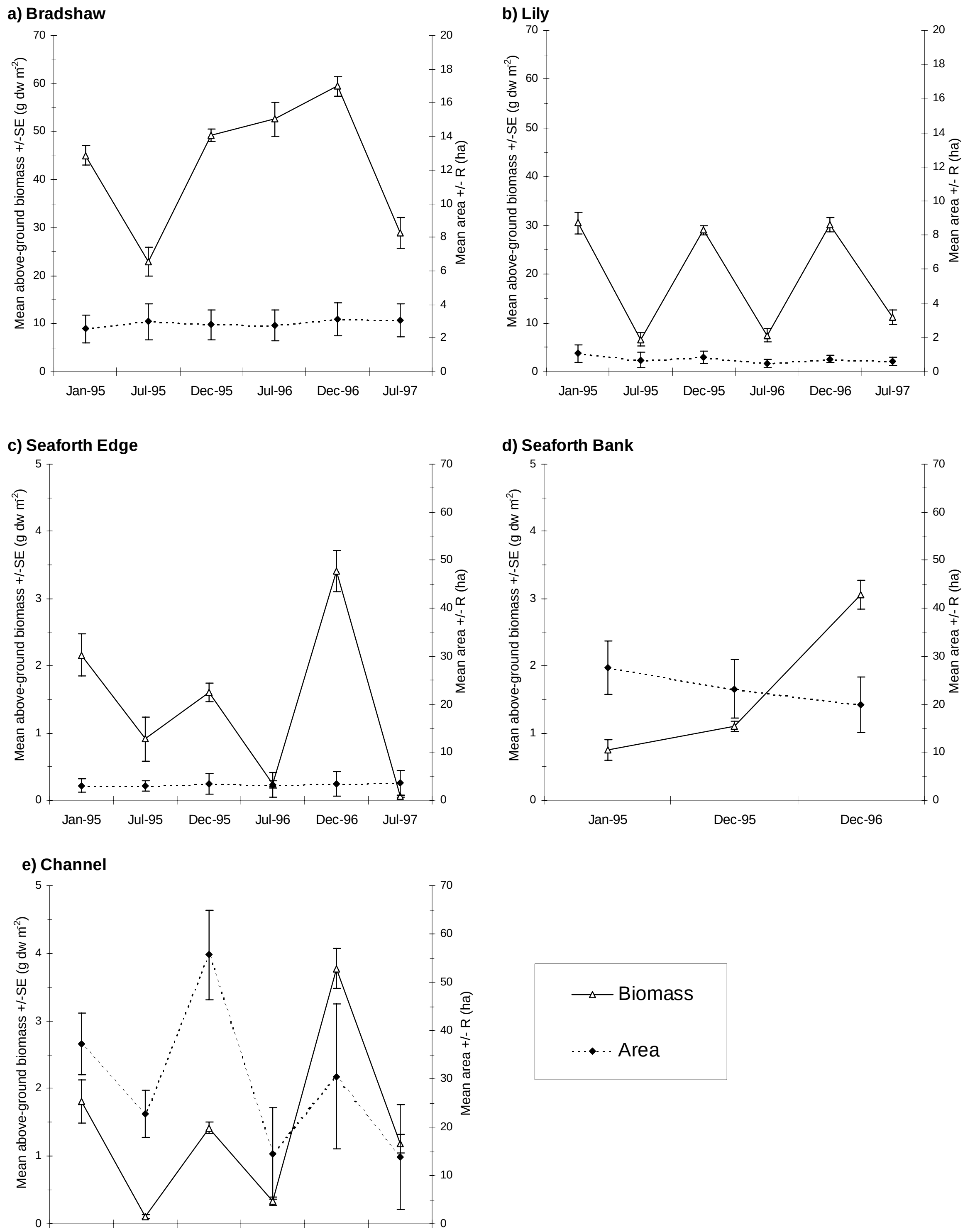

Figure 2. Mean above-ground biomass ± SE and Mean area ± R (estimate of reliability) for each meadow selected for monitoring in Mourilyan Harbour over the monitoring period (NB Seaforth Bank was not sampled during Summer monitoring events).

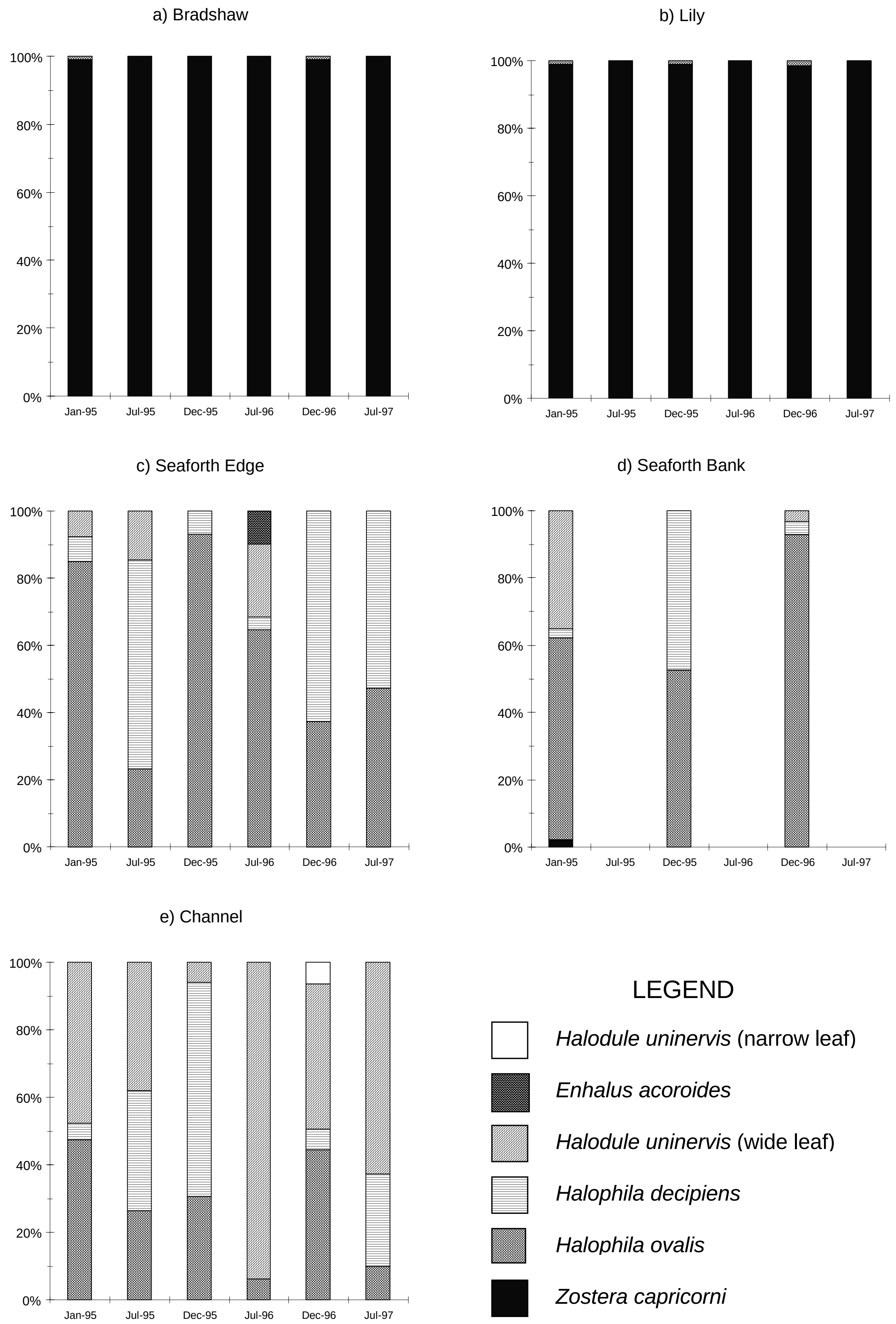

Figure 3. Percentage composition of above-ground biomass for each seagrass species in each meadow monitored in Mourilyan Harbour.

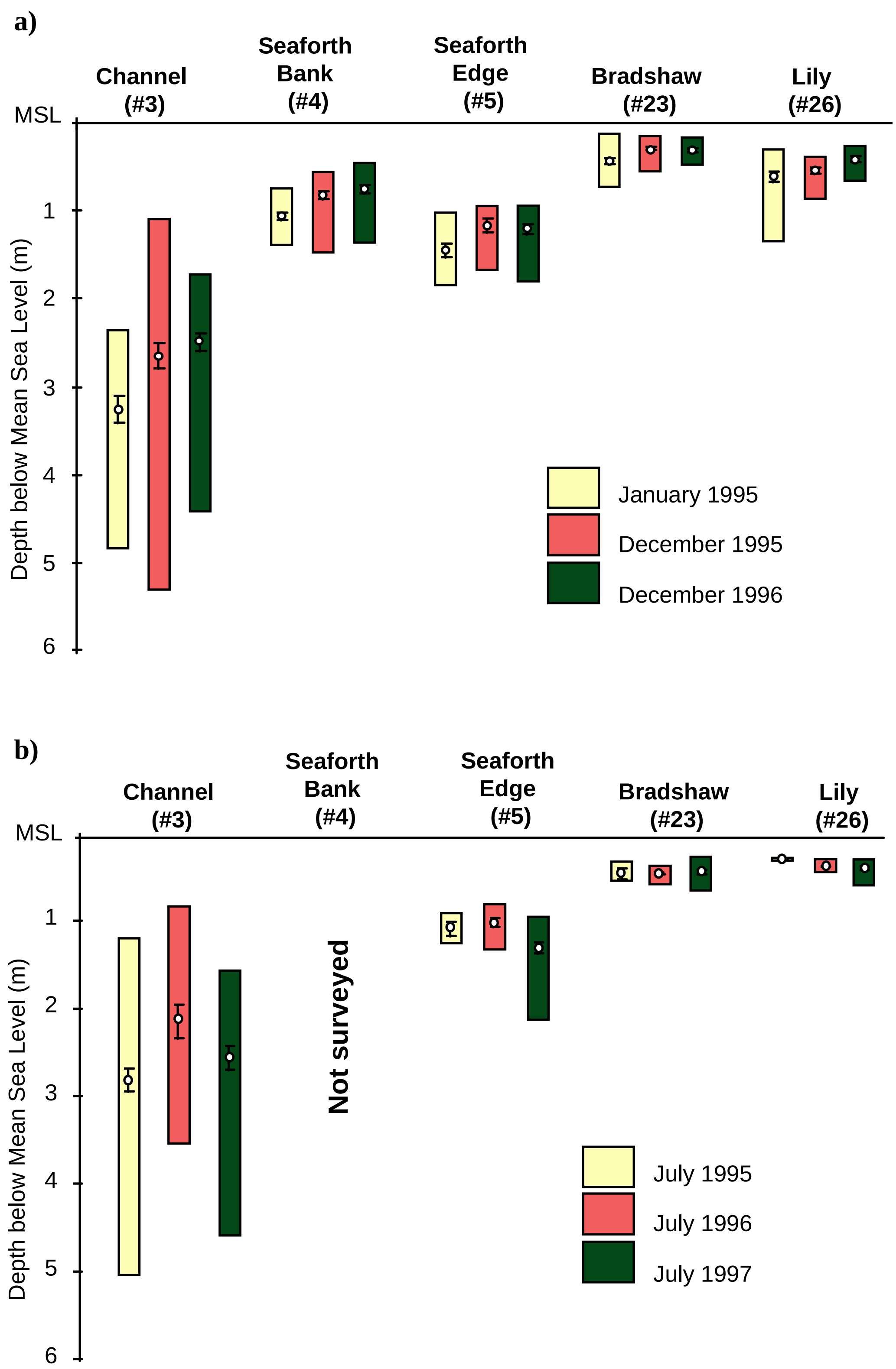

Figure 4. Means, ranges and standard error of the depth distribution of seagrass meadows selected for monitoring in Mourilyan Harbour in Summer (a) and Winter (b).

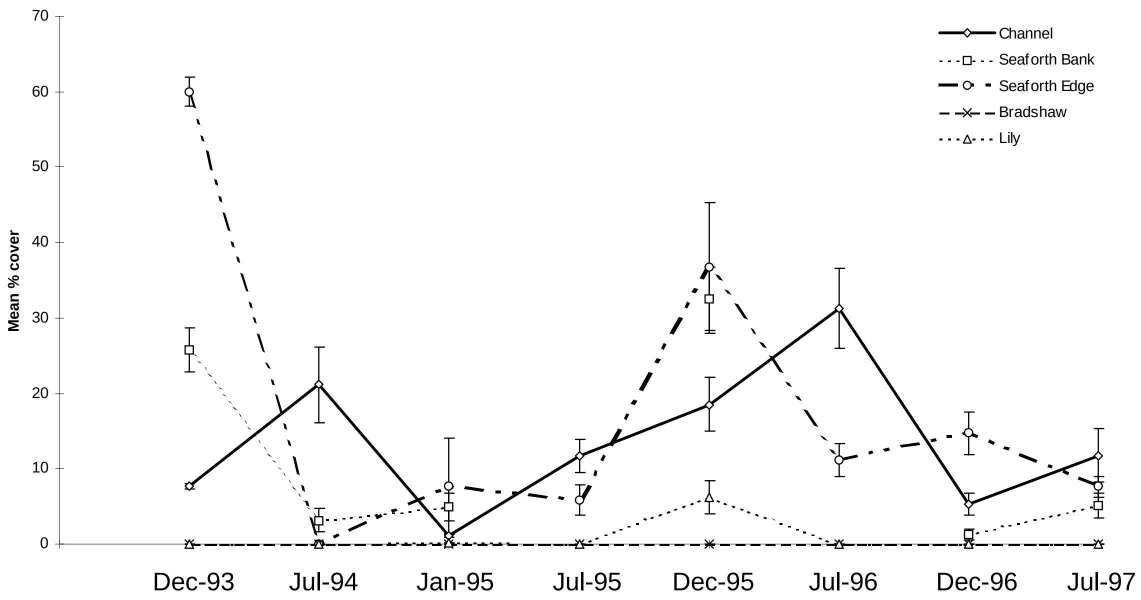

Figure 5. Mean percent cover of algae (all types pooled) in each of the meadows selected for monitoring in Mourilyan Harbour, for each survey.

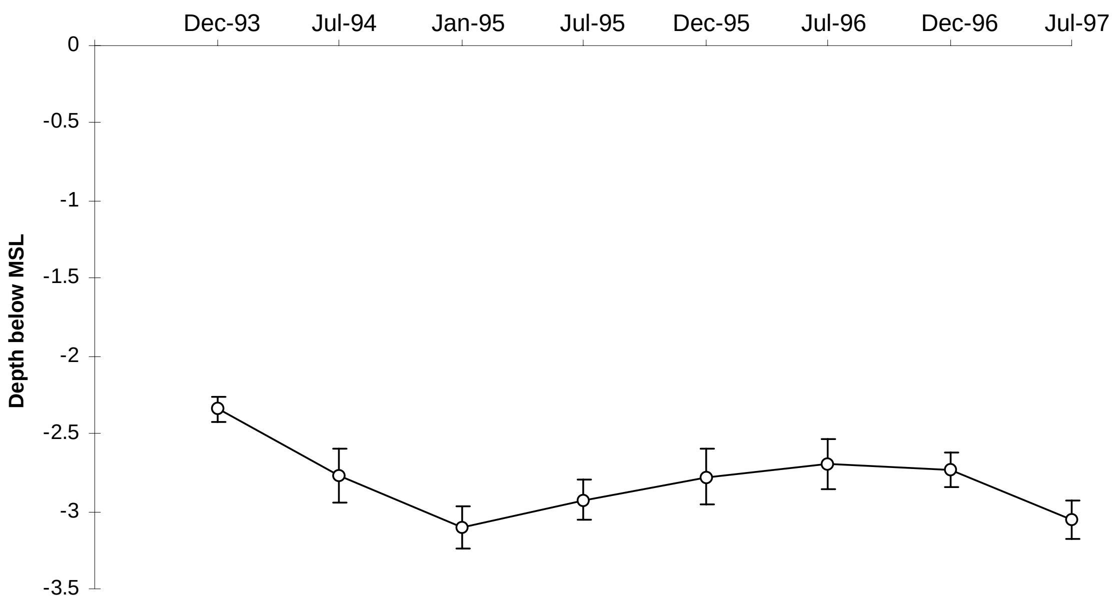

Figure 6. Changes in the depth of Mourilyan Harbour channel (seagrass and non-seagrass sites pooled) over the study period.

Table 1. Date conducted and type for each survey of Mourilyan Harbour seagrasses.

Survey	**Survey date**	**Survey type**
Summer baseline	22-23 December 1993	all meadows
Winter baseline	26-27 July 1994	all meadows
Summer interim#1	4-5 January 1995	monitoring meadows only
Winter interim #1	7-8 July 1995	monitoring meadows only
Summer interim #2	12-13 December 1995	monitoring meadows only
Winter interim #2	18-19 July 1996	monitoring meadows only
Summer final	10-11 December 1996	all meadows *(incl. monitoring meadows)*
Winter final	18-19 July 1997	all meadows *(incl. monitoring meadows)*

Table 2 Estimate of the number of sites and quadrats per site, such that the percentage change in the mean will be detected at the 90% level with 90% assurance of detecting a true difference for each of the primary monitoring meadows in Mourilyan Harbour for Summer and Winter surveys.

Species Codes: HD, *Halophila decipiens*; HO, *Halophila ovalis*; HU, *Halodule uninervis*; ZC, *Zostera capricorni*. NP = not possible

Meadow ID	Description	Summer			Winter		
		Detectable % change	# Sites	# Quads	Detectable % change	# Sites	# Quads
3	Channel (HD, HO, HU)	75	30	10	100	40	5
4	Seaforth Bank (HO, HD)	75	30	10	NP	NP	NP
5	Seaforth Edge (HD, HO)	30	10	10	75	15	2
23	Bradshaw Is (ZC)	30	20	10	75	10	2
26	Lily Is (ZC, HO)	30	20	10	75	15	2

Table 3. Mean above-ground biomass and area for Mourilyan Harbour seagrass meadows for each summer survey

Values in brackets for biomass are % change since previous survey, and for area are the estimates of reliability (R)

Meadow (ID No)	**# of sites**				**Mean biomass ± SE (g dw. m-2)**				**Area (ha)**			
	Dec 1993	**Jan 1995**	**Dec 1995**	**Dec 1996**	**Dec 1993**	**Jan 1995**	**Dec 1995**	**Dec 1996**	**Dec 1993**	**Jan 1995**	**Dec 1995**	**Dec 1996**
Lily (26)	1	20	21	20	16.12 ± 4.37	30.47 ± 2.16 *(+89%)*	29.04 ± 0.93 *(-5%)*	30.15 ± 1.46 *(+4%)*	1.0 *(0.1 - 2.3)*	1.1 *(0.7 - 1.6)*	0.8 *(0.6 - 1.2)*	0.7 *(0.5 - 0.9)*
Bradshaw (23)	5	20	20	20	42.22 ± 6.01	45.05 ± 2.12 *(+8%)*	49.25 ± 1.30 *(+9%)*	59.47 ± 2.01 *(+20%)*	3.8 *(1.9 - 6.2)*	2.6 *(1.8 - 3.4)*	2.8 *(2.0 - 3.7)*	3.1 *(2.1 - 4.1)*
Seaforth Edge (5)	5	14	10	17	2.04 ± 0.25	2.16 ± 0.31 *(no change)*	1.61 ± 0.14 *(-25%)*	3.41 ± 0.31 *(+212%)*	2.7 *(2.6 - 7.4)*	3.1 *(1.8 - 4.5)*	3.4 *(1.5 - 5.6)*	3.4 *(0.9 - 5.9)*
Seaforth Bank (4)	14	31	30	29	1.10 ± 0.10	0.75 ± 0.15 *(-36%)*	0.96 ± 0.07 *(+28%)*	3.06 ± 0.22 *(+282%)*	22.3 *(16.0 - 29.0)*	27.7 *(22.4 - 33.3)*	23.2 *(17.5 - 29.3)*	19.9 *(14.1 - 25.7)*
Channel (3)	8	30	34	37	0.51 ± 0.10	1.81 ± 0.32 *(+280%)*	1.25 ± 0.08 *(-31%)*	3.77 ± 0.30 *(+271%)*	20.2 *(15.9 - 24.8)*	37.3 *(31.1 - 43.7)*	55.7 *(46.7 - 64.9)*	30.5 *(15.5 - 45.5)*
Others *(pooled)*	99	na	na	242	1.02 ± 0.12	na	na	2.93 ± 0.27 *(+187%)*	15.0 *(10.0 - 16.0)*	na	na	13.5 *(4.9 - 22.1)*
TOTAL *monitoring only*	33	115	115	123	7.14 ± 1.18	14.07 ± 0.75 *(+98%)*	15.20 ± 0.65 *(+10%)*	17.83 ± 0.78 *(+14%)*	49.9 *(36.6 - 69.7)*	71.6 *(57.3 - 85.6)*	85.9 *(68.2 - 104.6)*	57.6 *(33.2 - 82.0)*
TOTAL *all combined*	132	na	na	365	4.02 ± 0.53	na	na	15.82 ± 0.69 *(+293%)*	65.0 *(46.0 - 86.0)*	na	na	71.1 *(38.6 - 103.6)*

Table 4. Mean above-ground biomass and area for Mourilyan Harbour seagrass meadows for each winter survey

Values in brackets for biomass are % change since previous survey, and for area are the estimates of reliability (R)

Meadow (ID No)	**# of sites**				**Mean biomass ± SE (g dw. m-2)**				**Area (ha)**			
	July 1994	**July 1995**	**July 1996**	**July 1997**	**July 1994**	**July 1995**	**July 1996**	**July 1997**	**July 1994**	**July 1995**	**July 1996**	**July 1997**
Lily (26)	10	15	18	15	9.59 ± 1.28	6.64 ± 1.31 *(-31%)*	7.47 ± 1.39 *(+13%)*	11.14 ± 1.53 *(+49%)*	1.3 *(0.2 - 2.4)*	0.7 *(0.3 - 1.1)*	0.5 *(0.3 - 0.7)*	0.6 *(0.4 - 0.8)*
Bradshaw (23)	10	10	16	12	26.56 ± 2.76	22.82 ± 3.00 *(-14%)*	52.56 ± 3.62 *(+130%)*	28.83 ± 3.22 *(-45%)*	4.4 *(2.4 - 6.4)*	3.0 *(1.9 - 4.0)*	2.7 *(1.7 - 3.7)*	3.1 *(2.1 - 4.0)*
Seaforth Edge (5)	8	15	15	16	0.73 ± 0.12	0.91 ± 0.33 *(+25%)*	0.24 ± 0.05 *(-73%)*	0.06 ± 0.01 *(-75%)*	3.8 *(1.4 - 6.2)*	2.9 *(1.9 - 4.0)*	3.2 *(0.6 - 5.8)*	3.7 *(1.2 - 6.2)*
Channel (3)	18	30	11	20	0.22 ± 0.06	0.11 ± 0.03 *(-50%)*	0.34 ± 0.06 *(+218%)*	1.19 ± 0.13 *(+250%)*	31 *(23.2 - 38.8)*	22.8 *(17.9 - 27.7)*	14.5 *(5.1 - 23.9)*	13.8 *(2.9 - 24.7)*
Others (pooled)	99	na	na	51	0.32 ± 0.12	na	na	0.52 ± 0.08 *(+62%)*	27.8 *(20.1 - 35.5)*	na	na	25.8 *(17.5 - 34.2)*
TOTAL *monitoring only*	46	70	42	63	8.07 ± 1.1	3.04 ± 0.53 *(-62%)*	12.92 ± 1.86 *(+325%)*	6.16 ± 0.85 *(-52%)*	40.4 *(26.9 - 53.9)*	29.4 *(21.9 - 36.9)*	20.9 *(7.7 - 34.1)*	21.2 *(6.5 - 35.8)*
TOTAL *all combined*	132	na	na	114	5.07 ± 0.72	na	na	4.01 ± 0.55 *(-21%)*	68.2 *(47.0 - 89.4)*	na	na	47.0 *(25.3 - 68.7)*

➯ 3. DISCUSSION & CONCLUSIONS

3.1 Entire Harbour Survey

The entire-harbour surveys (December 1996 and July 1997) indicate that the area of seagrass habitat in Mourilyan Harbour has increased since the 1993/94 baseline surveys. However this trend is within the estimated ranges of mapping error, indicating no measurable change in overall area.

The *Zostera*-dominated meadows of the harbour have changed little over the 4 year period, however the *Halophila* spp. meadows have changed shape, abundance and position. Seasonal and year to year changes in shape and location of the *Halophila* spp. meadows is expected to be naturally greater than for most other species (Birch & Birch 1984; McKenzie *et al*. 1996).

Isolated plants of *Enhalus acoroides* were found in the Seaforth Bank and Seaforth Edge meadow, and in a small patch approximately 600 m upstream in Armit Creek. Distribution of this seagrass species has remained patchy in surveys of Mourilyan Harbour and is not likely to be ecologically important at this location. However, *Enhalus acoroides* at Mourilyan Harbour is close to its southern geographical limits of distribution and survival of these plants is important to seagrass biodiversity in this part of Australia.

3.2 Meadows Selected for Monitoring

No measurable change or trend in overall distribution of the seagrass meadows selected for monitoring (all meadows pooled) could be detected, as they varied greatly throughout the monitoring period. The degree of variation in meadow area differed between meadow type (seagrass community) and season.

Seagrass growth extended deeper in Summer than in Winter, for almost every species and every meadow, possibly resulting from higher intensities of incident light and light penetration during Spring-Summer periods.

Seasonal changes (Summer to Winter) in area and biomass were greatest for meadows dominated by *Halophila* species (Seaforth Edge and Bank, and Channel meadow). Increased mean above-ground biomass of the Channel meadow over three Summers, may be in part a result of an increase in the proportion of *Halodule uninervis* (wide leaf).

The Bradshaw Island, Seaforth Edge and Lily Island meadows are the highest biomass seagrass habitats in Mourilyan harbour and most important to prawn and fish production (McKenzie *et al.* 1994); significant changes in area, seagrass species composition, or seagrass above-ground biomass of these meadows would be expected to influence fisheries productivity. Large year-to-year changes in the Channel or Seaforth Edge *Halophila* meadows may be useful early indicators of significant natural change or environmental impact.

The *Halophila*-dominated meadows could only be used as an indicator of significant environmental impact if a 100% change (particularly loss) in Summer-time abundance occurred. For the relatively stable *Zostera* meadows a loss of

50% or more would be significant. Neither of these habitat types have changed in area to this degree. Changes in biomass and species in the Channel meadow are evidence for possible low-level impact and investigation during further studies is warranted.

Mean above-ground seagrass biomass in the *Zostera*-dominated Bradshaw Island meadow has continued to increase over the past 3 surveys, although the area of the meadow has remained relatively stable. The average depth of this meadow has decreased by approximately 20 cm since December 1993, although this could be an artefact of changes in sampling distribution (shallower inshore sites were only accessible in the later surveys). The observed decrease in depth of this meadow could also be a result of sediment accretion across the whole meadow, as observed in other studies (Fonseca and Fisher 1986; Almasi *et al*. 1987; Fonseca and Cahalan 1992).

The continued decrease in the area of the Seaforth Bank meadow since January 1995 may be the result of the accretion of sand along the eastern edge of the bank, causing greater exposure (desiccation) and loss of the seagrasses in that area. This may be a natural dynamic pattern in the estuary and is considered no cause for concern.

With the exception of the Lily Island meadow, which has remained stable, above-ground biomass increased over consecutive Summer surveys in the monitoring meadows. Algal cover and the presence of the low-light tolerant red algae (Bidwell 1979) in the channel (displacing green algae) also increased in the later surveys. If the trend of increasing seagrass biomass continues, then causes for change (eg., changes in depth, water turbidity or nutrient loads) may require investigating.

Mean depth of the Channel meadow was significantly less each Summer, although analysis of all sites in the channel (within and outside the meadow) showed no significant decrease in overall channel bathymetry during the monitoring period (Figure 6). The Channel meadow is now present in the northern section of the channel which is the shallowest part. There is a need to determine whether these changes reflect natural events or human-related impacts in the port or catchment.

3.3 Conclusions

The observed changes in seagrass species, area and abundance within Mourilyan Harbour meadows span a monitoring period of four years (one baseline year and three years of monitoring) and provides the best available measure of year-to-year change in seagrasses for any north Queensland estuarine location. The levels of variability in biomass are within the range of seasonal and year-to-year changes observed in other tropical northern Queensland seagrass habitats (Mellors *et al*. 1993; McKenzie 1994; Lee Long *et al*. 1996), but the limited time-span of all these studies is insufficient to determine if seagrass systems are stable or changing. A reliable measure of the range of natural variability requires a long term monitoring strategy, including remapping the entire harbour at least every 3 years and/or immediately after major climatic or anthropogenic impacts. Trends observed over four Summer and four Winter surveys of Mourilyan Harbour indicate that Summer monitoring alone would be sufficient in future; and also indicates that there is a need to investigate further the causes for changes in the Channel, Seaforth Bank and Bradshaw Island meadows, eg., possible shallowing, or changes in light availability and nutrient levels.

It appears that during the 4 year monitoring period, impacts on Mourilyan Harbour seagrasses from natural events, port developments/operations, and other land-use practices in the Moresby catchment were not large enough to be of ecological importance.

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APPENDIX 1 - Statistical analyses

Table 5. Results of linear regressions of each diver's seagrass biomass estimation with harvested above-ground biomass (g DW. m^{-2}), for each seagrass calibration type for each survey.
Calibration type: Z= *Zostera*, H= *Halodule/Halophila*, M= mixed species

Survey	Diver	Type	r^2	*F*	*P*
January 1995	R. Coles	M	0.86	35.91	0.001
	C. Creighton	M	0.90	51.36	«0.001
	W. Lee Long	M	0.92	68.19	«0.001
	K. Vidler	M	0.91	61.30	«0.001
July 1995	L. McKenzie	Z	0.98	173.34	«0.001
	M. Rasheed	H	0.99	477.49	«0.001
	A. Roelofs	H	0.94	50.31	0.006
December 1995	E. Bradshaw	H	0.99	234.89	0.004
	L. McKenzie	Z	0.95	60.51	0.004
	A. Roelofs	H	0.84	15.37	0.029
July 1996	A. Roelofs	Z	0.97	139.82	0.0003
	A. Roelofs	H	0.98	210.29	«0.001
December 1996	W. Lee Long	H	0.96	88.30	«0.001
	L. Makey	H	0.96	86.88	«0.001
	L. McKenzie	Z	0.99	740.55	«0.001
	C. Roder	H	0.96	89.95	«0.001
	A. Roelofs	H	0.96	88.55	«0.001
July 1997	P. Daniel	H	0.88	28.43	0.006
	L. McKenzie	Z	0.88	28.43	0.006
	C. Roder	H	0.99	375.05	«0.001
	A. Roelofs	H	0.98	242.0	«0.001

Table 6. Results of two-way ANOVA for above-ground biomass verses Summer monitoring event for each meadow selected for monitoring (Ln (x+1)).

MEADOW NAME & ID #	SS	DF	MS	F	*P*
Channel #3					
Within + residual	284.7	792	0.36		
Year	11.17	2	5.59	15.54	0
Site	131.52	29	4.54	12.62	0
Year by site	229.83	56	4.1	11.42	0
(Model)	421.78	87	4.85	13.49	0
(Total)		879	0.8		
Seaforth Bank #4					
Within + residual	199.38	774	0.26		
Year	30.77	2	15.38	59.72	0
Site	92.37	29	3.19	12.37	0
Year by site	159	54	2.94	11.43	0
(Model)	315.2	85	3.71	14.4	0
(Total)	514.58	859	0.6		
Seaforth Edge #5					
Within + residual	133.46	378	0.35		
Year	4.22	2	2.11	5.97	0.003
Site	48.06	16	3	8.51	0
Year by site	106.42	23	4.63	13.1	0
(Model)	167.07	41	4.07	11.54	0
(Total)	300.54	419	0.72		
Bradshaw #23					
Within + residual	362.96	540	0.67		
Year	36.3	2	18.15	27.01	0
Site	82.08	19	4.32	6.43	0
Year by site	109.17	38	2.87	4.27	0
(Model)	227.56	59	3.86	5.74	0
(Total)	590.51	599	0.99		
Lily #26					
Within + residual	410.96	549	0.75		
Year	2.85	2	1.43	1.91	0.15
Site	197.45	20	9.87	13.19	0
Year by site	271.09	38	7.13	9.53	0
(Model)	522.61	60	8.71	11.64	0
(Total)	933.57	609	1.53		

Table 7. Results of two-way ANOVA for above-ground biomass verses Winter monitoring event for each meadow selected for monitoring(Ln (x+1)).

MEADOW NAME & ID #	SS	DF	MS	F	*P*
Channel #3					
Within + residual	10.7	244	0.36		
Site	14.64	29	0.5	11.51	0
Year	1.44	2	0.72	16.39	0
Site by Year	22.74	29	0.78	17.88	0
(Model)	53.54	60	0.89	20.35	0
(Total)	64.54	304	0.21		
Seaforth Edge #5					
Within + residual	0.94	46	0.02		
Site	4.04	16	0.25	12.42	0
Year	0.53	2	0.27	13.14	0
Site by Year	9.47	28	0.34	16.61	0
(Model)	15.08	46	0.33	16.11	0
(Total)	16.02	92	0.17		
Bradshaw #23					
Within + residual	7.57	38	0.2		
Site	7.45	15	0.5	2.49	0.012
Year	3.66	2	1.83	9.18	0.001
Site by Year	11.38	20	0.57	2.85	0.003
(Model)	60.65	37	0.83	4.16	0
(Total)	38.22	75	0.51		
Lily #26					
Within + residual	20.71	48	0.43		
Site	29.28	17	1.72	3.99	0
Year	2.1	2	1.05	2.44	0.098
Site by Year	44.25	28	1.58	3.66	0
(Model)	82.85	47	1.76	4.09	0
(Total)	103.56	95	1.09		

Table 8. Results of one-way ANOVA for depth below Mean Sea Level (MSL) verses Summer monitoring event for each meadow selected for monitoring (Bradshaw Island meadow data transformed to (Ln(x+1)).

MEADOW NAME & ID #	SS	DF	MS	F	*P*
Channel #3					
Between Years	7.83	2	3.9	6.94	0.0015
Within Years	53.03	94	0.56		
Total	60.86	96			
Seaforth Bank #4					
Between Years	0.71	2	0.36	14.07	0.003
Within Years	4.62	81	0.057		
Total	5.33	83			
Seaforth Edge #5					
Between Years	0.25	2	0.12	1.94	0.1569
Within Years	2.49	39	0.06		
Total	2.74	41			
Bradshaw #23					
Between Years	0.01	2	0.01	0.66	0.5189
Within Years	0.5	56	0.01		
Total	0.5	58			
Lily #26					
Between Years	0.19	2	0.1	2.66	0.0784
Within Years	2.08	58	0.03		
Total	2.27	60			

Table 9. Results of one-way ANOVA for depth below Mean Sea Level (MSL) verses Winter monitoring event for each meadow selected for monitoring.

MEADOW NAME & ID #	SS	DF	MS	F	*P*
Channel #3					
Between Years	3.8031	2	1.9016	4.1627	0.0204
Within Years	26.9516	59	0.4568		
Total	30.7547	61			
Seaforth Edge #5					
Between Years	0.7536	2	0.3768	9.0915	0.0005
Within Years	1.9065	46	0.0414		
Total	2.6602	48			
Bradshaw #23					
Between Years	0.004	2	0.002	0.2904	0.7491
Within Years	0.4312	57	0.0076		
Total	0.4356	59			
Lily #26					
Between Years	0.1099	2	0.0549	13.617	0
Within Years	0.2501	62	0.004		
Total	0.36	64			

Notes: