Port of Mourilyan
Seagrass Monitoring Baseline Surveys

PORTS CORPORATION QUEENSLAND

CRC Reef Research Centre

DPI QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES

• Summer (December) 1993 • Winter (July) 1994

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Cover Image
Port of Mourilyan

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EXECUTIVE SUMMARY

Key Results

- 65 ha of seagrass habitat was mapped within Mourilyan Harbour in the summer (December 1993) survey and 68 ha in the winter (July 1994) survey.

- There was a loss of 12 small "ephemeral" meadows, a reduction in seagrass biomass and an increase in total seagrass area of 2 ha in winter compared with the summer survey. This is considered to be well within the range of natural change expected due to seasonality.

- Five seagrass species were recorded in the surveys: *Zostera capricorni, Halophila ovalis, Halophila decipiens, Halodule uninervis* and *Enhalus acoroides*. *Enhalus acoroides* was only found in the summer (December 1993) survey.

- Six species of penaeid prawns were collected in summer and 8 species in winter. The endeavour prawn (*Metapenaeus endeavouri*) was the most abundant species collected. 90% of penaeid prawns collected in summer (December 1993) were of importance to the northern prawn fishery, as compared to 66% in winter (July 1994).

- 26 fish taxa were collected in beam trawls in summer and 27 in winter. The family Gobiidae was the most abundant. 14% of fish collected in summer were of direct commercial importance compared to 1% in winter.

- High abundances of small crustacea collected were likely to support complex predatory food chains, including fish species of commercial importance.

- The high biomass *Zostera* meadow adjacent to Bradshaw Island supported the greatest abundance and diversity of macrofauna in the Harbour.

- A future monitoring strategy and sampling design for both summer and winter was determined based on results of the summer (December 1993) and winter (July 1994) surveys.

Key Issues

- Juvenile tiger prawns (*Penaeus semisulcatus* and *Penaeus esculentus*) are considered to be almost entirely dependant on shallow, coastal, seagrass meadows for growth and survival, and the densely vegetated *Zostera capricorni* and *Halophila* meadows in Mourilyan Harbour are regionally significant prawn and fish nursery habitats. Seagrasses also play a critical ecological role in buffering sediment and nutrient loads in the estuary, so their viability is paramount to sustained fisheries production and environmental health.

- Seasonal differences in seagrass biomass and distribution reinforce the need to conduct both winter and summer monitoring events

- Monitoring of individual seagrass meadows, rather than considering seagrasses in Mourilyan Harbour as a whole, allows detection of finer changes in seagrass biomass and more detailed information on seagrass species composition changes within the available budget.

- Measures of change in seagrass meadows should not be based solely on the detection of statistically significant changes in seagrass biomass, but should include other information gained from mapping and surveys. The following indicators of change could be used, where necessary to raise cautionary "flags":
  a) three consecutive changes of biomass in one direction (either increase or decrease), leading to a **trend** in biomass change (even if not statistically significant);
  b) a measurable change in areal extent of seagrass meadows;
  c) a measurable change in depth distribution of seagrasses;
  d) a change in seagrass species to more opportunistic species such as *Halophila*.

➯ 1. 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 has developed an Environmental Management Plan (EMP) for the port. This EMP includes funding the Queensland Department of Primary Industries (QDPI) Northern Fisheries Centre (NFC) to conduct seagrass monitoring within Mourilyan Harbour. Seagrasses and their associated macrofaunal communities comprise an important component of Mourilyan Harbour's marine environment and were a suitable target for monitoring environmental change including potential impacts of port operations and development.

As seagrasses have seasonal differences in their distribution and abundance it was decided that two surveys a year, summer and winter, would be performed and monitoring programs would only compare within seasons (ie summer with summer or winter with winter). This report presents the results of the first summer (December 1993) and winter (July 1994) surveys. For these first surveys the following objectives were set:

- *Establish a summer and winter baseline of seagrass distribution in Mourilyan Harbour.*
- *Estimate seagrass biomass for the major areas of seagrass habitat.*
- *Determine the most suitable seagrass meadows for future summer and winter monitoring programs.*
- *Develop monitoring schemes and sampling strategies for future seagrass monitoring that will be statistically defensible.*

The results of the summer (December 1993) and winter (July 1994) surveys form the baseline for further ongoing monitoring at the Port of Mourilyan. PCQ will use the results of this 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) (Figures 1 & 2). 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

Seagrass meadows in northern Queensland support important commercial species of juvenile penaeid prawns and fish (Coles *et al*. 1993; Watson *et al*. 1993). Seagrasses are essential food for dugong, *Dugong dugon* (Miller), and green sea turtles, *Chelonia mydas* (Linnaeus), and act as nutrient and sediment sinks (Short 1987). Seagrasses in coastal regions play important roles in maintaining sediment stability and water clarity. Coastal seagrass meadows are therefore an important resource economically and ecologically.

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). Activities that lead to a change in these factors, such as runoff from agriculture and turbidity from dredging, could potentially have a negative impact on seagrass growth and distribution. Seagrasses show measureable growth responses to changes in ambient water quality conditions and can therefore be used as effective indicators of environmental health (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 and the causes of loss can be natural such as cyclones and floods (Poiner *et al.* 1989), or due to human influences such as agricultural runoff (Preen *et al*. 1995), industrial runoff (Shepherd *et al*. 1989), oil spills (Jackson *et al.* 1989) and dredging (Pringle 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 has been 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. 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. Seagrass Distribution and Abundance

Seagrass surveys were conducted in the lower region of the Moresby River estuary, downstream of Mourilyan Creek, on 22 - 23 of December 1993 and the 26 - 27 of July 1994 (Figure 3). Survey sites (area 10 m radius) were located approximately every 50 m along transects and at selected spots between transects, based on aerial photographs (28 August 1992) and preliminary reconnaissance from a vessel. Transects were used as they were the most effiecient method for locating meadows not visible with remote sources (aerial photos) and spots were used to check for continuity of meadows. Estimates of seagrass standing crop (above-ground biomass), species composition, % cover of algae and sediment characteristics were made by divers (usually 2) at each site.

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 per metre measured (g dry wt. m^{-2}).

Species were identified according to Kuo and McComb (1989). Sediment characteristics were differentiated by visual estimate of grain size: shell grit, rock, gravel (>2000 µm), coarse sand (>500 µm), sand (>250 µm), fine sand (>63 µm) and mud (<63 µm). A global positioning system (GPS) was used to locate each survey site (latitude and longitude) and record UTC. 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.

For mapping, an aerial photograph was scanned and rectified; using known permanent survey marks and differential GPS fixes. The rectified aerial photograph was transferred into a Geographic Information System, into which all survey points were imported. Survey points were transformed to Australian Map Grid (AMG) co-ordinates using the GPS fixes.

The boundaries of seagrass meadows were determined in the field by divers and by surface observation from a vessel where possible. The position of meadow boundries was mapped directly onto a navigation chart from GPS and from features such as distance from shore or other landmarks. The boundary maps were used together with survey site data to produce meadow boundries on the GIS. The error in determining the area of seagrass meadows was set from ±10 m to ±30 m (depending on meadow) and was based on the distance between survey sites. Other errors associated with mapping, such as GPS and position of diver under the vessel, were assumed to be embedded within this range.

The presence or absence of seagrass is defined by the above-ground biomass, as 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. "Patchy" meadows have areas within them that do not have seagrass.

2.2. Macrofaunal Communities

Macrofaunal sampling was conducted to produce an inventory of species and provide an indication of the importance of Mourilyan Harbour seagrasses for species of commercial fisheries importance. Faunal sampling was not intended as a parameter for ongoing monitoring due to low sampling efficiencies and high variability of fauna. Monitoring change in macrofauna would require frequent, intensive sampling which is beyond the scope of this program.

Four sites were chosen for macrofaunal collection based on the representative seagrass communities of the harbour (Table 1, Figure 4).

Sampling was conducted at night (at high water). A beam trawl (1.5 m wide, 0.5 m high with a 2.0 mm mesh) was towed along 100 m transects at approximately 0.5 m s^{-1} (cf. Coles *et al.* 1993). 3 replicate trawls were conducted at each site.

All Penaeidae (prawns) were identified to species according to Dall (1957) and Grey *et al*. (1983). Carapace length was measured (posterio-dorsal margin of the carapace to the orbit of the eye) to the nearest 0.1 mm. All fish were identified and standard length (tip of snout to last vertebra) measured to the nearest 0.1 mm.

Brachyura (crabs) were identified to family level and numbers of Caridea (shrimps), Isopoda, Amphipoda and other crustaceans were pooled and recorded for each trawl. Biomass of crustacea from each trawl was also determined by drying (60°C, 48 hrs) and weighing samples. Molluscs, polycheates and other phyla were not examined.

Abundances are presented as the number of individuals per trawl (catch rate), as beam trawl efficiencies were not determined for each taxa in this study.

Standard parametric analysis of variance (ANOVA) and T-tests were used to analyse the data (Zar 1984; Sokal and Rolf 1987). Prior to ANOVA procedures, residuals were plotted against fitted values and Bartlett's test for homogeneity of variance was conducted to check if assumptions of the ANOVA were satisfied. Non-parametric tests (Kruskal-Wallis) were used when data was non-normal.

➪ 3. RESULTS

3.1. Seagrass Distribution and Abundance

Five species of seagrasses (3 families) were found within the Mourilyan Harbour survey area (Appendix 3, Plates 3 - 7).

Family Cymodoceaceae
Enhalus acoroides (L.*f*.) Royle
Halodule uninervis (Forsk.) Aschers. in Boissier

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

Family Zosteraceae
Zostera capricorni Aschers.

All species, with the exception of *Enhalus acoroides,* were found in both summer (December 1993) and winter (July 1994) surveys.

In summer (December 1993), 65 ha of seagrass in 22 meadows was recorded from 132 survey sites. The majority of seagrass was located in shallow areas close to the mangrove-lined banks of the harbour and islands (Figure 3). A narrow meadow of seagrass on the eastern side of the harbour near Georgie Hill comprised medium cover of low biomass *Halophila decipiens*/ *Halophila ovalis* (Plate 1). A dense meadow of *Zostera capricorni* occurred adjacent to this, near Bradshaw Island (Plate 2). On the western side, isolated meadows of *Halophila* species were located at the mouths of Walter and Armit Creeks. A low density and very patchy *Halodule uninervis*/ *Halophila ovalis* meadow was present in the harbour channel and a dense meadow of *Zostera capricorni* was found between Lily and Maizie Islands in the south. No seagrass was detected upstream of Maizie Island in the Moresby River or Mourilyan Creek. Seagrass was uncommon at the entrance of the harbour and outside the harbour from north of Goodman Point to Hayter Point in the south (Figure 3).

In winter (July 1994) 68 ha of seagrass in 10 meadows was recorded from 119 survey sites (Figure 4). 10 of the meadows present in the summer (December 1993) survey were still present in the winter (July 1994) survey. The two *Zostera capricorni* meadows, adjacent to Bradshaw Island and between Lily and Maizie Islands, remained although areas changed slightly (Table 2). Similarly, the distribution of the large mixed *Halophila* meadow on the mud bank west of Seaforth Valley and the narrow *Halophila* meadow along the eastern edge of the main Seaforth meadow, all remained relatively unchanged. The distribution of the *Halophila/Halodule* meadow in the central channel however increased further south into the estuary.

Several other small, low biomass *Halophila* meadows were found on the slopes of the intertidal mud banks around the harbour, similar to the summer (December 1993) survey (Figure 4).

12 of the small seagrass meadows documented in the summer (December 1993) survey were absent in the winter (July 1994) survey. All of the meadows that were lost were dominated by *Halophila* species, apart from a small stand of *Zostera* on the northern edge of Lily Island. The 12 meadows lost measured 12 ha in area.

Above-ground biomass of seagrass was higher in summer than winter and highest at sites where *Zostera capricorni* was the dominant species (34.94 ±4.4 g DW. m^{-2} in summer & 19.03 ± 1.9 g DW. m^{-2} in winter) (Figure 5). Biomass at sites where *Halodule* and *Halophila* species dominated never exceeded 1.56 g DW. m^{-2} in summer and 0.57 g DW. m^{-2} in winter (Figure 5).

Seagrass mostly occurred in mud or mud/sand substrates, apart from some sand and sand/mud sites in the channel *Halophila* meadows.

Depth ranges of all species occurred exclusively below MSL, with *Zostera capricorni* present at the shallowest depth (0.42 m below MSL in summer & 0.27 m below MSL in winter) and *Halophila decipiens* at the deepest (3.7 m below MSL in summer and 3.8m below MSL in winter) (Figure 6).

3.2. Penaeid Prawns

3.2.1. *Summer*

436 juvenile or sub-adult penaeid prawns (6 species) were collected (Table 3). There were differences in species composition and abundance between trawl sites (Appendix 1, Table 6). The greatest number of individuals (32 % of total) were collected in the *Halophila decipiens*/*Halophila ovalis* (high biomass) meadow near Seaforth Valley. Catch rates at more vegetated trawl sites were significantly higher than on the less vegetated channel meadow. There was no significant difference in the size of individuals (both individual and pooled species) or total biomass (all species pooled) between trawl sites (Table 6 and ANOVA F=2.91, 3x10 d.f., p=0.09, respectively). 90 % of the penaeid prawns sampled were species of economic value in the north-eastern Queensland prawn fishery, the remainder of minor or no importance (Table 3).

Metapenaeus endeavouri was present at all trawl sites and was the most abundant penaeid collected. All individuals were immature, the majority less than 6.0 mm carapace length. More individuals were collected at trawl sites of mid-range seagrass biomass (Figure 7).

High abundances of *Penaeus semisulcatus* were present on the Seaforth-Bradshaw bank as opposed to lower abundances of individuals at other trawl sites. *Penaeus esculentus* was more abundant at *Zostera capricorni* sites (Bradshaw and Lily) and *Metapenaeopsis novaeguineae* was absent from *Zostera capricorni* trawl sites. *Metapenaeus ensis* was absent from the Channel, and found predominantly at sites with higher seagrass biomass. *Metapenaeopsis palmensis* was uncommon and only present in the Seaforth meadow.

3.2.2. *Winter*

217 juvenile or subadult prawns (8 species) were collected (Table 3). The greatest number of individuals (33.6% of total) were collected on the Bradshaw Island *Zostera capricorni* meadow, although abundances per trawl were not significantly different between trawl sites (Appendix 1, Table 7). Size of individuals

(both individual and pooled species) was not significantly different between trawl sites (Appendix 1, Table 7). 66% of individuals collected were species of economic importance in the northern prawn fishery.

The true endeavour prawn, *Metapenaeus endeavouri*, was the most commonly collected species present at all four trawl sites (Figure 7), but with significantly higher abundances at Lily. All individuals were immature, carapace lengths less than 10.9 mm. The false endeavour prawn, *Metapenaeus ensis* was also present at all sites but in low abundance.

The brown tiger prawn, *Penaeus esculentus*, was found only in the Bradshaw *Zostera* meadow. It was the second most abundant prawn species collected. Juvenile/subadult grooved tiger prawns, *Penaeus semisulcatus*, were present only at Bradshaw and Seaforth trawl sites, in low abundances.

3 species of coral prawns *Metapenaeopsis novaeguineae, Trachypenaeus curvirostrus* and *Trachypenaeus granulosus* were found in the low biomass, *Halophila/Halodule*, Channel meadow.

3.3. Fish

3.3.1. *Summer*

1128 individual fish were collected by beam trawling (Table 4). Fish catch rates were significantly lower in the Channel than at any other trawl site (ANOVA $F=7.22$, 3x8 d.f., $p=0.01$, Figure 8a).

Fish collected were generally small sized (mean= 17.02 ±0.26 mm) and ranged in length from 5.1 to 142.6 mm (median = 15.7 mm). Smaller fish were collected at the Channel and Lily Island trawl sites than on the Seaforth-Bradshaw bank (ANOVA $F=17.47$, 3x8 d.f., $p<0.001$). Fish contributed 43% on average to the overall biomass of macrofauna collected.

26 fish taxa were identiified, with significantly more species at the Bradshaw site than the Channel site (Figure 9a). The most abundant family of fish collected was the Gobiidae (51 % of total individuals) of which an unidentified species (Gobiidae spA) was the most dominant (84 % of Gobiidae). The unidentified Gobiidae species was more abundant in the mid-high seagrass biomass sites than in the Channel (Appendix 1, Table 8). The abundance of the remaining Gobiidae was not significantly different between sites.

The second most abundant family was the Siganidae (14 % of total individuals). *Siganus canaliculatus* was the most abundant of the 2 species collected. *Siganus canaliculatus* was more abundant at the *Zostera capricorni* sites (Bradshaw and Lily) than at the Seaforth and Channel trawl sites, respectively. Although *Siganus guttatus* was absent from the Channel site, it's abunadance was not significantly different between any of the other sites.

Ambassis nalua (glass perchlet) was also absent from the Channel site and was significantly more abundant in trawls at the more vegetated sites (Bradshaw, Lily and Seaforth, respectively).

14 % of fish were species of commercial significance. The most abundant family of commercial importance was the Lethrinidae (emperors). Due to the small size of these individuals no accurate species identifications were possible. No Lethrinidae were collected at the Channel site. Abundances were significantly higher at Seaforth and Lily sites than at Bradshaw. The other species of fish of commercial importance were Lutjanus fulviflammus, Cymbacephalus nematophthalmus and Carangidae sp., which were collected only in Zostera capricorni meadows. Epinephelus tauvina was collected only on the Seaforth-Bradshaw bank trawl sites.

3.3.2. *Winter*

1155 individual fish were collected from beam trawl samples, representing at least 28 taxa (Table 4). Catch rates at the Lily site were significantly higher than at the other locations (ANOVA F= 22.15, 3x7 d.f., p<0.001) (Figure 8b). Significantly more species were found at the high biomass Bradshaw *Zostera* site than at other trawl locations (ANOVA F=23.54, 3x7 d.f., p<0.001) (Figure 9b).

Fish collected were generally small sized (mean = 15.90 $\pm$ 0.30mm) and ranged in length from 5.5 to 160mm (median = 13.6mm). Larger individuals were collected at Bradshaw than at any other site (ANOVA F=23.88, 3x7 d.f., p<0.001).

The most abundant fish family was the Gobiidae (76% of total individuals) of which an unidentified species (Gobiidae spA) dominated (78% of Gobiidae). The unidentified Gobiidae species was more abundant at Lily than any other trawl site (ANOVA F = 16.44, 3x7 d.f., p<0.002).

Teraponidae was the second most abundant family with *Pelates quadrilineatus* (trumpeters) comprising 86% of the 3 teraponid species. Teraponidae were only present at the Bradshaw trawl site.

Three species of direct commercial importance were found, Carangidae sp. (trevallies), Platycephalidae sp. (flathead) and *Epinephelus coioides* (estuary cod). Individuals of these three species represented only 1% of the total fish numbers.

3.4. Other Crustacea

3.4.1. *Summer*

2857 individual crustacea (excluding Penaeidae) were collected by beam trawls in Mourilyan Harbour. Crustacean biomass (mean = 32.96 ±1.15 g DW. trawl^{-1}) was significantly greater at the Bradshaw trawl site than any other (ANOVA F=5.15, 3x8 d.f., p=0.03).

2695 caridean shrimps (5 families) were collected. Catch rates were significantly greater at Bradshaw and Channel trawl sites than at Seaforth or Lily (Appendix 1, Table 9).

The most dominant caridean family was Palaemonidae, which was more abundant at Bradshaw than any other site. Processidae was the second most common family, which was more abundant at the Channel and Seaforth sites. The families

Hippolytidae and Alpheidae were more abundant at the Seaforth and Bradshaw sites, respectively. The family Crangonidae was only present in samples from the Channel and Lily Island, although abundances were so variable that no significant difference could be detected between trawl sites.

Other crustaceans collected included Sergestidae (*Acetes sibogue australis*) which were more abundant at Seaforth than any other site (Appendix 1, Table 10). Mysidacea and Amphipoda were collected only in the Channel.

Three families of brachyura (crabs) were collected. The most abundant was Grapsidae, with no significant difference between trawl sites. Leucosidae were present only at Lily and Portunidae only at Bradshaw.

Two families of isopods were collected. Chirolanidae abundances were significantly greater at Seaforth and Lily than the Channel, and Sphaeromatidae was present only at Bradshaw.

Other fauna collected included a stomatopoda and a tanaidacean, at Lily and Channel sites, respectively.

3.4.2. *Winter*

7227 individual crustacea (excluding Penaeidae) were collected by beam trawl. Crustacean biomass (mean = 2.17 $\pm$ 0.63 g DW. trawl^{-1}) and numbers of individuals (mean = 645.18 $\pm$ 215.87 individ. trawl^{-1}) were significantly greater at the Bradshaw *Zostera* site than at any other trawl site (Appendix 1, Table 11).

Brachyurans (crabs) contributed only 2% of the total number of individual crustacea (excluding prawns) but 31% of the total biomass. 3 families of Brachyura were collected (Appendix 1, Table 11). Grapsidae was present at all sites in similar abundance. Portunidae were absent from Lily and Hymenopsidae absent from Bradshaw. Total Brachyuran biomass (all families pooled) was significantly higher at Bradshaw than at any other site (Kruskal-Wallis one-way ANOVA F = 4.34, 3x7 d.f., $p<0.05$).

3.5 Future Monitoring Scheme and Sampling Design

3.5.1. *General Considerations*

The seagrass monitoring program was designed to ensure that any impacts and changes detected were

1. statistically significant and
2. ecologically or economically important.

For the monitoring scheme to be successful, sampling procedures were carefully selected so that changes (such as increases or decreases in seagrass biomass) will be detected. Sampling strategies were mathematically determined to predict, with a certain level of confidence, that changes of a given amount would be detected. However, these calculations depended on

1. the estimate of variance;
2. the size of the change to be detected;
3. the level of significance to be used (probability of a Type I error);
4. the assurance with which it is desired to detect the difference (probability of a Type II error).

An **estimate of variance** was obtained from the baseline data sets of the summer (December 1993) and the winter (July 1994) surveys. The **size of the change to be detected** was realistically set. This required prior estimation of the variability observed in the data and consideration of the magnitude of change that would be *biologically* and/or *economically* important (Lee Long *et al.* 1996).

The **levels of significance** and **assurance** were based on Type I and Type II errors, respectively. A Type I error is made when a difference is detected but does not really exist (i.e. the null hypothesis is rejected when it is true). The probability of such an error (α) is set prior to the experiment and is often set at 5%. A Type II error is made when a real difference exists but is not detected (i.e. the null hypothesis is accepted when it is false). The probability of a Type II error (β) depends on the choice of α and the size of the difference between the means under the null and alternate hypotheses (The *power* (*P*) of a test is related to the Type II error with P=1-β).

In determining sampling strategies both types of error were considered. It was preferable for the probabilities of both Type I and II errors to be as small as possible. However, a reduction in the probability of a Type I error resulted in an increase in the probability of a Type II error. Therefore, we considered the seriousness of the different types of error in choosing levels of significance. In monitoring environmental factors such as seagrass abundance, a Type II error is likely to be more costly than a Type I error (Fairweather 1991; Peterman 1990) suggesting that it is better to say there is a difference when one doesn't exist (being over-cautious) than to say there is no difference when in fact a difference does exist. Hence the probability of a Type I (α) error may be sacrificed in an attempt to reduce the probability of a Type II error (β). The probability of a Type I error was therefore set at 10% (i.e. α = 0.10) and the probability of a Type II error also at 10% (i.e. β = 0.10; Power = 90%) for the Mourilyan Harbour monitoring program.

3.5.2. *Sampling Design for Mourilyan Harbour*

The optimal use of available time and resources in monitoring changes in Mourilyan Harbour seagrasses was to consider selected meadows rather than the entire harbour. A fixed point design was considered inappropriate due to the dymnamic nature of the meadows.

The proposed monitoring scheme will survey above-ground seagrass biomass twice yearly, summer (high biomass) and winter (low biomass) for the next three years (1994/5, 1995/6, 1996/7). As growth patterns and hence variability in seagrass biomass differs markedly from winter to summer, quantitative comparisons over time will only be made within seasons (ie. summer with summer and winter with winter). Semi-quantitative comparisons between seasons (ie. summer with winter) will be made as a secondary consideration.

Within each primary meadow, seagrass biomass will be estimated at *r* randomly selected sites and *q* quadrats (replicates) within each site. The analysis of variance to compare above-ground biomass over the three years will be of the form:

<u>ANOVA 1.</u>

Source	df	E[MS]		F
Time(T)	2	$\sigma^2 + q\sigma_S^2 + qr\sigma_T^2$	(= TMS)	TMS/EMS
Site(S):T	3(*r*-1)	$\sigma^2 + q\sigma_S^2$	(= EMS)	
Quadrat(Q):ST	3*r*(*q*-1)	σ^2		

where σ^2 = variance component for Quadrat
σ_S^2 = variance component for Site
σ_T^2 = variance component for Time
TMS = treatment (Time) mean square
EMS = error mean square

The S:T term is the appropriate term for testing the effect Time (T). In practice the estimates s^2, s_S^2 and s_T^2 of σ^2, σ_S^2 and σ_T^2, respectively are used. Pairwise testing among the three times will be performed by the least significant difference (LSD) test. That is

$$LSD = t_{3(r-1)}\sqrt{\frac{2}{qr}\left(s^2 + qs_S^2\right)} \qquad \textit{equation } (1)$$

where $t_{3(r-1)}$ is the 5% t-value with 3(*r*-1) df.

The summer (December 1993) and winter (July 1994) surveys provide information about the primary meadows being considered. As the summer survey was primarily designed to map the distribution of seagrass meadows in the Mourilyan Harbour and to measure seagrass biomass for the major areas of seagrass habitat, the number of sites and quadrats/site on a given meadow was not predetermined and hence varies considerably. For the winter survey the number of sites varied between meadows, although the number of quadrats/site was always 3. For illustrative purposes assume that, for a particular meadow, there were *n* sites and *m* quadrats. Then the analysis of variance table is of the form

ANOVA 2.

Source		df	MS
Site(S)	(Between)	*n*-1	$s^2 + m s_S^2$
Quadrat(Q):S	(Within)	*n*(*m*-1)	s^2

where s^2 = estimate of the variance component for Quadrat
s_S^2 = estimate of the variance component for Site

Assuming s^2 and s_S^2 will be satisfactory estimates of the variance components for future monitoring, these values can be substituted for σ^2 and σ_S^2, respectively, in ANOVA 1. Furthermore, from the initial surveys an estimate ($\bar{x}$) of the mean biomass for the meadow and also the range of sampled biomass were available. This was important in determining the desired limit of detection.

Equation 2 below was used to determine the number of sites (*r)* and the number of quadrats/site (*q*) such that a change in biomass of *d* would be detected at the 90% level (Type I error of 10 %) with 90% assurance of detecting a true difference of this size (Type II error of 10 %).

$$qr = \frac{2(t_0 + t_1)^2 (s^2 + q s_S^2)}{d^2} \qquad \textit{equation (2)}$$

where d = difference to detect
t_0 = the *t* value associated with Type I error = 10% t-value on 3(*r*-1) df
t_1 = the *t* value associated with Type II error = 20% t-value on 3(*r*-1) df
(t_1 equals tabulated *t* for probability 2(1-*P*) where *P* is the required probability of detecting *d* if such a difference exists (Steel and Torrie 1960))
s^2 = quadrat variance component
s_S^2 = site variance component

Rearranging (2) gives

$$q = \frac{2(t_0 + t_1)^2 s^2}{d^2 r - 2(t_0 + t_1)^2 s_S^2} \qquad \textit{equation (3)}$$

Note that t_0 and t_1 depend on *r*. Given s^2 and s_S^2 and setting the number of sites (*r*) and the difference to detect (*d*) , equation (3) can be used to determine the number of quadrats required.

3.5.3. *Summer Sampling Design*

The summer (December1993) survey identified 22 meadows in the harbour on the basis of species composition and biomass and the winter survey identified 11. Many of these meadows however, may be considered 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* *meadows* have been selected for future monitoring. These are meadows 3 (Channel), 4 (Seaforth bank), 5 (Seaforth edge), 23 (Bradshaw Island) and 26 (Lily Island) (Figure 10).

Given the quadrat and site variance components for each primary meadow, the number of sites and quadrats per site has been determined so that the least percentage change in mean biomass will be detected at the 90% level (Type I of 10 %) with 90% assurance of detecting a true difference (Type II of 10 %).

Table 5 lists the seagrass species present in each meadow and the appropriate sampling scheme for summer monitoring (determined from Tables 12-15, Appendix 2). Tables 12-15 show the number of quadrats/site required for various number of sites for meadows 3 (Channel), 4 (Seaforth Bank), 5 (Seaforth Edge) and 23 (Bradshaw Is.) respectively. Note that as only one site was surveyed for the Lily Island meadow, variance components could not be estimated. As Lily Island and Bradshaw Island meadows were relatively similar, it was considered that the monitoring/ sampling strategy for Bradshaw Island would be applied to Lily Island.

3.5.4. *Winter Sampling Design*

For the winter monitoring program 4 primary meadows have been selected. These are meadows 3 (Channel), 5 (Seaforth edge), 23 (Bradshaw Is.) and 26 (Lily Is.) (Figure 10). Table 5 lists the mean and range of seagrass biomass, the seagrass species present in each meadow, and the appropriate sampling scheme for winter monitoring (determined from Tables 16-20, Appendix 2). Tables 16-20 show the number of quadrats/site required for various number of sites for meadows 3 (Channel), 5 (Seaforth Edge), 23 (Bradshaw Is.) and 26 (Lily Is.) respectively. The appropriate sampling strategy for each meadow was chosen from consideration of what can be realistically conducted, depending on the overall size of the meadow, the number of sites possible (depends on available time) and the number of quadrats required per site.

Figure 1. Location of Mourilyan Harbour study area.

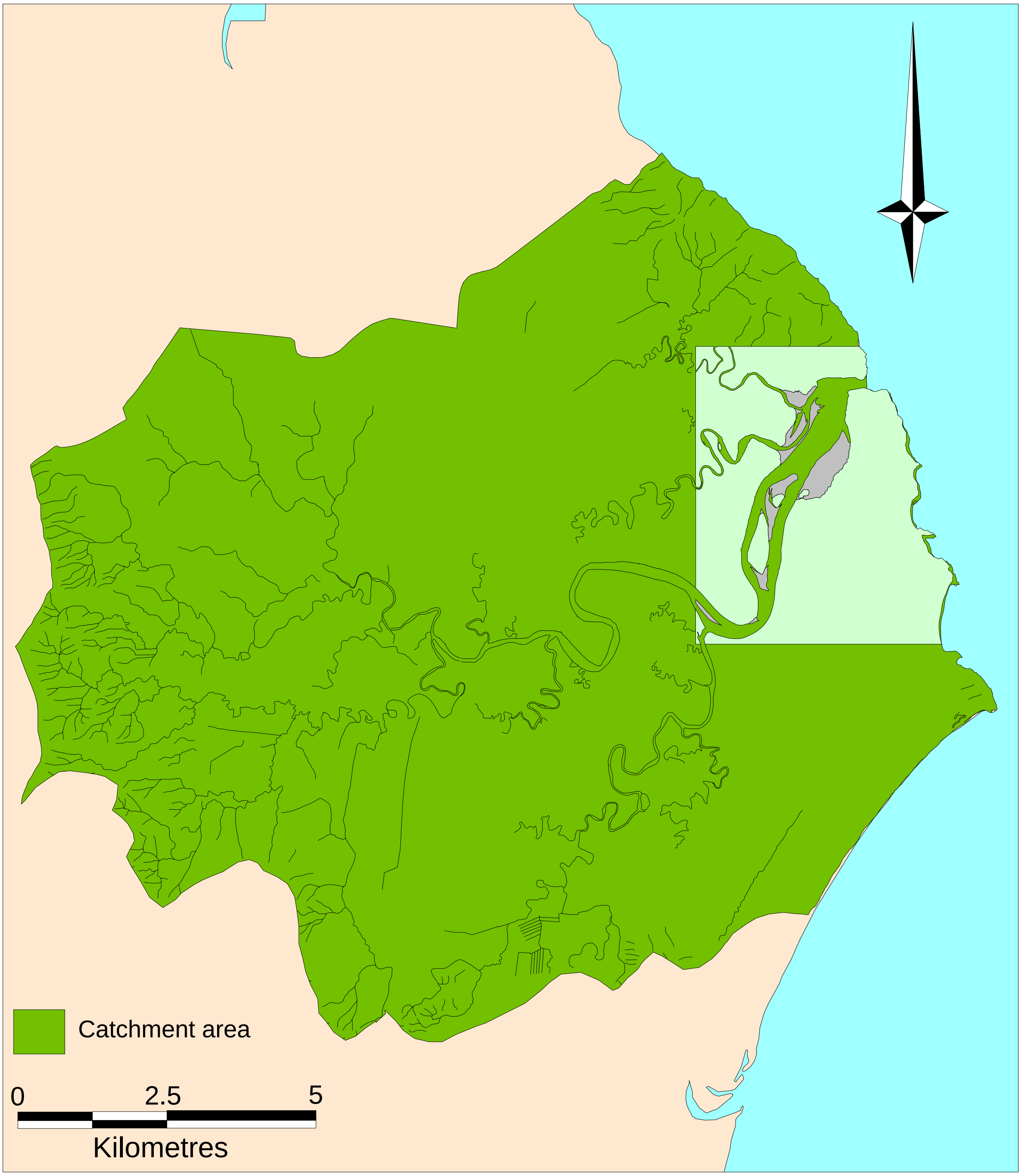

Figure 2. Moresby River catchment area (enclosed area, see Fig 3)

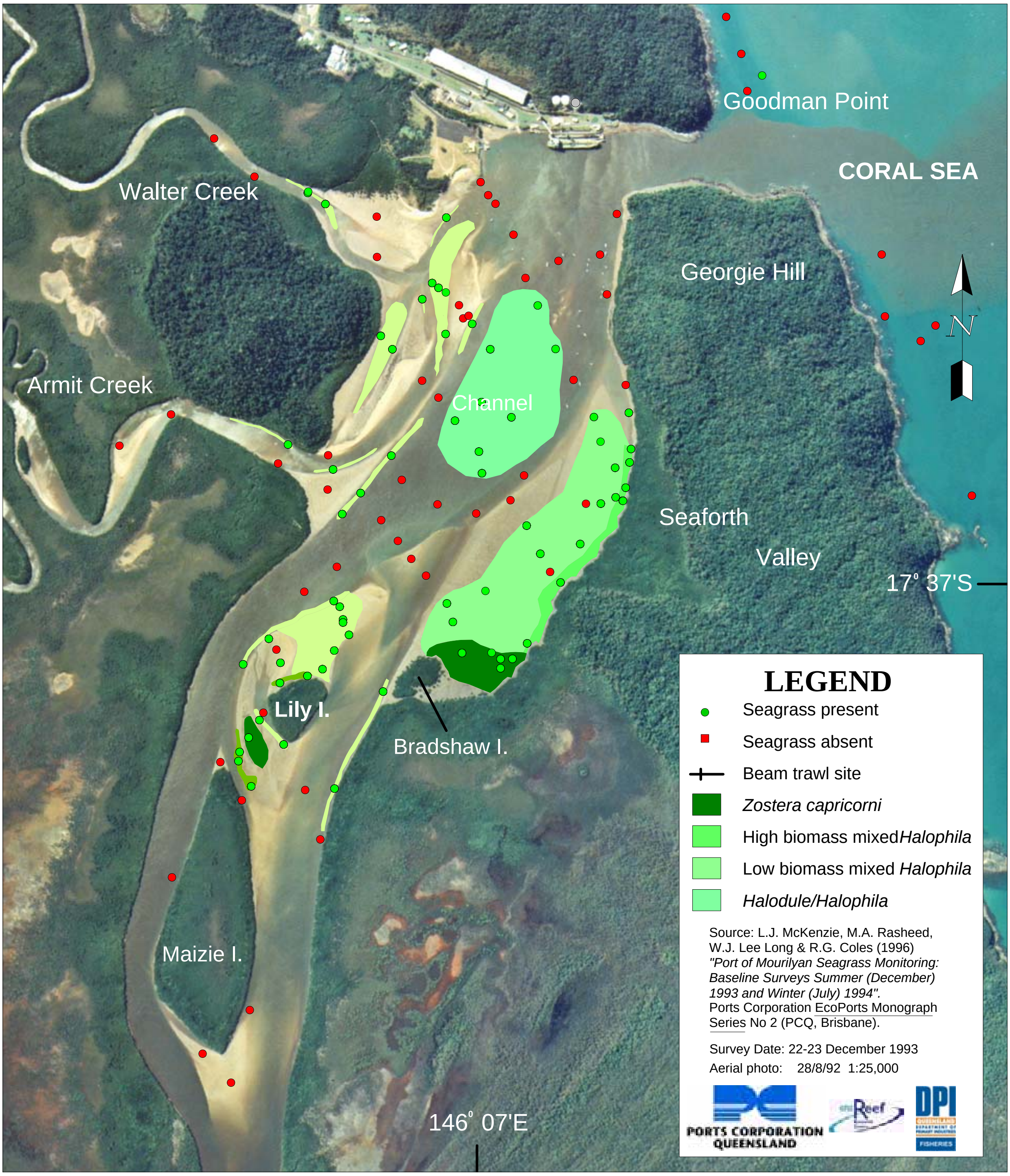

Figure 3. Location of survey sites (seagrass present & absent), seagrass meadows and beam trawl sites at Mourilyan Harbour in December 1993.
(Site codes; 1. Channel; 2. Seaforth; 3. Bradshaw; 4. Lily).

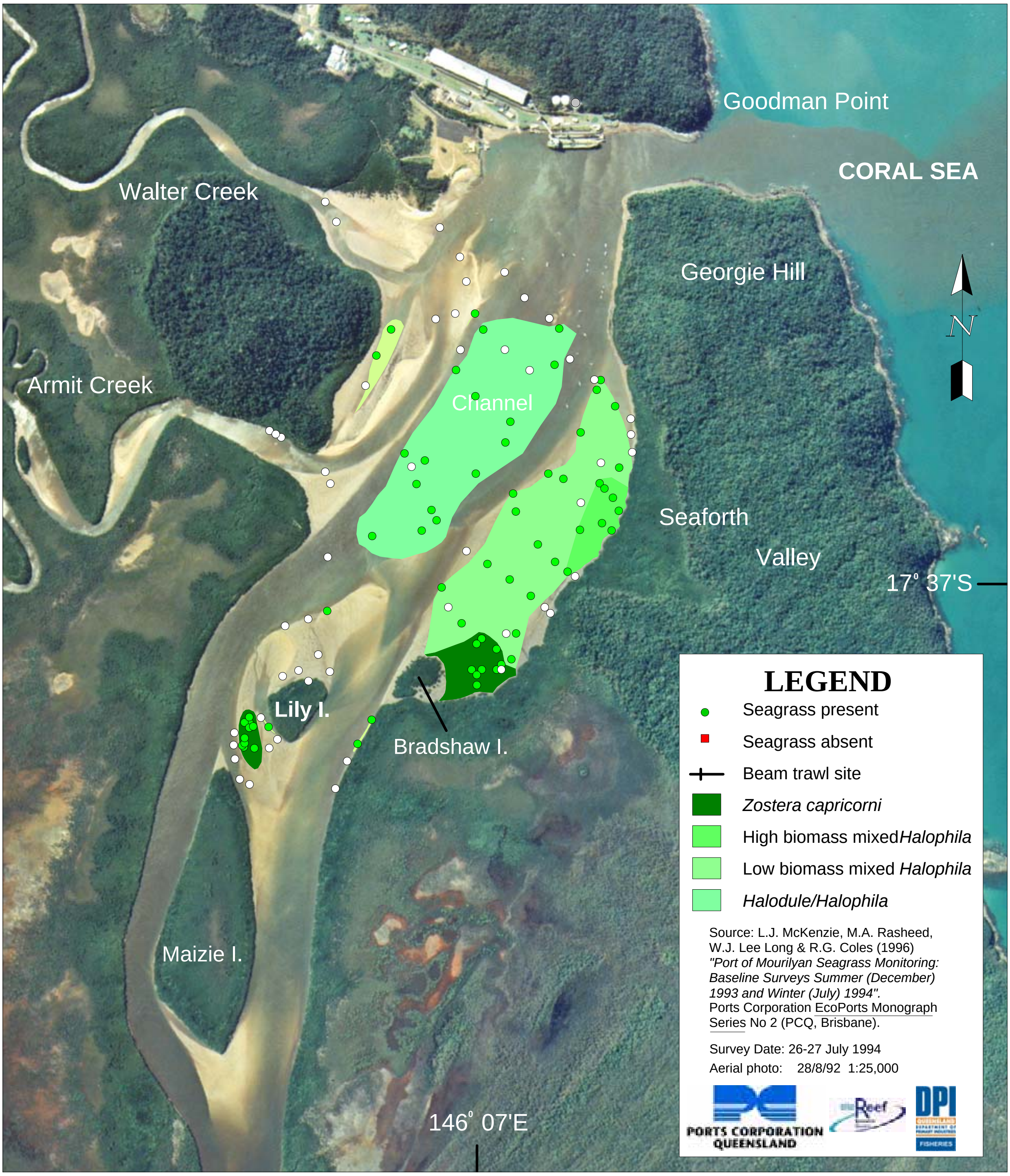

Figure 4. Location of survey sites (seagrass present & absent), seagrass meadows and beam trawl sites at Mourilyan Harbour in July 1994.
(Site codes; 1. Channel; 2. Seaforth; 3. Bradshaw; 4. Lily).

Plate 1. Habitat of *Halophila* species seagrasses, Mourilyan Harbour (December 1993)

Plate 2. Habitat of *Zostera capricorni* seagrass in Mourilyan Harbour (December 1993)

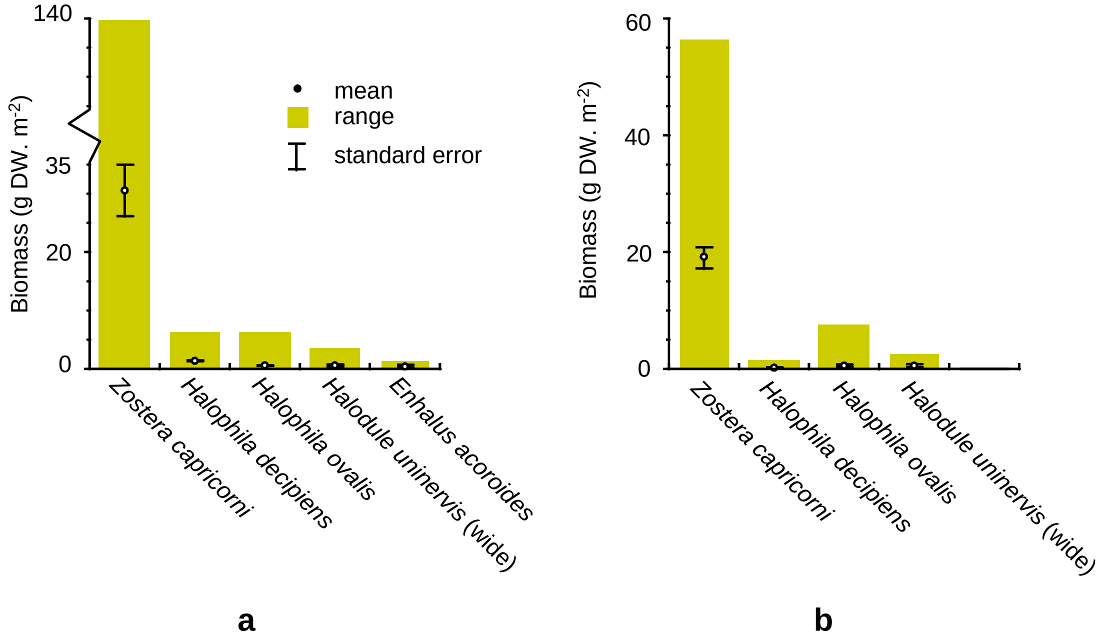

Figure 5. Means, standard errors and ranges of above-ground biomass for seagrass species (at sites where they were the dominant species present) in Mourilyan Harbour: a, December 1993; b, July 1994.

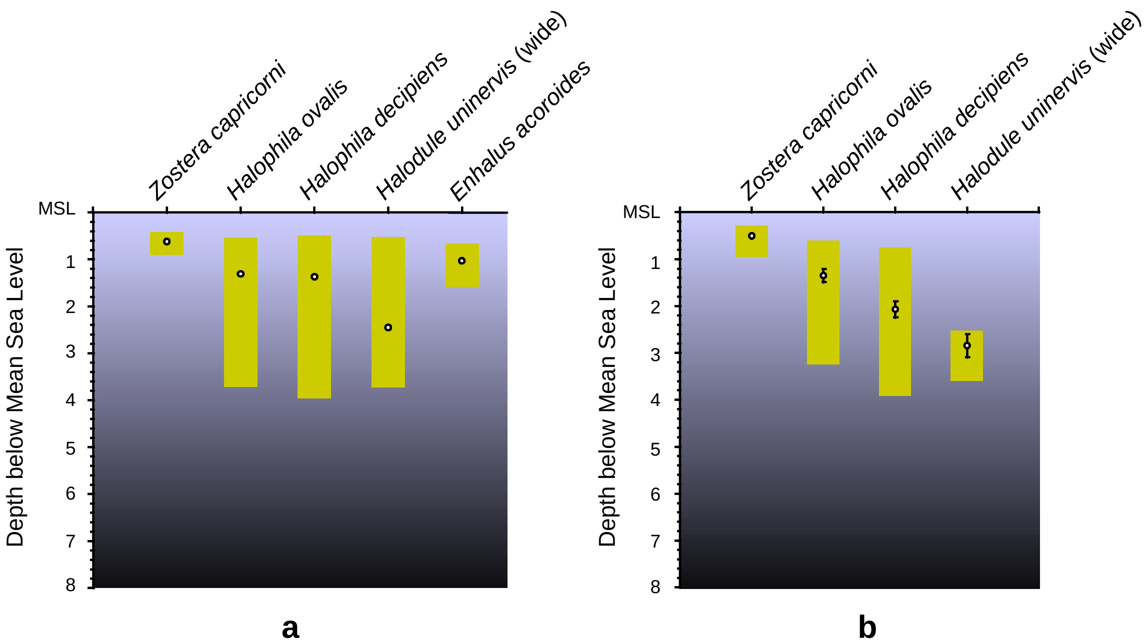

Figure 6. Means, standard errors and ranges of depths of occurrence for seagrasses in Mourilyan Harbour; a, December 1993; b, July 1994.

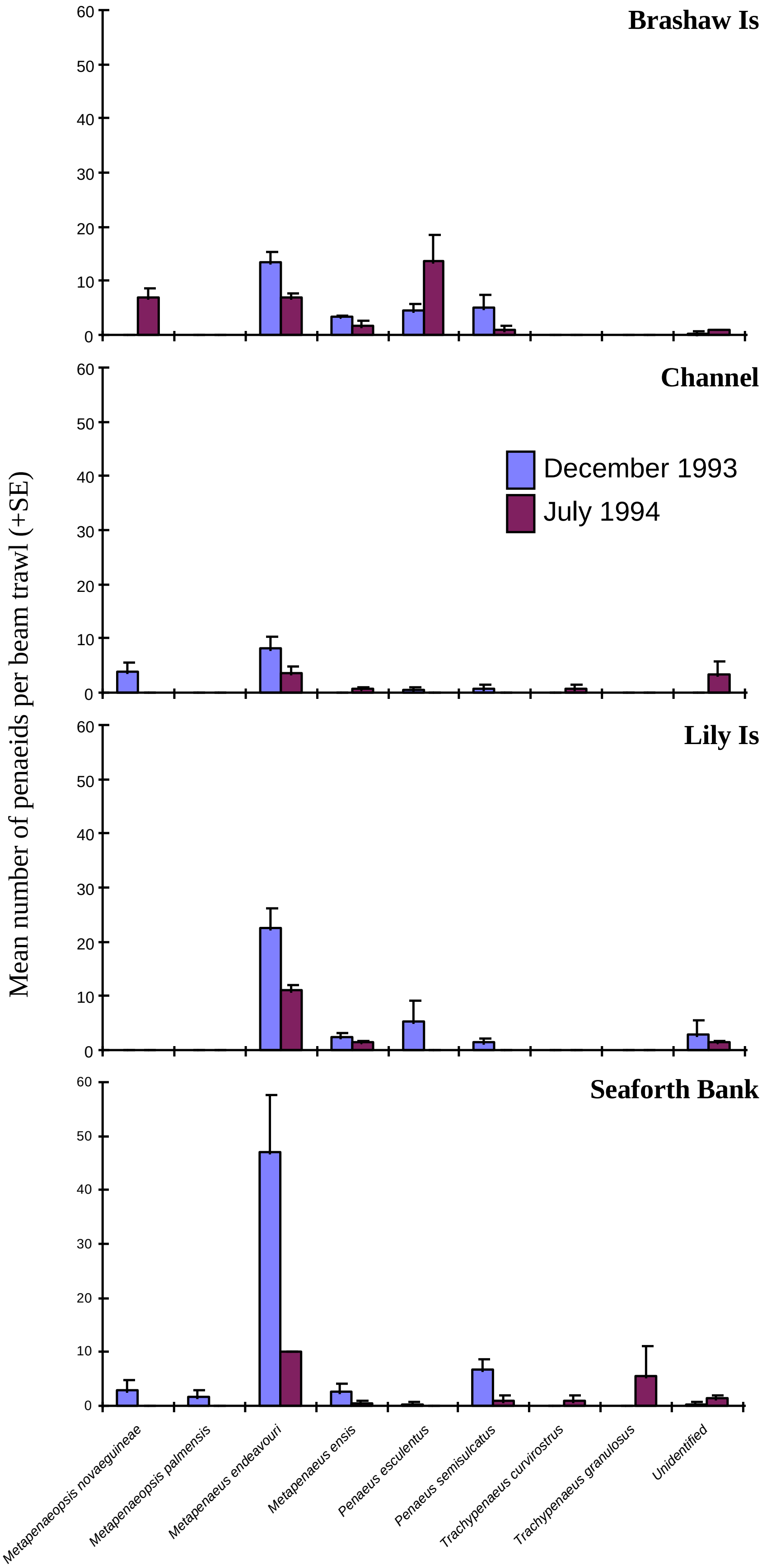

Figure 7. Mean abundance of penaeid prawns per trawl at each beam trawl site (error bars are + standard error), Mourilyan Harbour, summer (December 1993) and winter (July 1994).

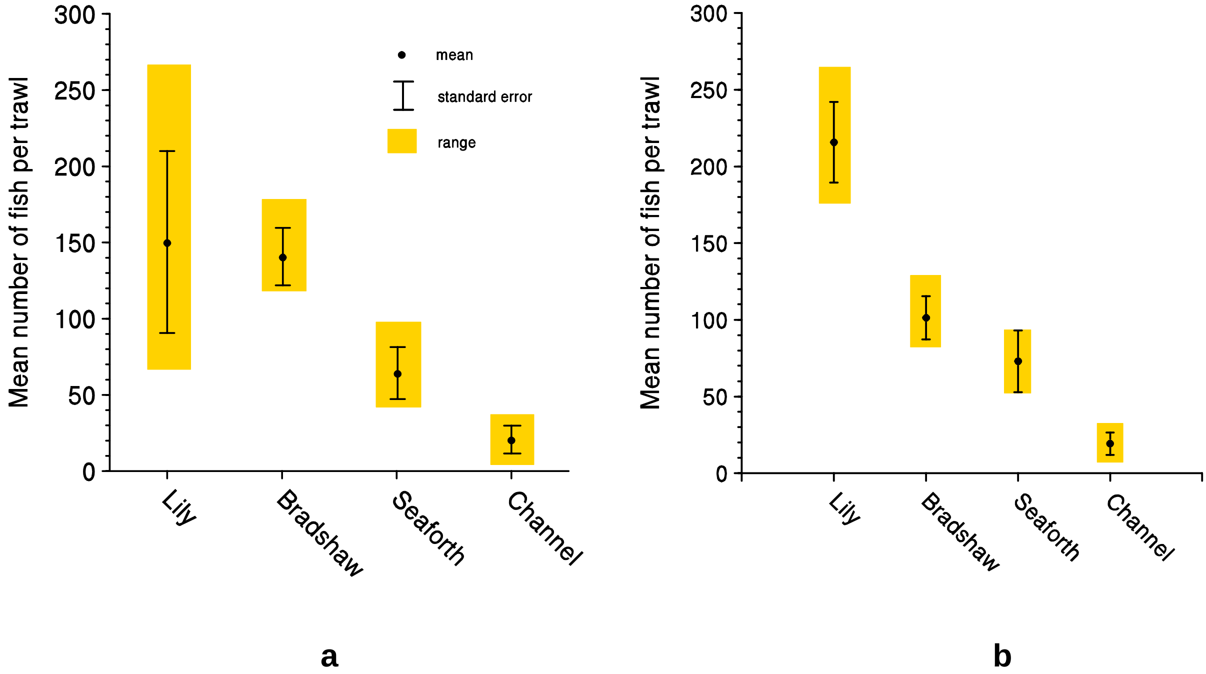

Figure 8. Mean number of individual fish at each beam trawl site.; a, December 1993; b, July 1994.

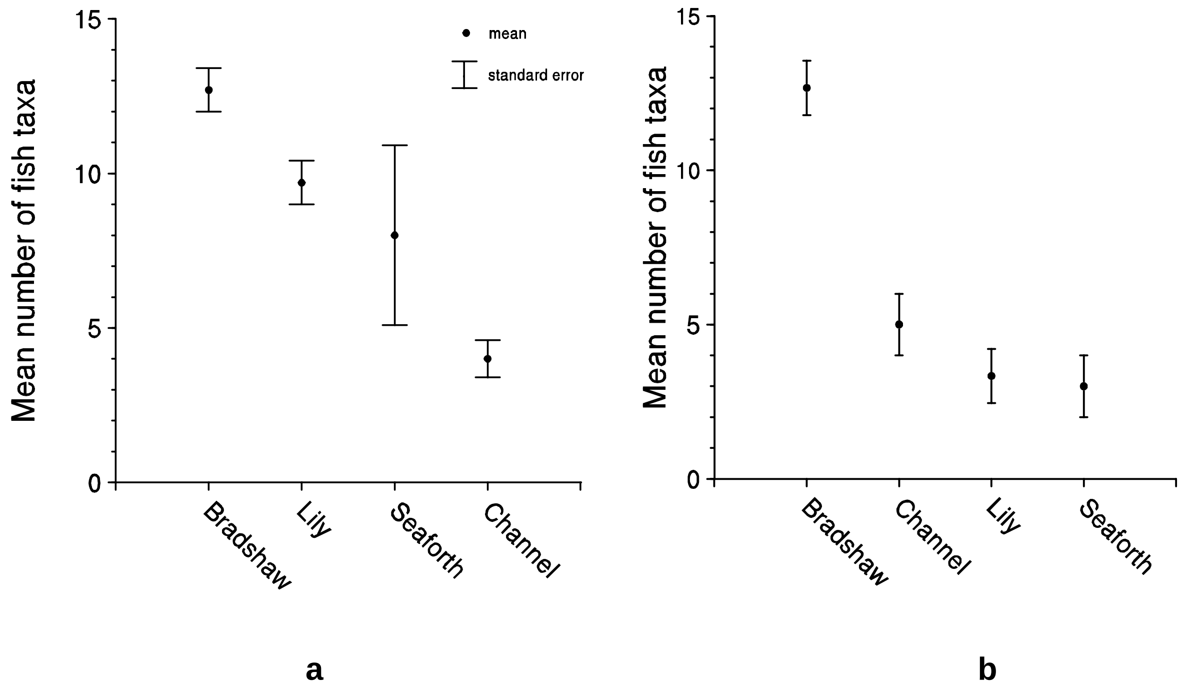

Figure 9. Mean number of fish taxa per trawl site.; a, December 1993; b, July 1994.

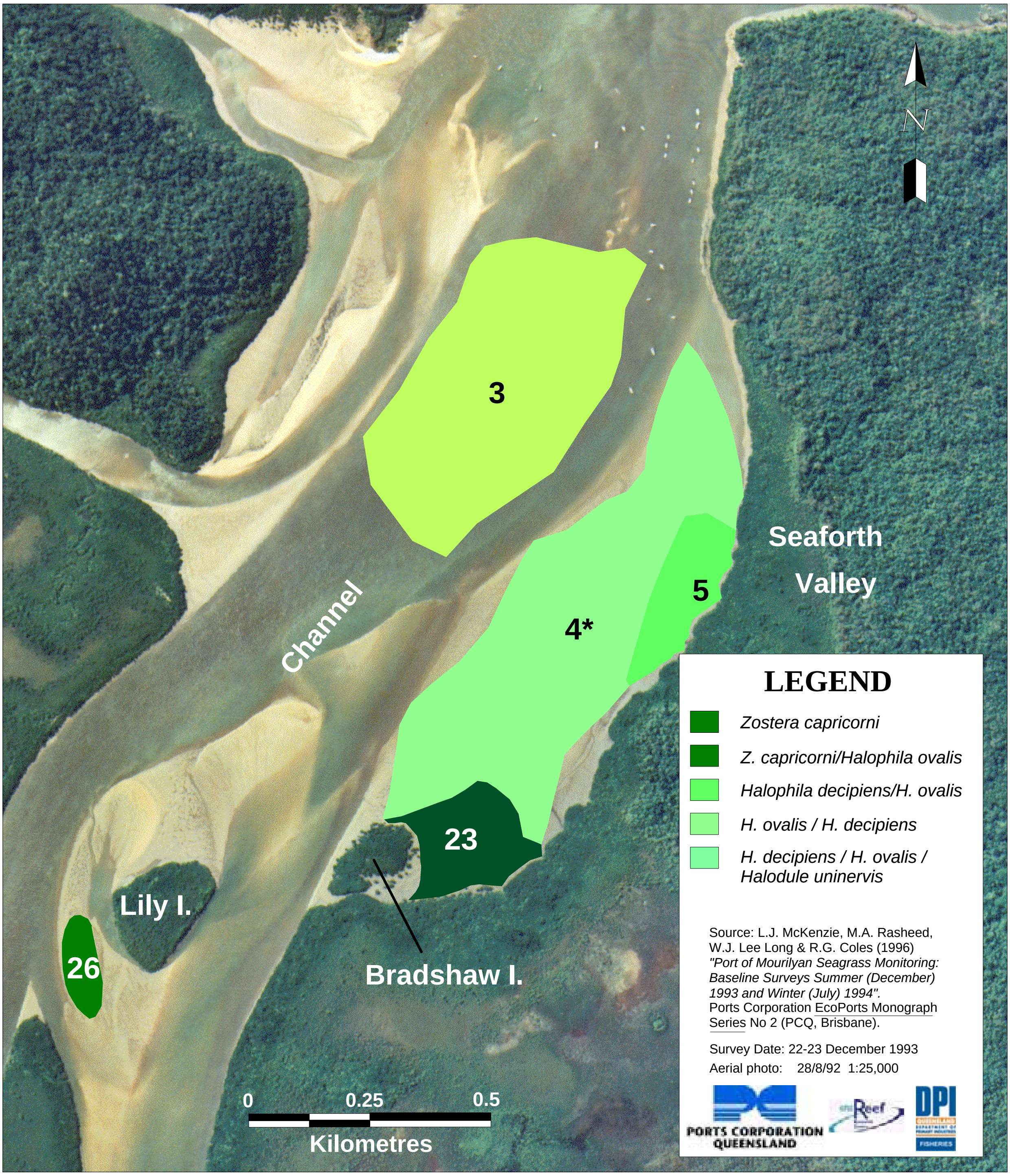

Figure 10. Location of seagrass meadows selected for monitoring in Mourilyan Harbour. (Meadow codes: 3. Channel; 4. Seaforth bank; 5. Seaforth edge; 23. Bradshaw I.; 26. Lily I.). *Meadow 4 not able to be monitored in winter (Section 4.5.).

Table 1. Description of beam trawl sites in Mourilyan Harbour, summer and winter.

Site	Seagrass Species	Biomass ±SE (g DW. m^{-2})		Substrate	Depth ±SE
		December 1993	July 1994		(m below MSL)
Channel	*Halodule uninervis* *Halophila ovalis/ H. decipiens*	0.51 ±0.10	0.91 ± 0.22	Sand/ Mud	2.63 ±0.07
Seaforth	*Halophila decipiens/ H.ovalis*	2.21 ±0.31	0.67 ± 0.13	Mud	1.26 ±0.07
Lily	*Zostera capricorni* (*H. ovalis* present in summer)	16.12 ±4.37	11.28 ± 1.77	Sand/ Mud	0.34 ±0.01
Bradshaw	*Zostera capricorni*	43.59 ±5.86	37.07 ± 3.89	Mud	0.51 ±0.01

Table 2. Species composition, biomass and distribution of Mourilyan Harbour seagrass meadows.
Range calculated as per section 2.1.

Site	Seagrass Species	December 1993		July 1994		Substrate
		Biomass (ranges in brackets) (g DW. m^{-2})	Area (ha) *range*	Biomass (ranges in brackets) (g DW. m^{-2})	Area (ha) *range*	
Channel	*Halodule uninervis Halophila ovalis/ H. decipiens*	0.51 ±0.10 (0.04 -3.60)	20 *16-25*	0.22 ± 0.06 (0-2.21)	31 *25-37*	Mud/ Sand
Seaforth Bank	*H.ovalis/ Halophila decipiens*	1.10 ±0.10 (0 - 6.24)	22 *16-29*	0.35 ± 0.16 (0-764)	26 *20-32*	Mud/ F.sand
Lily	*Zostera capricorni (H. ovalis present in summer)*	16.12 ±4.37 (0 -46.40)	1 *0.1-2.3*	9.59 ± 1.28 (0-24.73)	1 *0.3-3*	Mud/ F.sand
Bradshaw	*Zostera capricorni*	42.20 ±4.90 (0-139.76)	4 *2-6*	26.56 ± 2.76 (0-56.46)	4 *2-7*	Mud
Seaforth Edge	*Halophila decipiens/ H.ovalis*	2.04 ±0.25 (0 -6.24)	3 *3-7*	0.73 ±0.12 (0.09-2.66)	4 *2-6*	Mud
Others (pooled)	*Halophila ovalis/ H. decipiens/ Zostera capricorni/ Halodule uninervis/ Enhalus acoroides*	1.02 ±0.12 (0 -20.84	15 *10-16*	0.20 ±0.04 (0-0.28)	2 *2-3*	Mud/ Sand
TOTAL		4.02±0.53 (0 -139.76)	65 *46-86*	5.07 ±0.72 (0-56.46)	68 *50-83*	

Table 3. Species, abundance, carapace lengths and fishery code for penaeid prawns caught in Mourilyan Harbour beam trawls, summer (December 1993) and winter (July 1994).

`Unidentified' are individuals for which identification was uncertain due to small size or poor condition. *Fishery code* : IV. important to the northern Australian prawn fishery; III. component of fishery; II. minor to insignificant importance; I. no importance to fishery.

Species	Common name	Fishery Code	Total #		Mean carapace length (ranges in brackets) (mm)		% Abundance	
			Dec	July	Dec	July	Dec	July
Metapenaeus endeavouri	True endeavour	IV	290	85	5.59 ±0.10(2.05 - 13.50)	4.7 ±0.22 (1.8 - 10.9)	66.51	39.17
Penaeus semisulcatus	Grooved tiger	IV	43	5	6.51 ±0.46(.20 - 13.90)	9.3 ±0.25 (8.5 - 10.0)	9.86	2.31
Penaeus esculentus	Brown tiger	IV	34	41	5.27 ±0.56(1.90 - 15.95)	7.5 ±0.44 (3.1 - 13.3)	7.80	18.89
Metapenaeopsis novaeguineae	Northern velvet	II	28	21	5.09 ±0.48(2.40 - 12.30)	5.1 ±0.45 (2.9 - 11.3)	6.42	9.68
Metapenaeus ensis	False endeavour	III	25	12	6.46 ±0.53(2.80 - 14.85)	10.5 ±1.20 (4.1 - 16.1)	5.73	5.53
Metapenaeopsis palmensis	Southern velvet	I	5		5.36 ±0.99 (3.15 - 8.75)	*Absent*	1.15	0
Trachypenaeus granulosus	Hardback	II	0	29	*Absent*	6.1 ±0.31 (4.1 - 12.0)	0	13.36
Trachypenaeus *curvirostrus*	Southern rough	II	0	4	*Absent*	7.4 ±0.66 (5.7 - 8.8)	0	1.84
Unidentified		?	11	20	3.30 ±0.28 (1.70 - 4.30)	3.6 ±0.31 (1.8 - 8.2)	2.53	9.22
TOTAL		-	436	217	5.61 ±0.11 (1.70 - 15.95)	5.83 ±0.19 (1.8 - 16.1)	100	100

Table 4. Taxa, abundance, size data and value codes for fish collected in Mourilyan Habour, summer (December 1993) and winter (July 1994). Value codes (from Coles *et al* . 1993): A, targeted aquarium species; a, incidental aquarium species; b, incidental baitfish species; c, incidental commercial species; R, targeted recreational species; r, incidental recreational species; T, targeted traditional (Aboriginal/Islander) species.

Family	Species	Common name	Code	Average length (ranges in brackets) (mm)		Total #	
				December 1993	July 1994	Dec	July
Apogonidae	*Apogon* spp.	Cardinal fishes	a	20.1 (10.3-41.3)		10	0
	Apogon brevicaudatus	Cardinal fish	?	49.8		1	0
	Apogon quadrifasciatus	Cardinal fish	a		52.6	0	1
Atherinidae	*Pranesus ogibyi*	Hardyhead	b		55.5	0	1
Bothidae	*Pseudorhombus elevatus*	Flounder	a	142.6		1	0
Callionymidae	*Callionymus macdonaldi*	Dragonet	A		19.3 (11.2-37.3)	0	7
Carangidae	sp.	Trevally	c?	12.8 (10.7-17.0)	13.4	69	1
Chandidae	*Ambassis gymnocephalus*	Perchlet	a		38.5	0	1
	Ambassis nalua	Perchlet	a	26.6 (20.8-40.8)		76	0
	Ambassis vachelli	Perchlet	a		37.8 (32.0-40.9)	0	7
Clupeidae	*Escualosa thoracata*	Herring	?	27.3		1	0
Gerreidae	*Gerres argyreus*	Silver biddy	b	24.7 (22.4-32.0)		13	0
	Gerres acinaces	Silver biddy	b	43.9 (43.9)		1	0
	Gerres abbreviatus	Silver biddy	b	37.2		1	0
Gobiidae	*Acentrogobius multifaciatus*	Goby	-		33.3	0	1
	Glossogobius biocellatus	Goby	-		36.9 (15.5-52.2)	0	6
	spA	Goby	-	13.7 (7.0-43.7)	12.7 (5.5-53.6)	482	684
	spB	Goby	-	33.1 (25.6-42.4)	14.4 (7.7-24.2)	11	145
	sp1	Goby	-	20.3 (12.7-47.5)		9	0
	spp	Goby	-	12.7 (6.6-28.3)		73	0
Leiognathidae	*Leiognathus splendens*	Ponyfish	-	25.2 (24.9-25.4)		2	0
Lethrinidae	*Lethrinus* spp	Emperor	c?	17.4 (12.7-23.2)		83	0
Lutjanidae	*Lutjanus fulviflammus*	Moses perch	ar	19.2 (17.8-20.7		13	0

Table 4. continued

Family	Species	Common name	Code	Average length (ranges in brackets) (mm)		Total #	
				December 1993	July 1994	Dec	July
Monacanthidae	spp.	Leatherjacket	a	13.7	29.5 (12.5-44.8)	1	9
Muraenidae	*Strophidon* sp	Moray eel	A		85.9	0	1
Platycephalidae	*Cymbacephalus nematophthalmus*	Fringe eyed flathead	cr	108.4		1	
	spp	Flathead	cr		22.0 (8.8-34.8)	0	10
Scorpaenidae	*Minous versicolour*	Scorpionfish	A		20.8	0	1
	Paracentropogon vespa	Scorpionfish	A		10.6	0	1
	spp	Scorpionfish	A		9.3 (7.0-11.6)	0	2
Serranidae	*Centrogenys vaigiensis*	False scorpionfish	A	41.3 (24.8-58.9)	28.9 (18.2-51.0)	3	5
	Epinephelus coioides	Esturine cod	cR		160.0	0	1
	Epinephelus tauvina	Esturine cod	cR	40.0 (35.4-44.6)		2	
Siganidae	*Siganus canaliculatus*	Rabbitfish	a	19.6 (15.7-37.3)	29.7 (27.4-31.9)	109	5
	Siganus guttatus	Rabbitfish	AT	24.1 (19.9-33.9)	37.7 (32.9-43.0)	48	8
Sillaginidae	*Sillago* sp.	Whiting	r	27.4		1	
Syngnathidae	spp	Pipefish	-	57.4 (40.4-76.9)	55.6 (38.8-86.4)	7	16
Teraponidae	*Pelates quadrilineatus*	Trumpeter	-	25.4 (12.8-48.8)	17.7 (12.3-28.7)	16	107
	Terapon caudavitatus	Trumpeter	-		72.8 (61.7-84.0)	0	2
	Terapon puta	Trumpeter	-		44.0 (34.2-51.3)	0	16
Tetraodontidae	*Arothron hispidus*	stars & stripes toadfish	a		53.6	0	1
	Arothron manilensus	Toadfish	a		36.3 (22.0-50.6)	0	2
	Chelonodon patoca	Toadfish	a		52.4	0	1
Triacanthidae	*Triacanthus angustifrons*	Tripodfish	a	23.1		1	
Unidentified			?	12.3 (5.1-22.4)	11.9 (6.9-17.2)	92	74
TOTAL				17.02 ±0.26 (5.1 - 142.6)	15.90 ±0.30 (5.5 - 160.0)	1127	1155

Table 5. 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 (from Appendix 2), for each of the primary monitoring meadows in Mourilyan Harbour for summer and winter surveys.

Species codes: HD10, *Halophila decipiens* ; HO4, *Halophila ovalis* ; HUW5, *Halodule uninervis* (wide); ZC14, *Zostera capricorni*
NP = not possible

Meadow ID	Description	Summer			Winter		
		Detectable % change	# Sites	# Quadrats	Detectable % change	# Sites	# Quadrats
3	Channel (HD10, HO4, HUW5)	75	30	10	100	40	5
4	Seaforth bank (HO4, HD10)	75	30	10	NP	NP	NP
5	Seaforth edge (HD10, HO4)	30	10	10	75	15	2
23	Bradshaw Is (ZC14)	30	20	10	75	10	2
26	Lily Is (ZC14, HO4)	30	20	10	75	15	2

⇘ 4. DISCUSSION

4.1. Seagrass Distribution and Abundance

The present summer survey documents a large reduction since 1987 in area of seagrasses in Mourilyan Harbour. The two sampling programs however are not directly comparable due to different sampling intensities and different site locations. The greater sampling intensity in the present study has also located many meadows which were missed in the 1987 survey. The edges of mud and sand banks in Mourilyan Harbour were not surveyed in 1987 by Coles *et al*. (1993), but were included in the summer (December 1993) and winter (July 1994) surveys. Seagrasses found on these shallow banks represented 69.5 % (46 ha) of the 66 ha mapped in the summer survey.

It is not possible to identify the cause(s) of such change or to confirm that the loss is not just an artifact of sampling technique, without historical information on environmental parameters of turbidity, light, nutrient concentrations, salinity, *etc*. Samples of juvenile prawns and fish in 1987 indicated high abundance and diversities on this meadow, and its near loss should be a concern with respect to fisheries production in the harbour.

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.

Between Cooktown (15°30'S) and Moreton Bay (27°S), *Zostera capricorni* meadows, like those in Mourilyan Harbour, are often high biomass, high shoot density, monospecific stands located in bays or inlets which receive high seasonal freshwater loads. *Zostera capricorni*, has a dense rhizome and root system and often occurs in sites with organically rich terrigenous muds and sands, such as in Mourilyan Harbour. These muddy sites are often very turbid and *Zostera capricorni* grows only in shallow intertidal levels (Coles *et al*. 1993; Lee Long *et al*. 1993), where it receives sufficient light for photosynthesis primarily during low tide (Pollard and Greenway 1993).

Halophila decipiens in Mourilyan Harbour occurred mostly on the slopes of sand or mud banks, between 0.5 and 1 m below MSL. This low biomass seagrass is common in sheltered muddy sites in Queensland, but is not restricted to shallow inlets. It is also common in the lee-side of islands and reefs and to depths of 20 m in the Great Barrier Reef lagoon (Coles *et al*. 1992; Lee Long *et al*. 1993).

In the present baseline surveys, *Halophila decipiens* commonly occurred with *Halophila ovalis* on shallow mud banks, where they received almost no exposure at low tide. *Halophila* species are considered to be colonising species (Birch and Birch 1984) and can be highly variable either seasonally or between years. This may cause variability in prawn and fish abundance in these meadows.

Mourilyan Harbour supported a small stand of *Enhalus acoroides* in summer,one of the most southerly occurrences on the north-eastern Australian coast. The species has not been found south of Magnetic Island (19°10'S) (Birch and Birch 1984). *Enhalus acoroides* was not recorded in the winter survey. As the stand of *Enhalus acoroides* was so small, it can be very difficult to relocate in the turbid waters of the harbour or it may have been lost due to seasonality. It will be of interest to see if plants of the species return in the future.

Application of nitrates and phosphates to cane lands already leads to seasonal (summer monsoon) pulses of NH_4^+-N and PO_4^{3-}-P into Moresby River waters and sediments (Eyre 1993), and natural patterns of seagrass growth in the harbour are most likely affected.

Phosphate levels do not appear high in this catchment, but the increased nitrogen levels (Eyre 1993) may lead to increased phytoplankton and epiphyte growth and eventual shading of seagrasses. Increases in nutrient, phytoplankton and turbidity will have greater effects on deep water seagrasses and may be a cause of the observed losses in the large channel meadow recorded in 1987.

Although 12 small seagrass meadows that were documented in the summer (December 1993) survey were not present in the winter (July 1994) survey, there was a slight increase in total seagrass area of 2 ha in winter. The expansion of the channel meadow in winter (July 1994) more than accounts for this increase in area. The addition and losses of these meadows typify the seasonal and ephemeral nature of the *Halophila* species in this estuary.

The distribution ot the two major *Zostera* meadows (Bradshaw and Lily) remained relatively stable but had substantially lower biomasses in winter than in the summer. Seasonal reduction in *Zostera* biomass is not unusual for the north Queensland region; McKenzie (1994) reports a similar seasonal trend in a *Zostera capricorni* meadow in Cairns Harbour.

The mean depth distribution of seagrass species remained similar between summer and winter surveys, but the depth range was different for some species. *Zostera capricorni* was found at shallower depths in winter than recorded in the summer survey. This is largely due to the increase in number of survey sites at the shallow Lily Island meadow in the winter survey.

Maintenance dredging of the berth area was conducted in 1992, using a small cutter section dredge. While dredge material was placed on land, it is possible that turbidity and sedimentation generated by dredging may have affected seagrasses. No turbidity or sedimentation monitoring was conducted so it is impossible to assess this effect.

Dredging and blasting of Mourilyan Harbour's entrance performed in the period between the summer and winter surveys was unlikely to have affected seagrass biomass and distribution in the Harbour. Turbidity monitoring of these operations found that Suspended Sediment Concentrations (SSC's) fell to background levels within 500 m of the dredging operations (Larcombe 1994). All seagrass meadows were located outside of the area affected by turbidity. Changes in tidal range due to the deepening of the harbour are also unlikely to have affected seagrasses. Tides had been predicted, by computer modelling, to be less than 1cm as part of pre-deepening impact assessment studies (WBM Oceanics 1993). Substantial deepening of the entrance had not been achieved at the time of these surveys (Raaymakers pers. comm.). Ongoing tide level and salinity monitoring is being conducted by PCQ throughout Mourilyan Harbour to confirm the model predictions. To date no significant changes have been detected (Raaymakers pers. comm.).

The differences in seagrass biomass and distribution between summer and winter surveys support the need to conduct both winter and summer monitoring events in Mourilyan Harbour.

Results of these surveys provide a reliable baseline for assessing any future changes in seagrass in Mourilyan Harbour and effects of impacts (natural and human) on the marine ecology of the harbour.

4.2. Penaeid Prawns

Juvenile tiger prawns (*Penaeus latisulcatus* and *Penaeus esculentus*) are considered to be almost entirely dependant on shallow, coastal, seagrass meadows for growth and survival, and the densely vegetated *Zostera capricorni* and *Halophila* meadows in Mourilyan Harbour provide typical habitat for these species. There are few other areas of productive prawn nursery habitat between the Hinchinbrook Channel and Cairns (Coles *et al.* 1993). This places a large regional significance on the Mourilyan Harbour meadows as prawn and fish nursery habitat.

In the summer and winter surveys, commercially important tiger prawns (*Penaeus esculentus* and *P. semisulcatus*) and endeavour prawns (*Metapenaeus endeavouri*) were more abundant than other less commercially important species. Prawn abundances in winter were lower than in summer and this may be because summer is the period for high abundance of juvenile tiger and endeavour prawns in north-eastern Queensland (Coles *et al.* 1993).

The Bradshaw Island trawl site produced the highest abundances and largest sizes of commercially important prawns. The commercially targetted brown tiger prawn (*Penaeus esculentus*) was only found at the Bradshaw site in winter. As Bradshaw was a high biomass *Zostera* trawl site, it may offer juvenile tiger prawns greater shelter from predators (Zimmerman and Minello 1984; Loneragan *et al.*1994) and provide greater food resources than the other less vegetated sites.

4.3. Fish

No previous studies have examined the fish communities of Mourilyan Harbour. Russell and Hales (1994) collected 88 species in the Johnstone River estuary (10 km north of Mourilyan Harbour) and Coles *et al*. (1993) collected 134 species in Trinity Inlet (75 km north), using beam trawls, gill and seine nets.

Beam trawl samples in the summer survey showed that fish represented an important macrofaunal component of the total beam trawl catch (43% of total biomass). 9 of the 27 species caught in the winter survey were similar to those in summer. The family Gobiidae was the most dominant group of fish collected in both summer and winter. Many species in the Gobiidae are not described due to their unclear taxonomy. The 2 most dominant species of fish from both surveys, Gobiidae spA and Gobiidae spB, have been sent to the Queensland Museum for taxonomic clarification.

Only 1% of the fish caught in the winter survey were of direct commercial importance compared with 14% in summer. A significant component of this difference is due to the absence of juvenile Lethrinidae and Carrangidae species in the winter survey. These families represented 93% of the commercial fish in the summer survey. This may indicate that recruitment of juveniles for these species occurs in summer for Mourilyan Harbour.

Beam trawls on *Zostera capricorni* meadows produced larger catches and higher species diversity than on less vegetated sites. The dense *Zostera* meadows are likely to offer juvenile fish greater shelter from large predators, and the high abundances of small crustaceans associated with these meadows may provide greater food resources than at the other trawl sites.

Beam trawling captures only a subset of the total fish community, and faster swimming species are unlikely to be caught by this method. Elsewhere *Zostera capricorni* meadows have been shown to support larger commercially targetted species such as garfish, mullet, queenfish, jewfish, king salmon and bream (Coles *et al*. 1993; Russel and Hales 1994). The large numbers of macrofauna collected in Mourilyan Harbour seagrass meadows are likely to support complex predatory food chains including commercially valuable species.

Numbers of fish species and individuals from beam trawl samples in both present surveys are high for north-eastern Queensland (Coles *et al.* 1992, 1993) and this places a large importance on these seagrass habitats to fish productivity. Fish and prawn production from seagrass meadows in northeastern Queensland inlets is typically high compared to that on bare (unvegetated) substrates (Blaber 1980; Coles *et al*. 1993).

4.4. Other Crustacea

Shrimps (Caridea) can be sampled relatively efficiently using beam trawls (McKenzie unpublished data) and results from this study easily compares to other studies in the region. The catch rate of shrimps at the Bradshaw Island site was similar to those on dense seagrass (*Zostera capricorni*) meadows in Trinity Inlet, Cairns (McKenzie unpublished data).

The overall abundance and families of shrimps in Mourilyan Harbour appears relatively typical of that from other nearshore seagrass meadows of the region (Mellors and Marsh 1993; McKenzie 1995), although the community structure is quite different and Crangonidae have not been reported before.

Numbers of individual crustacea (excluding Penaeidae) from beam trawls in winter were high when compared to the summer catch (603 per trawl in winter; 204 per trawl in summer) but biomass was lower (8.75± 2.14 g DW. trawl^{-1} compared to 32.96 ± 1.15 g DW. trawl^{-1}). This indicates that higher numbers of smaller individuals were caught in the winter survey.

As with other macrofauna groups, numbers of crustacea were greatest in the high biomass *Zostera* meadow at Bradshaw. The dense seagrass at Bradshaw is likely to offer more shelter from predators and provide more food resources than less vegetated areas.

4.5. Future Monitoring Strategy and Sampling Design

The 5 meadows chosen for monitoring in summer surveys offer a range of biomasses and species compositions which are typical of seagrasses found in

Mourilyan Harbour. 4 of these 5 meadows have also been selected for winter monitoring, providing the opportunity to compare seasonal differences in meadows in future. Meadow #4 (Seaforth bank) could not be used for winter biomass monitoring due to the high variance of the above-ground biomass.

The design of the monitoring program for Mourilyan Harbour (section 3.5) predicts that the finest possible changes in seagrass biomass at selected meadows can be detected given the variability of the meadows. Utilizing a design focused on meadows, that incorporates both sites and replicates within sites, also enables a more efficient use the time and resources available. A sampling design considering the seagrasses of Mourilyan Harbour as a “whole”, with no replicates at sampling sites, would require a far greater sampling effort and could detect only a coarser change in biomass (for example:1000 sites in summer to detect a 50% change, and 500 sites in winter to detect a 52% change). Also, as species of seagrass differ in their responses/recovery to impacts, it would be unwise to pool meadows as it would make any change detected difficult to interpret.

Biomass measures from the meadows selected for monitoring provide only part of the available information when assessing impacts on Mourilyan Harbour’s seagrasses. Trends in biomass change observed over three consecutive surveys, even if not statistically significant, should raise a cautionary “flag” (ie., when the biomasses of three consecutive surveys (summer/ winter/ summer) are progressively lower or higher). Seagrass species composition and areal extent of seagrass meadows may also vary when biomass within meadows remains unchanged. We would consider that a 50% change in the area of a meadow between successive surveys (of the same season) should raise concerns. It should be emphasised that these indicators are not intended to conclusively show that seagrasses have changed beyond background variation but to raise cautionary “flags” leading to closer investigation. This information could be important to port managers as early warnings and subsequent action could prevent environmental damage.

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APPENDIX 1 - Statistical analyses

Table 6. Results of one-way ANOVA for abundance verses site and carapace length verses site for penaeid prawns caught in Mourilyan Harbour beam trawls (December 1993).

\`Unidentified' are individuals for which identification was uncertain due to small size or poor condition.
Asterisks = data ln(x + 1) transformed.

Species	Common name	Abundance vs Site			Carapace vs Site		
		F	d.f.	p	F	d.f.	p
Metapenaeus endeavouri	True endeavour	11.66	3,10	0.001	1.86	3,10	0.20
Penaeus semisulcatus	Grooved tiger	3.81	3,10	0.047	1.62	3,5	0.297
Penaeus esculentus	Brown tiger	5.52	3,10	0.017*	0.70	3,6	0.59
Metapenaeopsis novaeguineae	Northern velvet	1.70	3,10	0.230	0.06	1,5	0.82
Metapenaeus ensis	False endeavour	5.49	3,10	0.017	0.95	2,5	0.45
Metapenaeopsis palmensis	Southern velvet	2.52	3,10	0.117	-	-	-
Unidentified		-	-	-	-	-	-
TOTAL		6.24	3,10	0.012	0.60	3,10	0.63

Table 7. Results of one-way ANOVA or two sampled T-tests for abundance verses site and carapace length verses site for penaeid prawns caught in Mourilyan Harbour beam trawls (July 1994).

\`Unidentified' are individuals for which identification was uncertain due to small size or poor condition.
Asterisks = Kruskal-Wallis non-parametric ANOVA

Species	Common name	Abundance vs Site			Carapace vs Site		
		F (t)	d.f.	p	F (t)	d.f.	p
Metapenaeus endeavouri	True endeavour	13.07	3,7	0.003	3.09	3,7	0.099
Penaeus esculentus	Brown tiger	*Bradshaw only*					
Trachypenaeus granulosus	Hardback	(0.10)	3	0.92	(2.37)	27	0.025
Metapenaeopsis novaeguineae	Northern velvet	*Channel only*					
Metapenaeus ensis	False endeavour	0.86	3,7	0.50	0.3	3,4	0.82
Penaeus semisulcatus	Grooved tiger	(0.0)	3	1.0	(0.65)	3	0.565
Trachypenaeus curvirostrus	Southern rough	(-0.29)	3	0.79	(-0.82)	2	0.50
Unidentified		0.32*	3,7*	0.812*	3.37	3,6	0.096
TOTAL		0.82	3, 7	0.524	7.97	3,7	0.012

Table 8. Between-site comparison of abundances for most common taxa of fish collected in Mourilyan Harbour (December 1993).

% abundance is for all individuals, all taxa, pooled. Asterisks= data ln(x+1) transformed.

Species	% Abundance	F	d.f.	p
Ambassis nalua	6.7	31.23	3, 8	<0.001*
Gobiidae spA	42.7	7.51	3, 8	0.01*
GOBIIDAE spp.	8.3	1.36	3, 8	0.322
Lethrinus spp.	7.4	34.51	3, 8	<0.001*
Lutjanus fulviflammus	1.2	22.25	3, 8	<0.001
Siganus canaliculatus	9.7	12.17	3, 8	0.002*
Siganus guttatus	4.3	3.73	3, 8	0.061*

Table 9. Abundance of Caridea and results of one-way ANOVA of abundance vs site (July 1994).

All data ln(x+1) transformed.

Family	% Abundance	mean ±s.e.	F	d.f.	p
Palaemonidae	52.32	117.5 ±48.7	8.83	3, 8	0.006
Processidae	38.44	86.33 ±29.9	5.37	3, 8	0.026
Hippolytidea	2.52	5.67 ±2.9	21.08	3, 8	<0.001
Alpheidae	0.67	1.5 ±0.7	6.12	3, 8	0.018
Crangonidae	0.11	0.3 ±0.2	0.70	3, 8	0.578
Unidentified	5.94	13.3 ±6.9	6.30	3, 8	0.017
TOTAL	100	224.6 ±54.7	4.43	3, 8	0.041

Table 10. Other miscellaneous crustaceans collected by beam trawl and the results of one-way ANOVA for abundance vs site (December 1993).

Asterisks= data ln(x+1) transformed.

Fauna	Abundance	F	d.f.	p
Acetes sibogue australis	53	17.93	3, 8	<0.001*
AMPHIPODA				
Ampeliscidae	1	*Channel only*		
Caprellidae	1	*Channel only*		
Gammaridae	1	*Channel only*		
Lysianassidae	6	*Channel only*		
BRACHYURA				
Grapsidae	14	0.18	3, 8	0.906
Portunidae	12	*Bradshaw only*		
Leucosidae	3	*Lily only*		
ISOPODA				
Chorilanidae	32	5.68	3, 8	0.022*
Sphaeromatidae	20	*Bradshaw only*		
MYSIDACEA	17	*Channel only*		
STOMATOPODA	1	*Lily only*		
TANAIDACEA	1	*Channel only*		
TOTAL	2857	3.73	3, 8	0.06

Table 11. Other miscellaneous crustaceans collected by beam trawl and the results of one-way ANOVA for abundance vs site (July 1994).

Asterisks= data ln(x+1) transformed.

Fauna	Total Abundance	F	d.f.	p
BRACHYURA				
Grapsidae	89	1.07	3, 7	0.4195
Portunidae	34	3.29	2, 5	0.1252
Hymenosomidae	7	0.53	2, 5	0.621
MISC. CRUSTACEA	7089	23.38	3, 7	<0.001*

➢ APPENDIX 2- Sampling strategy tables

Table 12. Estimate of the number of quadrats per site such that , for various numbers of sites, a given percentage change in the mean will 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%) for the Channel meadow (#3)(summer).

The mean, quadrat variance component and site variance component from the December 1993 survey are 0.5109, 0.5248 and 0.1883 g DW. m^{-2} respectively. NP = Not Possible to obtain a sampling procedure satisfying the given criteria

Number of Sites (r)	Degrees of Freedom 3(r-1)	t_0	t_1	Required percentage change in mean			
				30 (0.1533)	50 (0.2555)	75 (0.3832)	100 (0.5109)
10	27	1.703	1.314	NP	NP	NP	NP
15	42	1.684	1.303	NP	NP	NP	17.0
20	57	1.671	1.296	NP	NP	NP	4.9
25	72	1.668	1.295	NP	NP	25.6	2.9
30	87	1.665	1.293	NP	NP	8.3	2.0
35	102	1.662	1.291	NP	NP	4.9	1.6
40	117	1.658	1.289	NP	NP	3.5	1.3
50	147	1.657	1.288	NP	NP	2.2	0.9

Table 13. Estimate of the number of quadrats per site such that , for various numbers of sites, a given percentage change in the mean will 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%) for the Seaforth bank meadow (#4)(summer).

The mean, quadrat variance component and site variance component from the December 1993 survey are 1.0926, 0.8831 and 0.9873 g DW. m^{-2} respectively. NP = Not Possible to obtain a sampling procedure satisfying the given criteria

Number of Sites (r)	Degrees of Freedom 3(r-1)	t_0	t_1	Required percentage change in mean			
				30 (0.3278)	50 (0.5463)	75 (0.8195)	100 (1.0926)
10	27	1.703	1.314	NP	NP	NP	NP
15	42	1.684	1.303	NP	NP	NP	61.0
20	57	1.671	1.296	NP	NP	NP	2.4
25	72	1.668	1.295	NP	NP	NP	1.2
30	87	1.665	1.293	NP	NP	5.4	0.8
35	102	1.662	1.291	NP	NP	2.5	0.6
40	117	1.658	1.289	NP	NP	1.6	0.5
50	147	1.657	1.288	NP	NP	0.9	04

Table 14. Estimate of the number of quadrats per site such that , for various numbers of sites, a given percentage change in the mean will 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%) for the Seaforth edge meadow (#5)(summer).

The mean, quadrat variance component and site variance component from the December 1993 survey are 2.0427, 0.5248 and 0.1883 g DW. m^{-2} respectively.

Number of Sites (r)	Degrees of Freedom 3(r-1)	t_0	t_1	Required percentage change in mean			
				30 (0.681)	50 (1.021)	75 (1.532)	100 (2.043)
10	27	1.703	1.314	7.9	1.4	0.5	0.2
15	42	1.684	1.303	2.6	0.7	0.3	0.2
20	57	1.671	1.296	1.6	0.5	0.2	0.1
25	72	1.668	1.295	1.1	0.4	0.2	0.1
30	87	1.665	1.293	0.9	0.3	0.1	0.1
35	102	1.662	1.291	0.7	0.3	0.1	0.1
40	117	1.658	1.289	0.6	0.2	0.1	0.1
50	147	1.657	1.288	0.5	0.2	0.1	0.05

Table 15. Estimate of the number of quadrats per site such that , for various numbers of sites, a given percentage change in the mean will 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%) for the Bradshaw Island meadow (#23)(summer).

The mean, quadrat variance component and site variance component from the December 1993 survey are 41.907, 929.961 and 64.6874 g DW. m^{-2} respectively. NP = Not Possible to obtain a sampling procedure satisfying the given criteria

Number of Sites (r)	Degrees of Freedom 3(r-1)	t_0	t_1	Required percentage change in mean			
				30 (12.752)	50 (20.954)	75 (31.430)	100 (41.907)
10	27	1.703	1.314	41.3	5.3	1.9	1.0
15	42	1.684	1.303	13.6	3.1	1.2	0.7
20	57	1.671	1.296	8.1	2.1	0.9	0.5
25	72	1.668	1.295	5.8	1.7	0.7	0.4
30	87	1.665	1.293	4.5	1.4	0.6	0.3
35	102	1.662	1.291	3.7	1.1	0.5	0.3
40	117	1.658	1.289	3.1	1.0	0.4	0.2
50	147	1.657	1.288	2.4	0.8	0.3	0.2

Table 16. Estimate of the number of quadrats per site such that , for various numbers of sites, a given percentage change in the mean will 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%) for the Channel meadow (#3) (winter).

The mean, quadrat variance component and site variance component from the July 1994 survey are 0.217, 0.11396 and 0.08311 g DW. m^{-2} respectively. NP = Not Possible to obtain a sampling procedure satisfying the given criteria

Number of Sites (r)	Degrees of Freedom 3(r-1)	t_0	t_1	Required percentage change in mean			
				30 (0.0723)	50 (0.1085)	75 (0.1628)	100 (0.217)
10	27	1.703	1.314	NP	NP	NP	NP
15	42	1.684	1.303	NP	NP	NP	NP
20	57	1.671	1.296	NP	NP	NP	NP
25	72	1.668	1.295	NP	NP	NP	NP
30	87	1.665	1.293	NP	NP	NP	NP
35	102	1.662	1.291	NP	NP	NP	10.0
40	117	1.658	1.289	NP	NP	NP	4.5
50	147	1.657	1.288	NP	NP	NP	2.2

Table 17. Estimate of the number of quadrats per site such that , for various numbers of sites, a given percentage change in the mean will 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%) for the Seaforth bank meadow (#4)(winter).

The mean, quadrat variance component and site variance component from the July 1994 survey are 0.3510, 0.89871 and 0.84724 g DW. m^{-2} respectively. NP = Not Possible to obtain a sampling procedure satisfying the given criteria

Number of Sites (r)	Degrees of Freedom 3(r-1)	t_0	t_1	Required percentage change in mean			
				30 (0.1053)	50 (0.1755)	75 (0.2632)	100 (0.3510)
10	27	1.703	1.314	NP	NP	NP	NP
15	42	1.684	1.303	NP	NP	NP	NP
20	57	1.671	1.296	NP	NP	NP	NP
25	72	1.668	1.295	NP	NP	NP	NP
30	87	1.665	1.293	NP	NP	NP	NP
35	102	1.662	1.291	NP	NP	NP	NP
40	117	1.658	1.289	NP	NP	NP	NP
50	147	1.657	1.288	NP	NP	NP	NP

Table 18. Estimate of the number of quadrats per site such that , for various numbers of sites, a given percentage change in the mean will 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%) for the Seaforth edge meadow (#5)(winter).

The mean, quadrat variance component and site variance component from the July 1994 survey are 0.7321, 0.18443 and 0.16311 g DW. m^{-2} respectively. NP = Not Possible to obtain a sampling procedure satisfying the given criteria

Number of Sites (r)	Degrees of Freedom 3(r-1)	t_0	t_1	Required percentage change in mean			
				30 (0.220)	50 (0.366)	75 (0.5491)	100 (0.7321)
10	27	1.703	1.314	NP	NP	73.8	1.4
15	42	1.684	1.303	NP	NP	2.0	0.6
20	57	1.671	1.296	NP	NP	1.0	0.4
25	72	1.668	1.295	NP	NP	0.7	0.3
30	87	1.665	1.293	NP	NP	0.5	0.2
35	102	1.662	1.291	NP	NP	0.4	0.2
40	117	1.658	1.289	NP	NP	0.3	0.2
50	147	1.657	1.288	NP	NP	0.3	0.1

Table 19. Estimate of the number of quadrats per site such that , for various numbers of sites, a given percentage change in the mean will 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%) for the Bradshaw Island meadow (#23)(winter).

The mean, quadrat variance component and site variance component from the July 1994 survey are 26.557, 54.4453 and 186.5999 g DW. m^{-2} respectively. NP = Not Possible to obtain a sampling procedure satisfying the given criteria

Number of Sites (r)	Degrees of Freedom 3(r-1)	t_0	t_1	Required percentage change in mean			
				30 (7.967)	50 (13.278)	75 (19.918)	100 (26.557)
10	27	1.703	1.314	NP	NP	1.7	0.27
15	42	1.684	1.303	NP	NP	0.4	0.13
20	57	1.671	1.296	NP	NP	0.2	0.09
25	72	1.668	1.295	NP	NP	0.1	0.07
30	87	1.665	1.293	NP	NP	0.1	0.05
35	102	1.662	1.291	NP	NP	0.09	0.04
40	117	1.658	1.289	NP	NP	0.07	0.04
50	147	1.657	1.288	NP	NP	0.06	0.03

Table 20. Estimate of the number of quadrats per site such that , for various numbers of sites, a given percentage change in the mean will 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%) for the Lily Island meadow (#26)(winter).

The mean, quadrat variance component and site variance component from the July 1994 survey are 9.5931, 22.0156 and 28.7145 g DW. m^{-2} respectively. NP = Not Possible to obtain a sampling procedure satisfying the given criteria

Number of Sites (r)	Degrees of Freedom 3(r-1)	t_0	t_1	Required percentage change in mean			
				30 (2.8779)	50 (4.7965)	75 (7.1948)	100 (9.5931)
10	27	1.703	1.314	NP	NP	NP	1.01
15	42	1.684	1.303	NP	NP	1.49	0.45
20	57	1.671	1.296	NP	NP	0.73	0.29
25	72	1.668	1.295	NP	NP	0.5	0.22
30	87	1.665	1.293	NP	NP	0.37	0.17
35	102	1.662	1.291	NP	NP	0.29	0.14
40	117	1.658	1.289	NP	NP	0.24	0.12
50	147	1.657	1.288	NP	NP	0.18	0.09

➯ APPENDIX 3 - Seagrasses

Plates 3 - 7.

The following plant specimens are typical of seagrass species collected from sites in Mourilyan Harbour

Plate 3. *Enhalus acoroides*
Plate 4. *Halodule uninervis*
Plate 5. *Halophila decipiens*
Plate 6. *Halophila ovalis*
Plate 7. *Zostera capricorni*

Plate 3. ***Enhalus acoroides***

2 cm

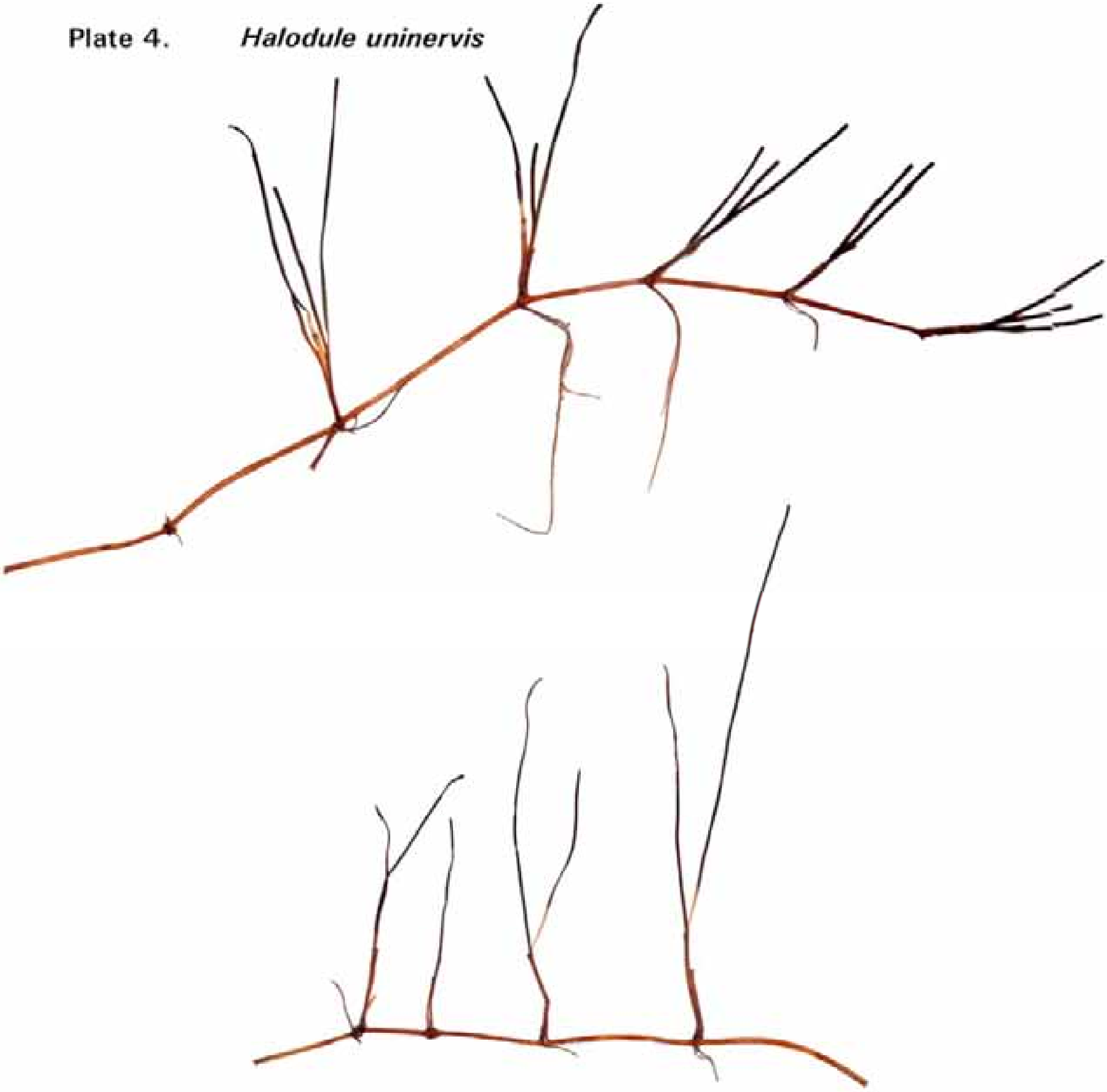
- ***Enhalus acoroides***

Source: L.J. McKenzie, M.A. Rasheed, W.J. Lee Long & R.G. Coles (1996) *"Port of Mourilyan Seagrass Monitoring: Baseline Surveys Summer (December) 1993 and Winter (July) 1994".* Ports Corporation EcoPorts Monograph Series No 2 (PCQ, Brisbane).

Survey Date: 22-23 December 1993 & 26-27 July 1994

PORTS CORPORATION QUEENSLAND

Plate 4. ***Halodule uninervis***



2 cm

● ***Halodule uninervis***

Source: L.J. McKenzie, M.A. Rasheed, W.J. Lee Long & R.G. Coles (1996) *"Port of Mourilyan Seagrass Monitoring: Baseline Surveys Summer (December) 1993 and Winter (July) 1994".* Ports Corporation EcoPorts Monograph Series No 2 (PCQ, Brisbane).

Survey Date: 22-23 December 1993 & 26-27 July 1994

PORTS CORPORATION QUEENSLAND

Plate 5. ***Halophila decipiens***

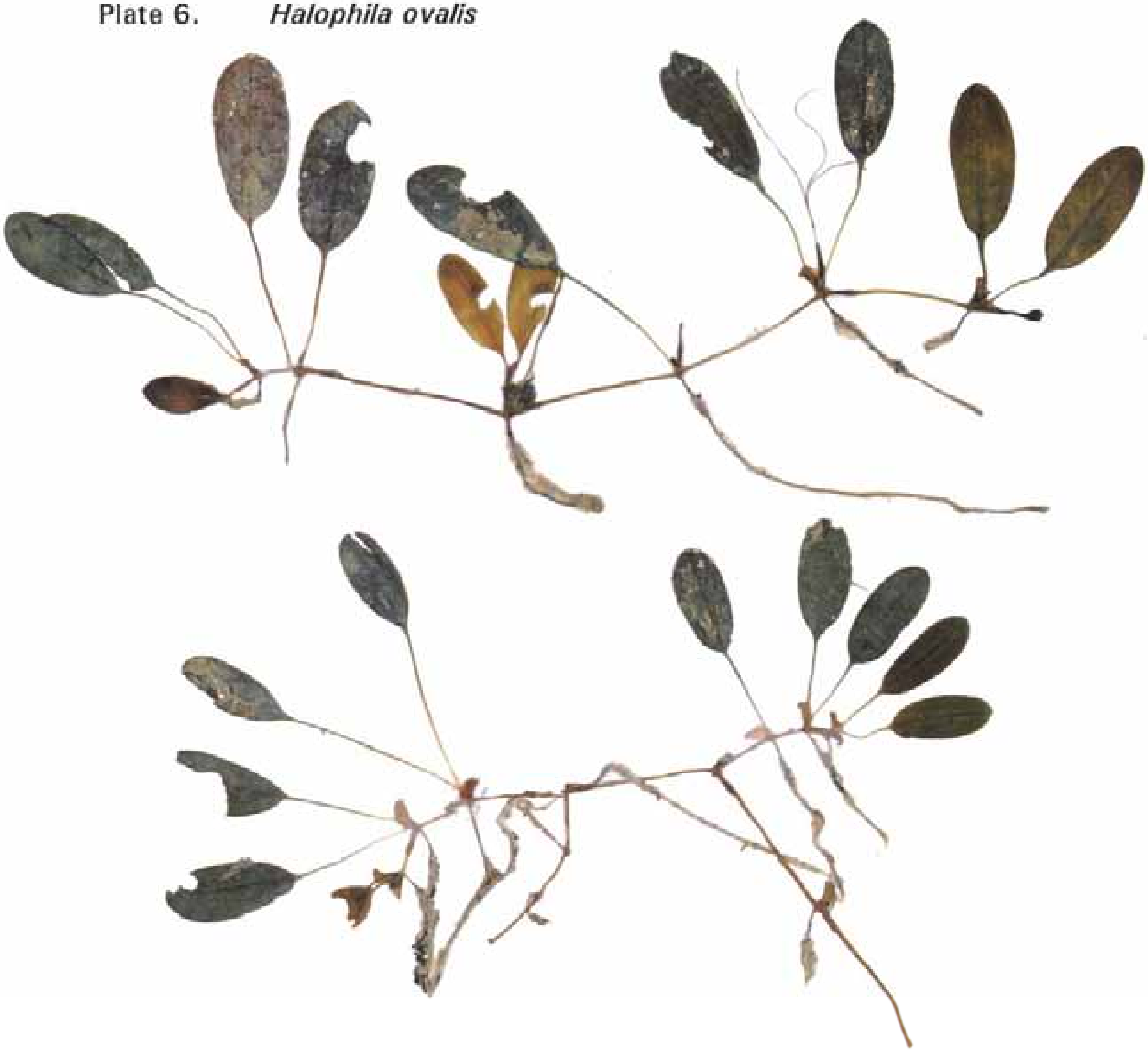
• *Halophila decipiens*

Source: L.J. McKenzie, M.A. Rasheed, W.J. Lee Long & R.G. Coles (1996) *"Port of Mourilyan Seagrass Monitoring: Baseline Surveys Summer (December) 1993 and Winter (July) 1994"*. Ports Corporation EcoPorts Monograph Series No 2 (PCQ, Brisbane).

Survey Date: 22-23 December 1993 & 26-27 July 1994

PORTS CORPORATION QUEENSLAND

Plate 6. *Halophila ovalis*



2 cm

• ***Halophila ovalis***

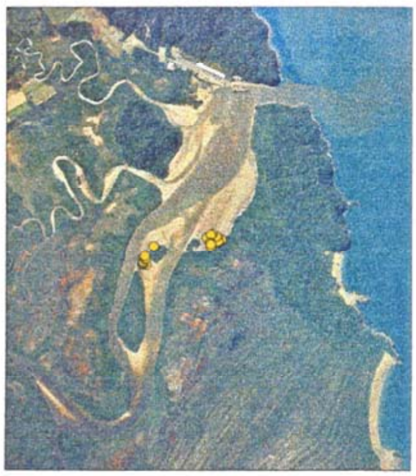
Source: L.J. McKenzie, M.A. Rasheed, W.J. Lee Long & R.G. Coles (1996) *"Port of Mourilyan Seagrass Monitoring: Baseline Surveys Summer (December) 1993 and Winter (July) 1994"*. Ports Corporation EcoPorts Monograph Series No 2 (PCQ, Brisbane).

Survey Date: 22-23 December 1993 & 26-27 July 1994

PORTS CORPORATION QUEENSLAND

Plate 7. *Zostera capricorni*

2 cm



• ***Zostera capricorni***

Source: L.J. McKenzie, M.A. Rasheed, W.J. Lee Long & R.G. Coles (1996) *"Port of Mourilyan Seagrass Monitoring: Baseline Surveys Summer (December) 1993 and Winter (July) 1994".* Ports Corporation EcoPorts Monograph Series No 2 (PCQ, Brisbane).

Survey Date: 22-23 December 1993 & 26-27 July 1994