RESEARCH PUBLICATION No. 44

Seagrass Communities in the Shoalwater Bay Region, Queensland

Spring (September) 1995 and Autumn (April) 1996

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A REPORT TO THE GREAT BARRIER REEF MARINE PARK AUTHORITY

ISSN 1037-1508

ISBN 0 642 23035 8

Published November 1997 by the Great Barrier Reef Marine Park Authority

This report was previously published as Queensland Department of Primary Industries Information Series Q196042.

National Library of Australia Cataloguing-in-Publication data:

Lee Long, W. J.
Seagrass communities in the Shoalwater Bay region, Queensland : spring (September) 1995 and autumn (April) 1996.

Bibliography.
ISBN 0 642 23035 8.

1. Seagrasses - Queensland - Shoalwater Bay. 2. Marine plants - Queensland - Shoalwater Bay. I. McKenzie, L. J. II. Coles, R. G. III. Great Barrier Reef Marine Park Authority (Australia). IV. Title. (Series : Research publication (Great Barrier Reef Marine Park Authority (Australia)) ; no. 44).

584.73099435

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Abstract

KEY RESULTS

❶ 13,076 ±800 ha of seagrass habitat was mapped in spring (September) 1995 and 13,001 ±890 ha in autumn (April) 1996.

❷ Eight species (from 3 families) of seagrasses were found in the survey area during both surveys. A new, undescribed, *Halophila* species was collected in September 1995 from near Stannage Bay.

❸ Seagrass habitats were located on soft substrates and mostly restricted to intertidal flats. Four main seagrass habitats were identified: large continuous meadows on intertidal banks, patchy meadows restricted to drainage channels and pools on intertidal banks in the southern section of the bay, meadows in narrow bands on some creek banks in the southern section of the bay and inlets and subtidal meadows adjacent to the south-western corner of Townshend Island and in Canoe Passage.

❹ 12 meadow types (seagrass communities) were identified in Shoalwater Bay. *Zostera capricorni* dominated meadows were more numerous, more extensive and generally much higher above-ground biomass than most other meadows.

❺ Above-ground biomass for most meadow types was significantly higher in September 1995 than April 1996.

❻ Above-ground seagrass biomass varied from 0.04 g DW. m^{-2} (*Halodule/Halophila*) to 106.42 g DW. m^{-2} (*Zostera capricorni*) in September 1995. In April 1996, above-ground biomasses were significantly lower and ranged from 0.02 g DW. m^{-2} (*Halodule/Halophila*) to 25.48 g DW. m^{-2} (*Zostera capricorni*).

❼ Seagrasses were found at depths from 0.7 m above MSL to 8.2 m below MSL in September 1995 and 6.5 m below MSL in April 1996.

❽ Commercially important species of prawns were the dominant catch in beam trawl samples at all sites. Juvenile penaeid prawns were more common at Port Clinton and Island Head Creek sites, where substrate types were mud and fine sand. The most abundant species caught in beam trawl samples were western king prawns and true endeavour prawns in September 1995 and April 1996, respectively.

❾ Fish collected by beam trawling in seagrass meadows were generally small sized and mostly gobies at all sites. Commercially importance species of fish were not common in beam trawls in September 1995 (0.2 % of the total catch) or in April 1996 (1 % of the total catch).

KEY ISSUES

❶ Distribution patterns in these surveys were similar to those from the original post-wet broad-scale survey in March 1987, where an estimated 7,000 ha of seagrasses was mapped. A number of intertidal meadows (approximately 1,300 ha in the present surveys) were not surveyed in March 1987 because of the sea conditions at the time.

❷ The area of subtidal seagrass habitat in Shoalwater Bay is small. Strong tidal currents and associated high water turbidity in Shoalwater Bay limit light penetration and therefore the depth to which seagrasses can grow (maximum 8.2 m below MSL). Seagrasses have been recorded to a depth of 53 m in other areas.

❸ With large tidal ranges seagrasses are exposed for long periods during low tide. This may influence the location of the upper limit of seagrass distribution. In places,

water is retained on the flats at low tide and seagrasses are better protected against desiccation, extending the upper limit to around 0.6 m above MSL.

❹ The nearest other large seagrass meadows exist 150 km south at Gladstone, patchy meadows 50 km north at Clairview and extensive meadows 300 km north at the Whitsunday Island group. This makes the Shoalwater Bay area regionally important as prawn and fish nursery habitat and as feeding area for dugongs and green sea turtles.

❺ Large numbers of other invertebrates and juvenile fish from beam trawl samples indicate a rich food source for local marine food webs. The Shoalwater Bay seagrass meadows provide a valuable nursery habitat where food and shelter are available for juveniles of commercially and recreationally important species forming the basis of very productive coastal marine communities.

❻ Potential influences on distribution and abundance of seagrasses in Shoalwater Bay (and elsewhere along the Queensland coast) may include freshwater and sediment runoff from the land, in addition to natural fluctuations in plant populations.

❼ These baseline surveys were designed to establish a data set on which monitoring programs can be based to investigate changes in seagrass biomass and distribution. These programs will enable measures of change in area of seagrass habitat and seagrass biomass within meadows to be quantified.

INTRODUCTION

Consultancy Brief

The Commonwealth Commission of Inquiry into Shoalwater Bay (Commission of Inquiry 1994) recommended equal priority be given to conservation and defence force training use in the Shoalwater Bay area, and that integrated management plans be developed for the terrestrial and marine environments. The Great Barrier Reef Marine Park Authority (GBRMPA) was given responsibility for developing management plans for a special Shoalwater Bay Marine Park. The GBRMPA commissioned a number of studies of marine resource inventories and use patterns in the Shoalwater Bay area for marine park zone planning. The present Spring and Autumn baseline surveys of seagrass resources is one of these studies.

Seagrasses have seasonal differences in distribution and abundance, so two baseline surveys - Spring (pre-wet) and Autumn (post-wet) - were recommended. This report presents the results of the two surveys conducted September 1995 and April 1996. The objectives were:

1. *To map the distribution of seagrass meadows in Shoalwater Bay during the Spring and Autumn periods.*
2. *To estimate seagrass species biomass for the major seagrass meadows.*
3. *To identify juvenile prawn and fish species present on selected seagrass areas.*
4. *To provide quantitative data on seagrass communities of Shoalwater Bay for use as a baseline for future monitoring of seagrass species composition, area or biomass.*

Site Description

Shoalwater Bay is located in the southern section of the Great Barrier Reef Marine Park World Heritage Area (Figure 1). The Shoalwater Bay Area covers 520 000 ha, of which approximately 50 % is marine (Commonwealth Commission of Inquiry 1994). There is relatively little human disturbance (coastal towns and development, *etc.*) and it is a largely intact natural system. The area has been reserved for defence force training since 1965. The most notable feature of the Shoalwater Bay area is the massive tidal range - up to 7 metres(Queensland Department of Transport 1995), which in some places has the effect of creating extensive tidal banks.

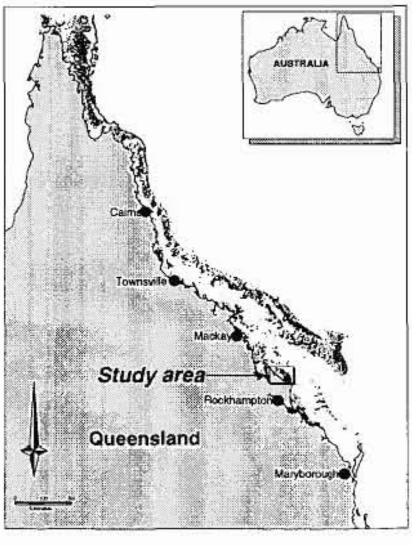


Figure 1. Location of Shoalwater Bay study area.

The area supports several inshore fishing industries. The Shoalwater Bay area produces less than 2% of the state's prawn and fin-fish production, but between 7-8% of the states commercial mud crab production (Fitzsimmons 1996). The low fish production in Shoalwater Bay is largely for reasons to do with the remoteness of the region and access problems posed for both recreational and commercial fishers, rather than low fish abundance (Fitzsimmons 1996). Seagrasses and mangroves in the Shoalwater Bay area are considered regionally important as nursery habitats for species of commercial and recreational fishing value.

The soils of the region are generally leached and infertile (Commission of Inquiry 1994). Some soils have potential acid sulphate properties. Rainfall is seasonal and highly variable between years. The south-eastern section is generally the wettest, and the coastal areas are wetter than inland areas, where long drought periods are reasonably frequent. Winds are south-easterly trade in the dry, cooler months of the year and light northerly winds occur during the summer monsoon season.

General Seagrass Ecology

Seagrass meadows in Queensland are important nursery habitats for commercial species of penaeid prawns and fish (Coles and Lee Long 1985; Coles *et al.* 1993; Watson *et al.* 1993). Seagrasses are essential food for dugong, *Dugong dugon* (Miller), and green sea turtles, *Chelonia mydas* (Linnaeus) (Lanyon *et al.* 1989) and act as "nutrient and sediment sinks" (Short 1987). Seagrasses in coastal regions also 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 measurable growth responses to changes in ambient water quality conditions and can therefore be used as effective indicators of environmental health (Dennison *et al.* 1993; Dennison and Kirkman 1996).

Tropical seagrass meadows are subject to natural temporal changes, varying 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).

Shoalwater Bay seagrasses

Seagrass meadows in and around Shoalwater Bay were first mapped during a broad scale survey from Bowen to Water Park Point in March and April 1987 (Coles *et al.* 1987b; Lee Long *et al.* 1993) and large areas of patchy and dense seagrass were found on the shallow banks within the bay.

The present surveys were designed to obtain detailed assessments of the seagrass resources for marine park planning. A separate collection of seagrass specimens, including fruit and flowers, were taken from Stannage Bay; immediately north west of the Shoalwater Bay area. Seagrass plants in Stannage Bay are possibly a new species which was first identified from collections from this locality in the Queensland Department of Primary Industries 1987 seagrass survey.

The present surveys also provide a qualitative measure of the prawn nursery habitat value of selected meadows. Local populations of fish, dugong and green sea-turtles also depend on these seagrasses; information on which are the subject of other reports (Fitzsimmons 1996).

↬METHODS

Survey Methods

The survey area for the purposes of this study was from Macdonald Point in the north of Shoalwater Bay, across the northern tip of Townshend Island and then to Port Clinton (Map1). The Cannibal Group of islands was also included in the April 1996 survey (Map 2).

Aerial photography, and helicopter reconnaissance flights prior to both dive-based surveys, were used to scope the extent of seagrass meadows, identify the priority areas to be surveyed and aid in the mapping of meadow boundaries. As large tidal ranges in the survey region limit access to the wide, shallow tidal flats for many hours each day, the helicopter was used to survey and check upper intertidal areas. The lower intertidal and sub-tidal seagrasses were surveyed by divers.

A field sampling design was developed to estimate area and biomass of seagrasses. The design was stratified by depth and meadow, taking into account the topography of the bay, time and tide constraints. On intertidal banks, survey sites were sampled approximately every 150-200 m along transects and at selected spots between transects. Transects were approximately 1-1.5 km apart. In subtidal areas, survey sites were sampled approximately 1.5-2.0 km apart along selected transects which traversed the bay.

A more detailed sampling regime was applied to seven "monitoring meadows", which represented the major seagrass habitat types found in the survey area, to give more precise estimates of species biomass at those locations and to be used as a management tool. At these meadows, sites were surveyed every 50 m haphazardly. These monitoring meadows will be used as baselines against which change in seagrass biomass can be compared and monitored in Shoalwater Bay.

Sampling was conducted between 13- 20 September 1995 and between 3 - 11 April 1996 (Maps 1 & 2). At each survey site estimates of above-ground seagrass biomass (3-5 replicates of a 0.25 m^2 quadrat), seagrass species composition, % cover of algae and sediment characteristics were recorded. The relative proportion of biomass of each seagrass species within each survey 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 convert above-ground biomass estimates into grams dry weight per metre of meadow (g DW m^{-2}), each diver's ranks were calibrated against a set of harvested quadrats.

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

A differential Global Positioning System (GPS) was used to accurately determine geographic location of survey sites (±5 m). Depths of survey sites were recorded with a depth sounder standardised to depth below Mean Sea Level (MSL), corrected to tidal plane datum (Queensland Department of Transport 1995). Tidal plane and time differences for the southern section of Shoalwater Bay and in Island Head Creek are not accurately known and corrected depth values for sites in these areas were approximated.

Additional sampling was conducted by staff from the Great Barrier Reef Marine Park Authority on 11- 18 December 1995 (Map 1) as part of a survey of Shoalwater Bay fringing reef habitats. At each survey site observers recorded seagrass presence/absence, seagrass species composition, estimate of seagrass cover and sediment characteristics. These results were used to assist with determining species distributions.

Macrofaunal communities

Qualitative sampling using beam trawls was conducted to produce an inventory of seagrass-associated macrofauna and to provide an indication of the importance of Shoalwater Bay seagrasses for species of commercial fisheries importance. Further monitoring of macrofauna abundance would require frequent, intensive sampling to be effective, because most species are seasonal in abundance. This is beyond the scope of this program.

Four trawling sites were chosen for macrofauna collection based on the representative seagrass communities of the survey area (Table 1, Maps 1 & 2). A fifth trawl site was sampled at Marquis Island in April 1996. Sampling was conducted at the time of high water at night. 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). Three or four replicate trawls were conducted at each site, once in September 1995 and once in April 1996.

Time constraints limited sampling to beam trawling and the species list may not include larger or fast moving seagrass inhabitants that are able to avoid a slow moving trawl net.

Table 1. Description of beam trawl sites in the Shoalwater Bay survey area.

Dates	Site	Seagrass species	Substrate	Depth (m)
13/9/95 3/4/96	Macdonald Pt	*Zostera capricorni, Halodule uninervis, Halodule pinifolia*	Sand/Mud	2.53
16/9/95 6/4/96	Triangular Is.	*Halodule uninervis, Halodule pinifolia*	Sand/Mud	3.71
18/9/95 8/4/96	Island Head Ck.	*Zostera capricorni*	Mud/Sand	1.27
19/9/95 9/4/96	Port Clinton	*Zostera capricorni*	Mud/Sand	0.52
7/4/96	Marquis Is	*Halodule uninervis (wide)* *Halophila ovalis*	Mud/Shell	3.05

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 as far as possible and standard length (tip of snout to last vertebra) measured to the nearest 0.1 mm for the largest and smallest individuals from each taxa in September 1995, and for all individuals collected in April 1996.

Numbers of Brachyura (crabs), squid, sepiolids (cuttlefish) and miscellaneous crustaceans (shrimps, isopods, amphipods, stomatopods) were pooled and recorded for each trawl. Dry weight biomass of crustacea from each trawl was determined by drying (60°C, 48 hrs) and weighing samples. Molluscs, polychaetes and other phyla were not examined.

Geographic Information System

All data from the surveys were entered onto a Geographic Information System (GIS). A GIS base map using a Thematic Mapper Satellite image (provided by Dr Brian Tunstall, CSIRO) was rectified to World Geodetic System (WGS) co-ordinates. A GIS of seagrass community distribution was created in ArcInfo® and MapInfo®.

Errors in GIS maps include those associated with digitising and rectifying aerial photographs onto basemaps and with Global Positioning System (GPS) fixes for survey sites. Thematic Mapper satellite images are based on 30 m^2 pixels and coastal outlines are accurate to 1:200 000 scale. The point at which divers estimated bottom vegetation may be up to 5 m from the point at which a GPS fix was obtained. Differentially corrected GPS fixes were also only precise to within 5 m.

Each seagrass meadow was assigned a qualitative mapping value, determined by the data sources and likely accuracy of mapping. A rank system for mapping quality was used, based on the range of mapping information available for each area and associated estimates of reliability in mapping meadow boundaries (Table 2). A mapping quality rank of 1 is the highest. Estimates of reliability in mapping meadow boundaries ranged from 5 m to 30 m.

Table 2. Ranks of mapping quality for seagrass meadows mapped in Shoalwater Bay.

Map Quality	Data Sets	Comments
1	Helicopter reconnaissance & aerial photos & TM satellite image & dive survey.	Detailed checking of meadow boundary during dive surveys. Images and photos of high resolution.
2	Helicopter reconnaissance & aerial photos, TM image, dive survey.	Some meadow boundaries checked, and several transects during dive survey. Images and photos of suitable resolution.
3	Helicopter reconnaissance & aerial photos, TM image & dive survey.	Occasional meadow boundaries checked during dive survey. Reasonable definition in images and photos.
4	Helicopter reconnaissance & dive survey.	No image or photo available at required resolution, some meadow boundaries checked in dive survey. High reliance on video from low level helicopter flight and dive survey data.
5	Dive survey only.	Subtidal meadows not visible in remote-sensing images. Data density generally low and reliant solely on dive surveys.
6	Helicopter reconnaissance & aerial photos only.	Photos of suitable resolution. Meadow boundaries checked by helicopter reconnaissance, no dive survey.

Analysis

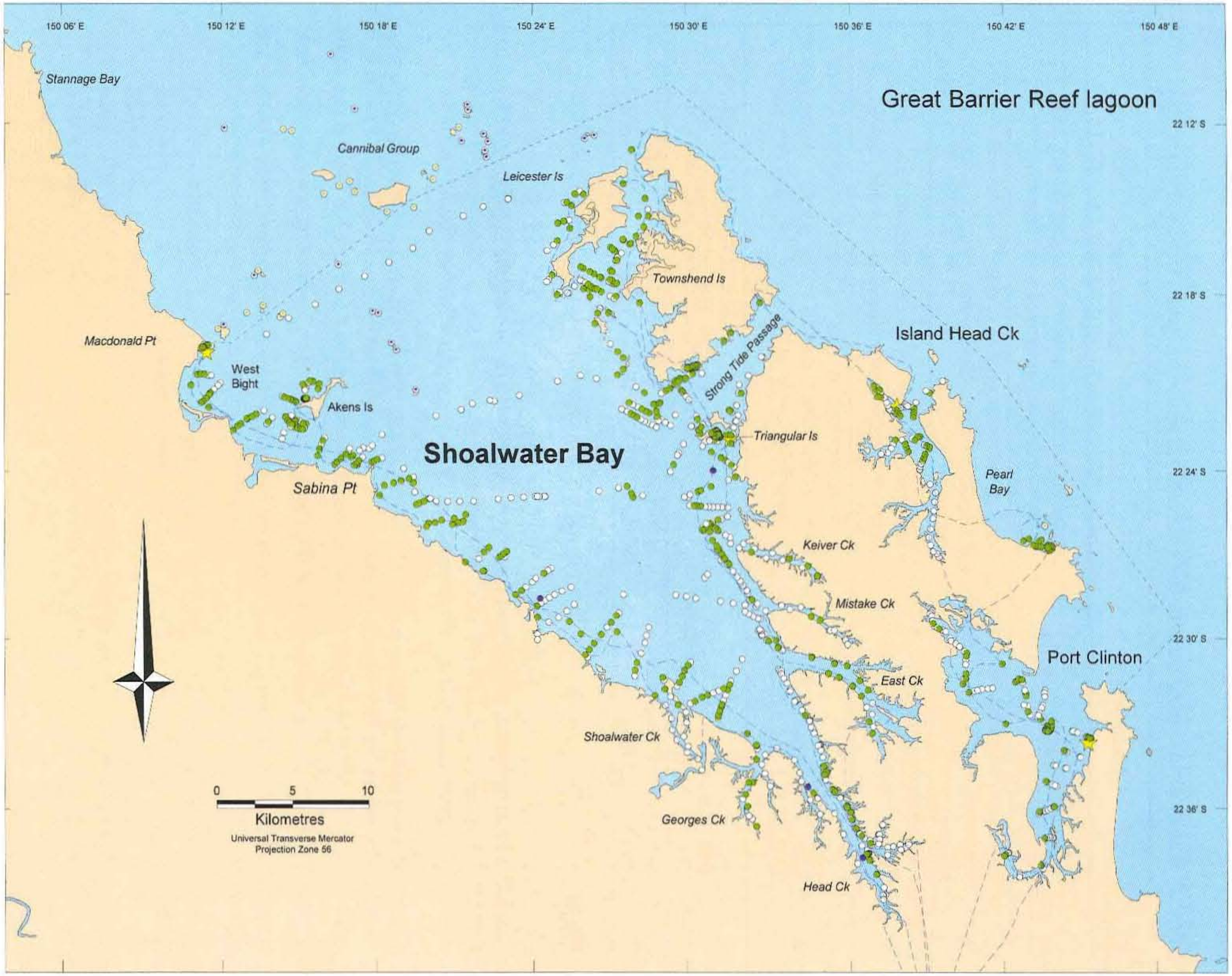
Standard parametric tests were used for analysis of data (Sokal and Rohlf 1987). All divers had significant linear regressions and $r^2 > 0.85$ for most divers when calibrating above-ground biomass estimates against a set of harvested quadrats (Appendix 1, Table 8).

We used a measure of precision to test that the seagrass biomass data set was adequate as a baseline from which a monitoring program could be established to measure change. Precision is a function of the Standard Error (SE) of a sample and the measure of precision used in this study was the ratio of the standard error to the mean ($SE/\bar{x}$). The level of precision which field programs usually aim for is 0.1 to no more then 0.2 (Downing and Anderson 1985; Thresher and Gunn 1986).

MAP 1.
Survey sites
- September 1995.

Legend

- Seagrass
- No seagrass
- Survey boundary
- Helicopter flight path
- Beam trawl sites
- GBRMPA survey - seagrass present
- GBRMPA survey - no seagrass



Source: Lee Long, W.J., McKenzie, L.J. and Coles, R.G. (1996) Seagrass communities in the Shoalwater Bay region, Queensland - Spring (September) 1995 & Autumn (April) 1996. QDPI Information Series QI96042 (QDPI, Brisbane) 38pp.

Survey Date: boat survey 13-20th September 1995, helicopter survey 9-11th August 1995; GBRMPA survey 11-18th December 1995.

Produced by the Seagrass Group, QDPI, Northern Fisheries Centre, Cairns, 1997

Funded by the Great Barrier Reef Marine Park Authority, the Queensland Department of Primary Industries and the Australian Cooperative Research Centres Program through the CRC for Ecologically Sustainable Development of the Great Barrier Reef.

CRC Reef Research Centre

DPI QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES FISHERIES

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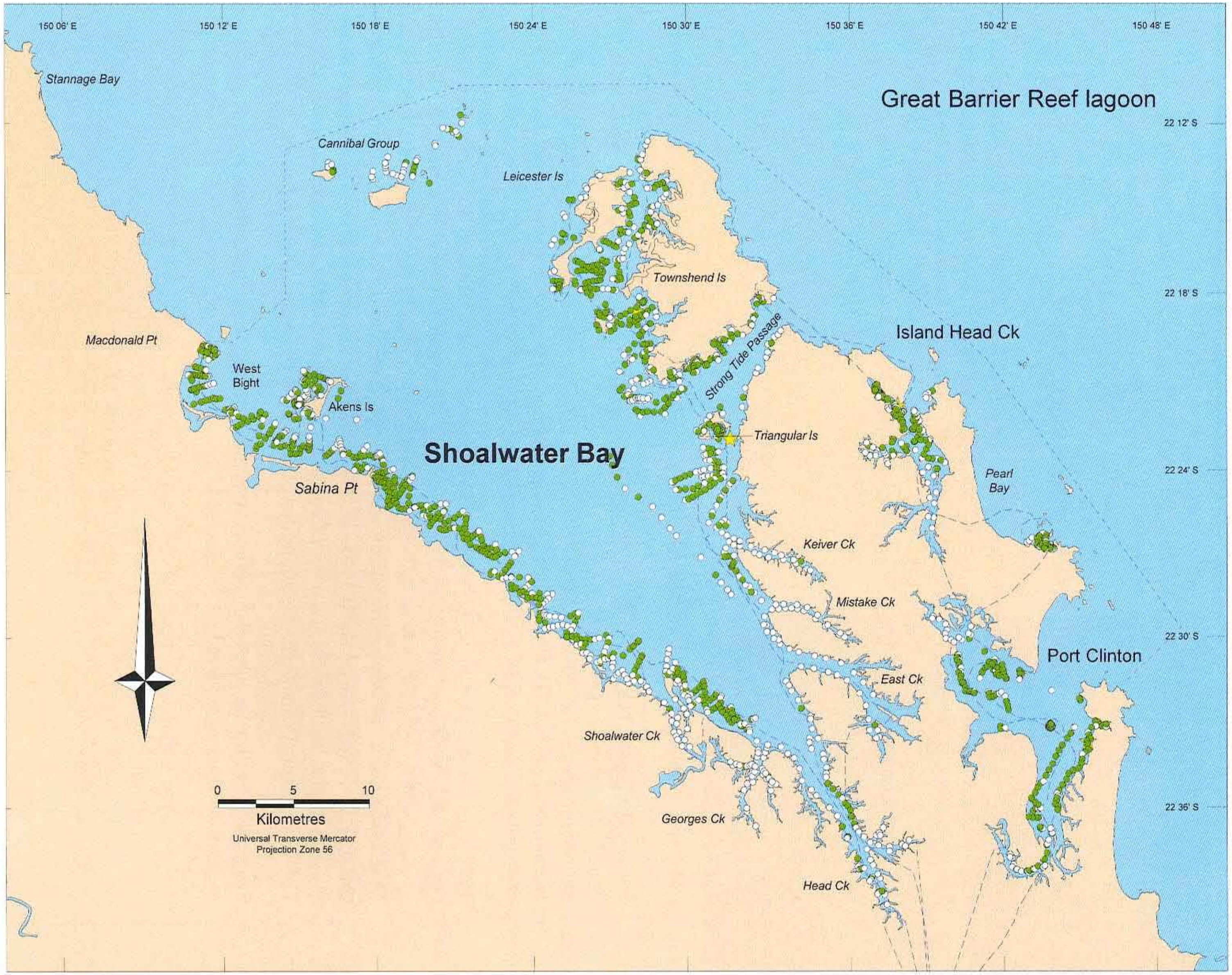
MAP 2.

Survey sites - April 1996.

Legend

- Seagrass
- No seagrass
- Survey boundary
- Helicopter flight path
- Beam trawl sites



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Survey Date: boat survey 3-11th April 1996, helicopter survey 18-19th March 1996.

Produced by the Seagrass Group, QDPI, Northern Fisheries Centre, Cairns, 1997

Funded by the Great Barrier Reef Marine Park Authority, the Queensland Department of Primary Industries and the Australian Cooperative Research Centres Program through the CRC for Ecologically Sustainable Development of the Great Barrier Reef.

↳RESULTS

Seagrass species, distribution and abundance

Eight species (from 3 families) of seagrasses were found in Shoalwater Bay surveys. A new, undescribed, *Halophila* species was collected in September 1995 from near Stannage Bay, north of the proposed Shoalwater Bay Marine Park area:

Family **ZOSTERACEAE** Dummortier
Zostera capricorni Aschers.

Family **CYMODOCEACEAE** Taylor
Cymodocea serrulata (R. Br.) Aschers. & Magnus
Halodule uninervis (wide & thin) (Forsk.) Aschers.
Halodule pinifolia (Miki) den Hartog
Syringodium isoetifolium (Aschers.) Dandy

Family **HYDROCHARITACEAE** Jussieu
Halophila decipiens Ostenfeld
Halophila ovalis (Br.) D.J. Hook.
Halophila spinulosa (R. Br.) Aschers. in Neumayer
Halophila sp. nov. (cf. *H. colesi*) (presently undescribed)

1068 sites were surveyed in September 1995 (Map 1) and 1799 sites in April 1996 (Map 2). Seagrass was present at 530 (49.6 %) of the sites in September 1995 and 992 sites (55.1 % of total) in April 1996. 13,076 ±800 ha of seagrass habitat was mapped in September 1995 between Macdonald Point (north-western Shoalwater Bay) and Port Clinton (south-east of Shoalwater Bay) (Maps 3, 5, 7, 9 & 11). In April 1996, 13,001 ±890 ha of seagrass habitat was mapped, although this survey also included the Cannibal Island group (north of Shoalwater Bay) (Maps 4, 6, 8, 10 & 12). The Cannibal Island group contributed 80 ±22 ha to the April 1996 total area.

Seagrass habitats were located on soft substrates, but mostly restricted to intertidal flats. Four main seagrass habitats were identified:

a) large continuous meadows on intertidal banks (dominated by either *Zostera capricorni* or *Halodule/Halophila*) comprised the majority of seagrass habitat (54 % of total area) (Maps 5 & 6);

b) patchy meadows restricted to drainage channels and pools on large intertidal banks in the southern section of the bay (*Zostera capricorni* or *Halodule/Halophila*) (21 % of total area);

c) meadows in narrow bands on creek banks in the southern section of the bay and inlets (dominated by *Zostera capricorni*, *Halodule uninervis* or *Halophila decipiens*) (Maps 9 & 10), and

d) subtidal meadows adjacent to the south-western corner of Townshend Island and in Canoe Passage (dominated by *Halophila ovalis* and *H. spinulosa*) (Maps 7 & 8).

Minor seagrass habitats included *Halophila decipiens* meadows in small areas or narrow bands in creeks (September 1995), and a sub-tidal meadow of *Zostera capricorni* and *Halophila ovalis* at Pearl Bay. *Syringodium isoetifolium* was found only at a few sites near Leicester Island.

The seagrass habitats in Shoalwater Bay were divided into 12 meadow types (seagrass communities), depending on species presence and dominance (Table 3). *Zostera capricorni* meadows were more numerous, more extensive and generally had a much higher above-ground biomass than other meadows.

Table 3. Mean above-ground biomass, number of individual meadows, and distribution for each seagrass meadow type identified in September 1995 and April 1996.

Meadow type	September 1995			April 1996		
	mean ±SE (range) (g DW m^{-2})	# meadows	Area (ha)	mean ±SE (range) (g DW m^{-2})	# meadows	Area (ha)
Cymodocea serrulata	5.11	1	1.0643	8.06 ±3.52 (1.20 - 12.85)	3	0.2901
Halodule pinifolia	-	-	-	4.81	1	0.04
Halodule uninervis	10.04 ±1.77 (1.59 - 30.33)	24	9.2343	4.60 ±0.68 (0.97 - 14.00)	27	11.1983
Halodule/Halophila	8.85 ±2.156 (0.01 - 29.73)	14	42.0676	5.22 ±0.57 (1.34 - 9.04)	16	42.6887
Halophila decipiens	3.95 ±0.78 (0.15 - 9.88)	16	0.8057	2.59 ±1.29 (0.65 - 5.04)	4	0.1338
Halophila ovalis	4.84 ±1.19 (0.01 - 15.25)	13	1.4391	3.11 ±0.59 (0.58 - 10.48)	25	2.627
Halophila spinulosa	4.99 ±0.89 (0.56 -8.50)	10	6.2279	2.60 ±0.47 (0.57 - 5.67)	13	4.8922
Halophila/Mixed	5.94 ±1.81 (0.99 - 9.71)	5	1.5736	2.96 ±1.32 (0.13 - 7.84)	5	1.6837
Halophila/Zostera	-	-	-	7.58	1	0.2608
Syringodium isoetifolium	-	-	-	0.41	1	0.0064
Zostera capricorni	14.84 ±1.22 (2.56 - 47.57)	90	64.7135	7.24 ±0.54 (0.26 - 20.60)	103	64.4598
Zostera/Mixed	9.62 ±1.56 (6.24 - 17.01)	7	3.6367	7.68 ±1.65 (3.63 - 12.37)	5	1.7253

Flowers or fruits were observed on most species throughout the survey area, but only in September 1995.

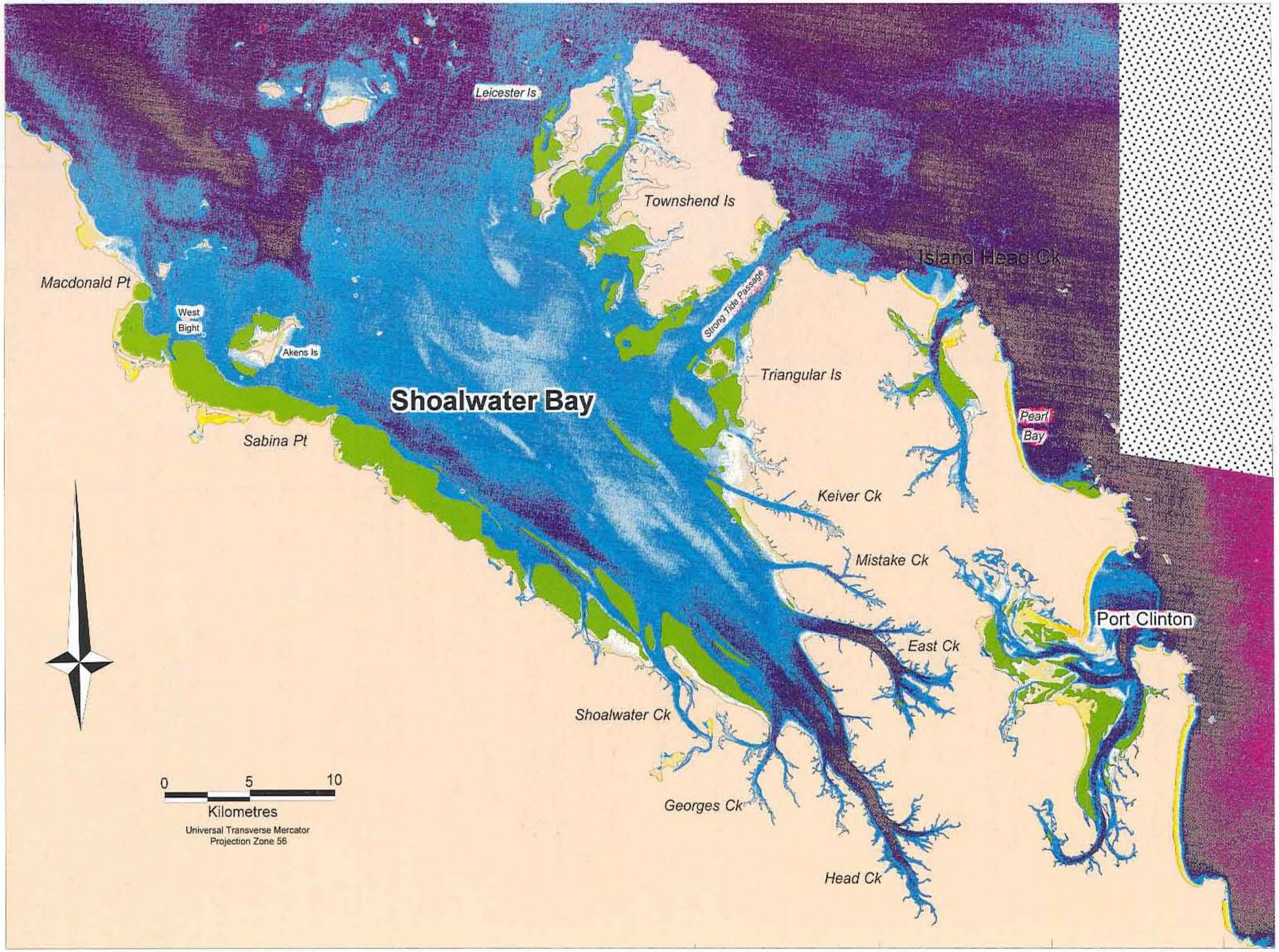
Mean above-ground biomasses were significantly higher in September 1995 than April 1996 for most meadow types, with the exception of *Cymodocea serrulata* (Figure 2, Table 3).

MAP 3.

Seagrass distribution - September 1995.

Legend

Seagrass



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Survey Date: boat survey 13-20th September 1995, helicopter survey 9-11th August 1995.

Produced by the Seagrass Group, QDPI, Northern Fisheries Centre, Cairns, 1997

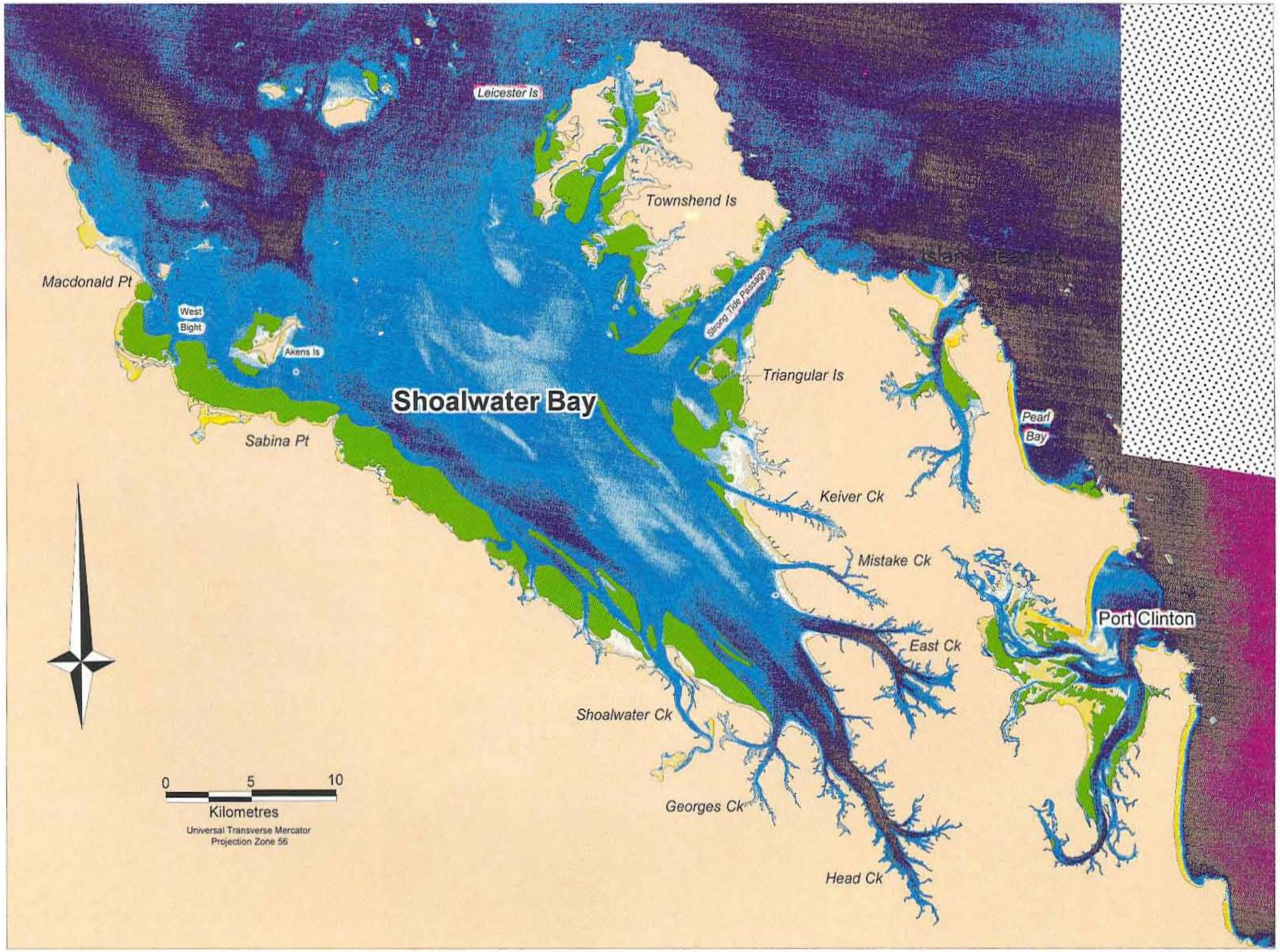
Funded by the Great Barrier Reef Marine Park Authority, the Queensland Department of Primary Industries and the Australian Cooperative Research Centres Program through the CRC for Ecologically Sustainable Development of the Great Barrier Reef.

MAP 4.

Seagrass distribution
- April 1996.

Legend

Seagrass



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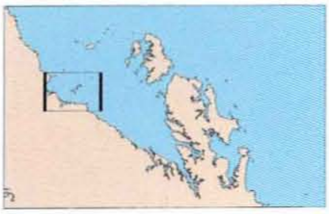
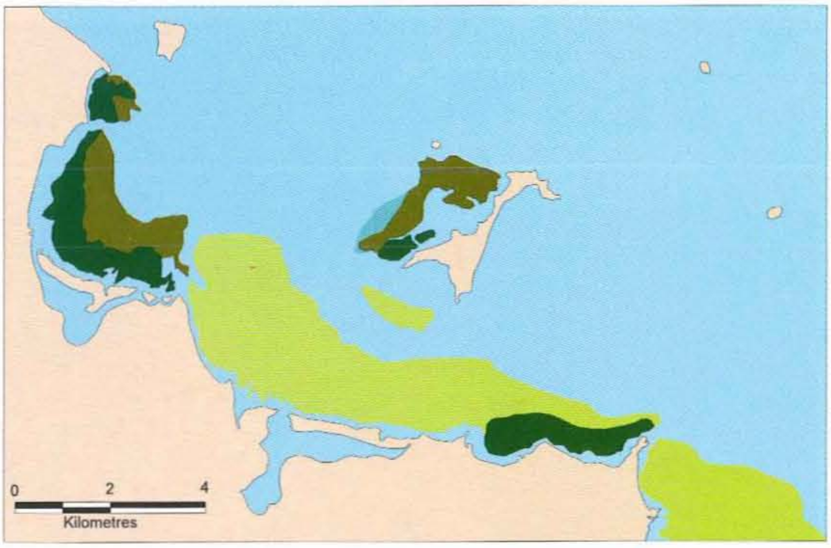
MAP 5.

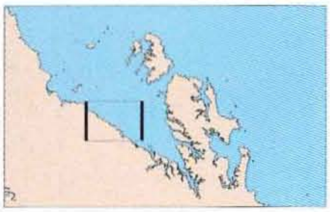
Seagrass distribution
- September 1995.

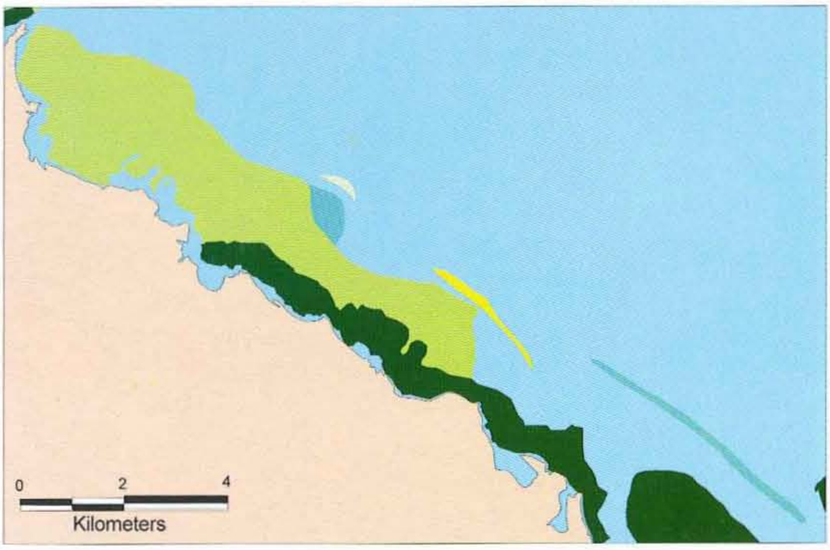
a. West Bight



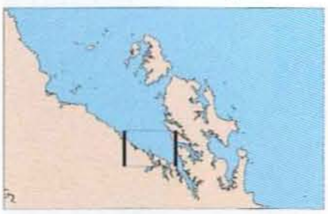


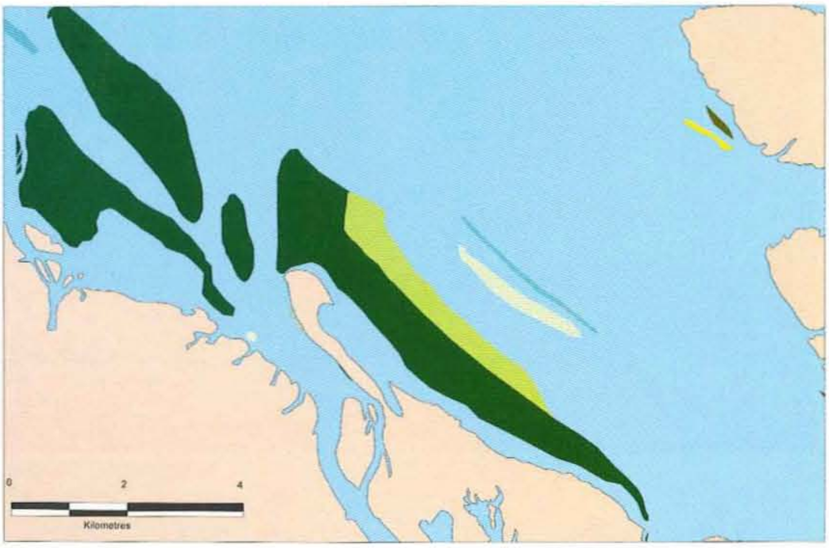
b. western bay





c. southern bay





Legend

Zostera capricorni	*Halodule/Halophila*	*Halophila decipiens*	*Halodule uninervis*
Zostera/Mixed	*Halophila/Mixed*	*Halophila ovalis*	*Halophila spinulosa*

Source: Lee Long, W.J., McKenzie, L.J. and Coles, R.G. (1997) Seagrass communities in the Shoalwater Bay region, Queensland - Spring (September) 1995 & Autumn (April) 1996. QDPI Information Series QI96042 (QDPI,Brisbane) 38pp.

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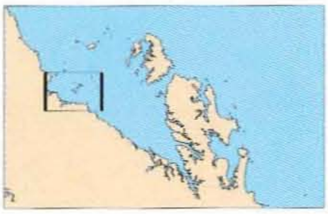
Survey Date: boat survey 13-20th September 1995, helicopter survey 9-11th August 1995.

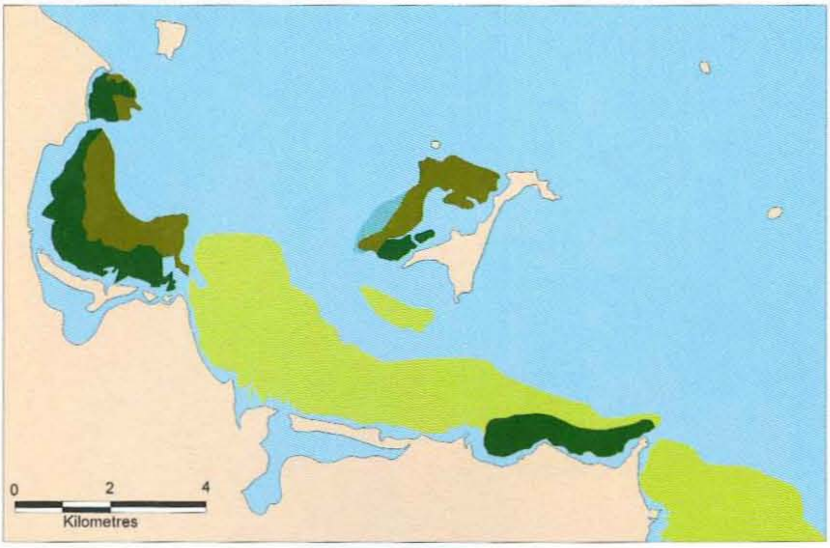
Produced by the Seagrass Group, QDPI, Northern Fisheries Centre, Cairns, 1997

MAP 6.

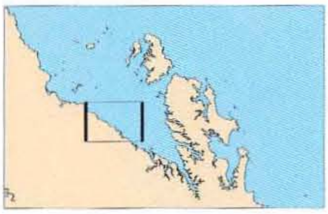
Seagrass distribution
- April 1996.

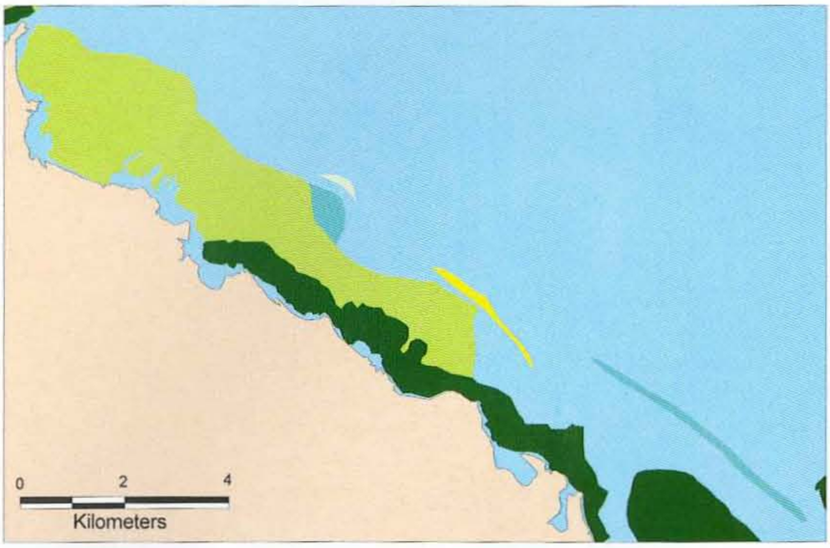
a. West Bight



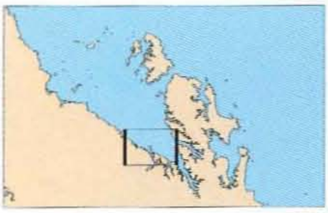


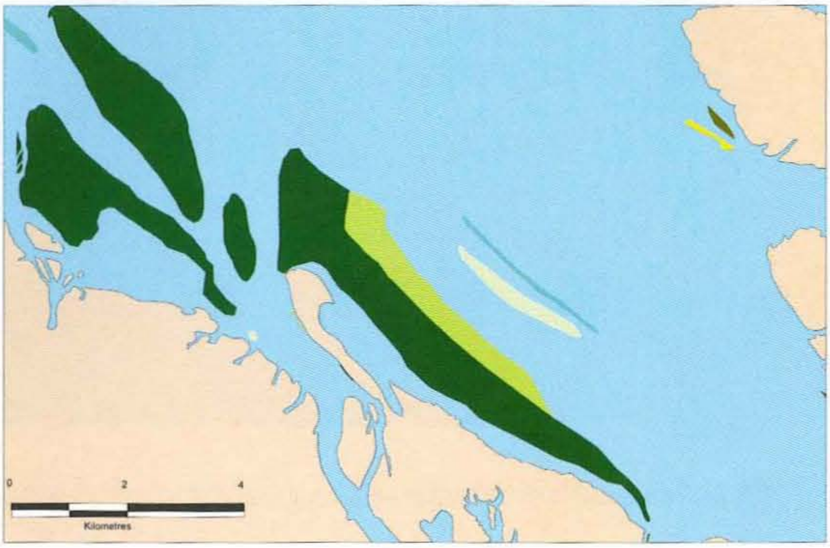
b. western bay





c. southern bay





Legend

Zostera capricorni	*Halodule/Halophila*	*Halophila decipiens*	*Halodule uninervis*
Zostera/Mixed	*Halophila/Mixed*	*Halophila ovalis*	*Halophila spinulosa*

Source: Lee Long, W.J., McKenzie, L.J. and Coles, R.G. (1997) Seagrass communities in the Shoalwater Bay region, Queensland - Spring (September) 1995 & Autumn (April) 1996. QDPI Information Series QI96042 (QDPI,Brisbane) 38pp.

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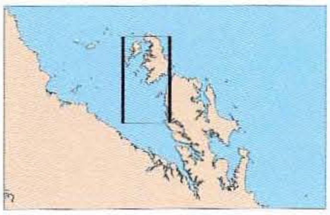
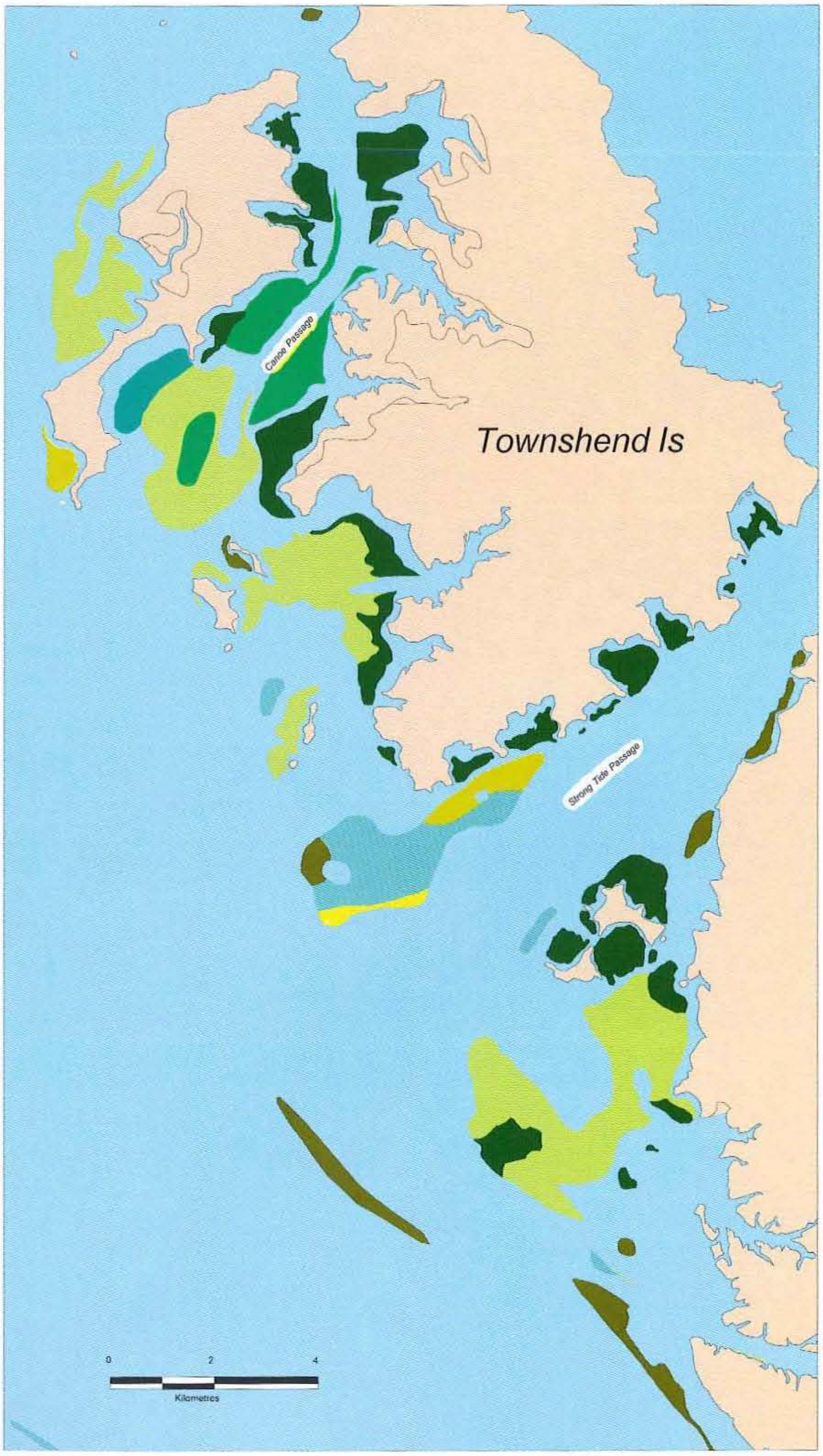
Survey Date: boat survey 3-11th April 1996, helicopter survey 18-19th March 1996.

Produced by the Seagrass Group, QDPI, Northern Fisheries Centre, Cairns, 1997

MAP 7.

Seagrass distribution
- September 1995.





Legend

Zostera capricorni	*Halodule/Halophila*	*Halophila decipiens*
Zostera/Mixed	*Halophila/Mixed*	*Halophila ovalis*
Halodule uninervis	*Halophila spinulosa*	*Cymodocea serrulata*

Source: Lee Long, W.J., McKenzie, L.J. and Coles, R.G. (1997) Seagrass communities in the Shoalwater Bay region, Queensland - Spring (September) 1995 & Autumn (April) 1996. QDPI Information Series QI96042 (QDPI,Brisbane) 38pp.

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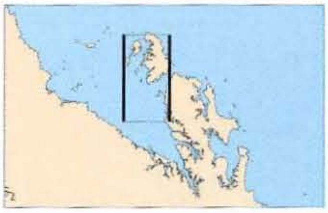
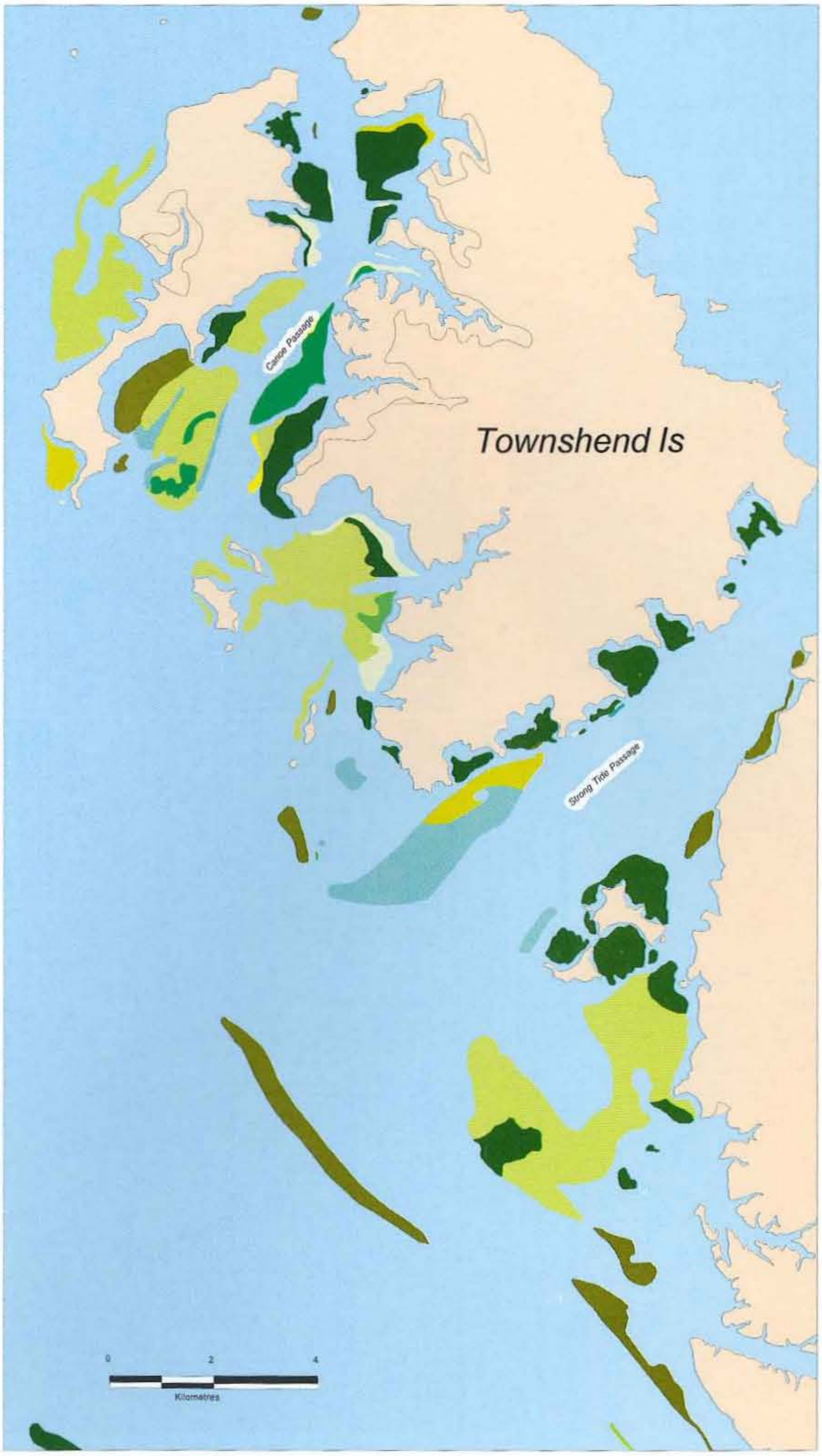
Survey Date: boat survey 13-20th September 1995, helicopter survey 9-11th August 1995.

Produced by the Seagrass Group, QDPI, Northern Fisheries Centre, Cairns, 1997

MAP 8.

Seagrass distribution
- April 1996.





Legend

- *Zostera capricorni*
- *Zostera/Mixed*
- *Halodule uninervis*
- *Halodule/Halophila*
- *Halophila/Mixed*
- *Halophila spinulosa*
- *Halophila decipiens*
- *Halophila ovalis*
- *Cymodocea serrulata*

Source: Lee Long, W.J., McKenzie, L.J. and Coles, R.G. (1997) Seagrass communities in the Shoalwater Bay region, Queensland - Spring (September) 1995 & Autumn (April) 1996. QDPI Information Series QI96042 (QDPI,Brisbane) 38pp.

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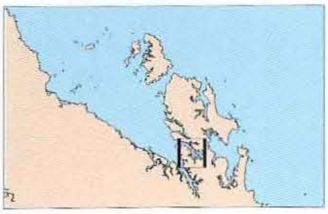
Survey Date: boat survey 3-11th April 1996, helicopter survey 18-19th March 1996.

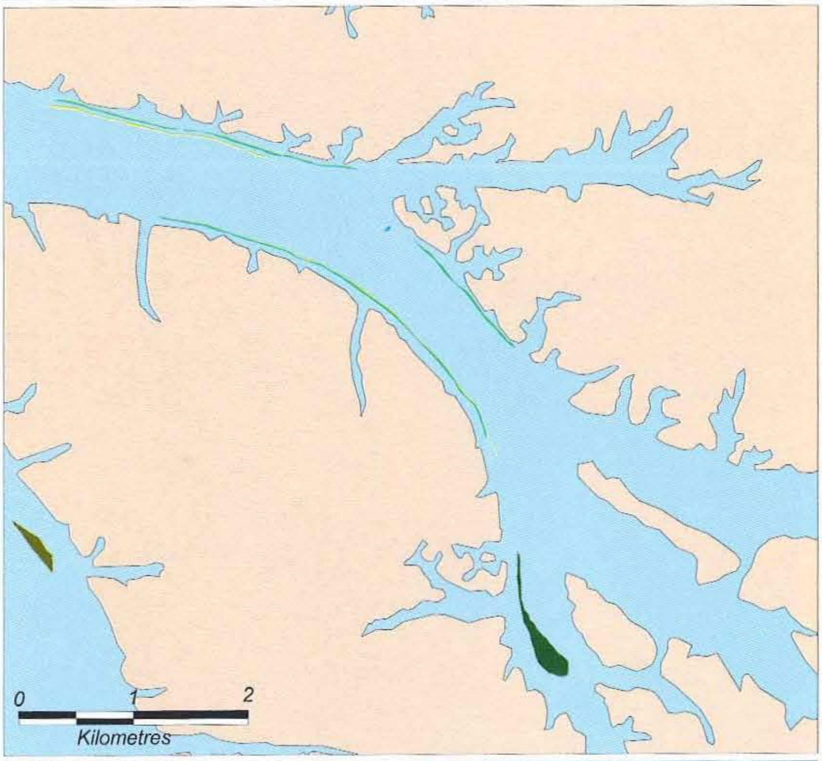
Produced by the Seagrass Group, QDPI, Northern Fisheries Centre, Cairns, 1997

MAP 9.

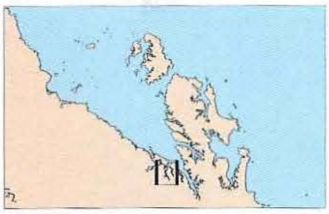
Seagrass distribution
- September 1995.

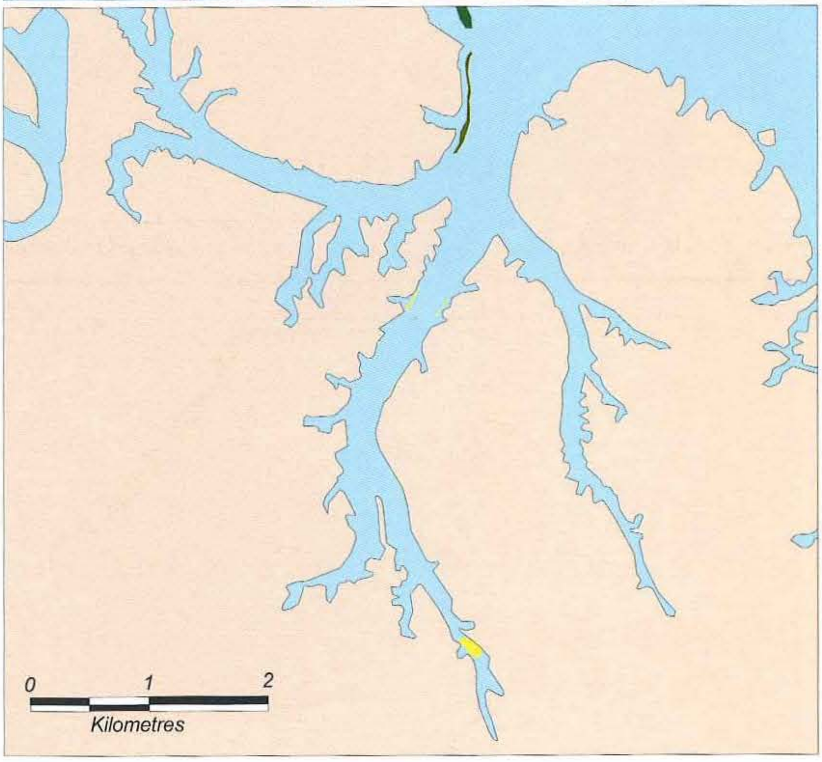
a. East Creek





b. Georges Creek





Legend

Zostera capricorni	*Halophila decipiens*
Zostera/Mixed	*Halodule uninervis*

Source: Lee Long, W.J., McKenzie, L.J. and Coles, R.G. (1997) Seagrass communities in the Shoalwater Bay region, Queensland - Spring (September) 1995 & Autumn (April) 1996. QDPI Information Series QI96042 (QDPI,Brisbane) 38pp.

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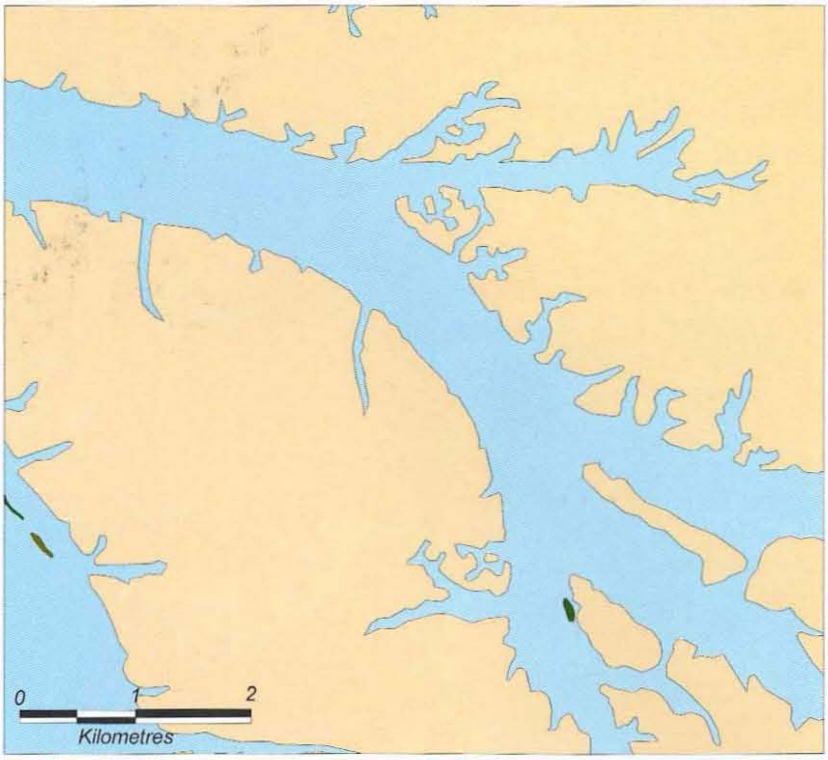
Survey Date: boat survey13-20th September 1995, helicopter survey 9-11th August 1995.

Produced by the Seagrass Group, QDPI, Northern Fisheries Centre, Cairns, 1997

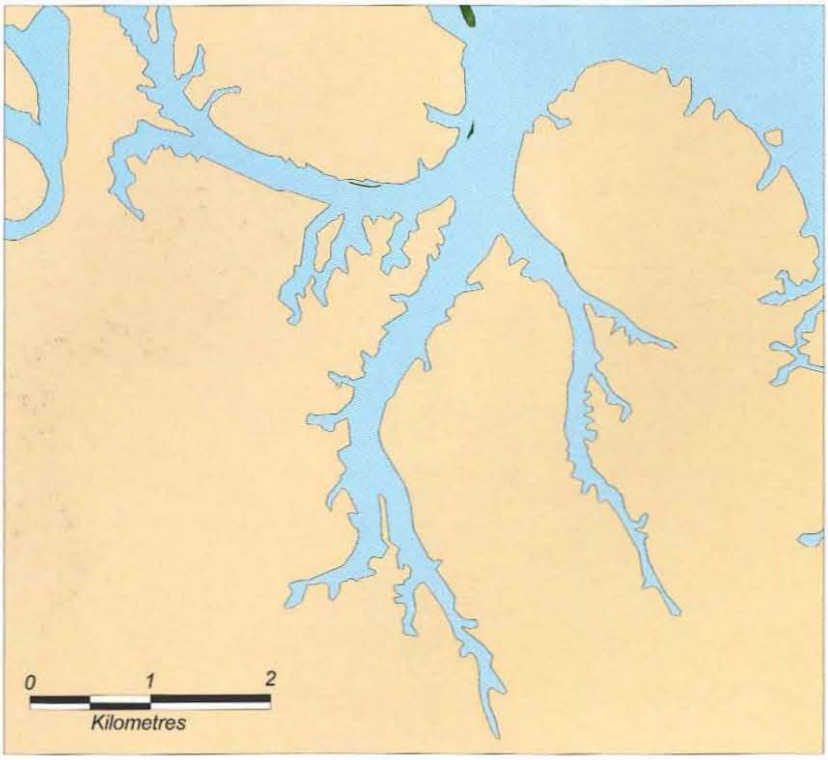
MAP 10.

Seagrass distribution
- April 1996.

a. East Creek



b. Georges Creek



Legend

Zostera capricorni

Halophila decipiens

Zostera/Mixed

Halodule uninervis

Source: Lee Long, W.J., McKenzie, L.J. and Coles, R.G. (1997) Seagrass communities in the Shoalwater Bay region, Queensland - Spring (September) 1995 & Autumn (April) 1996. QDPI Information Series QI96042 (QDPI,Brisbane) 38pp.

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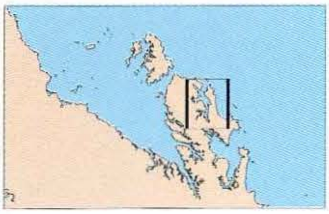
Survey Date: boat survey 3-11th April 1996, helicopter survey 18-19th March 1996.

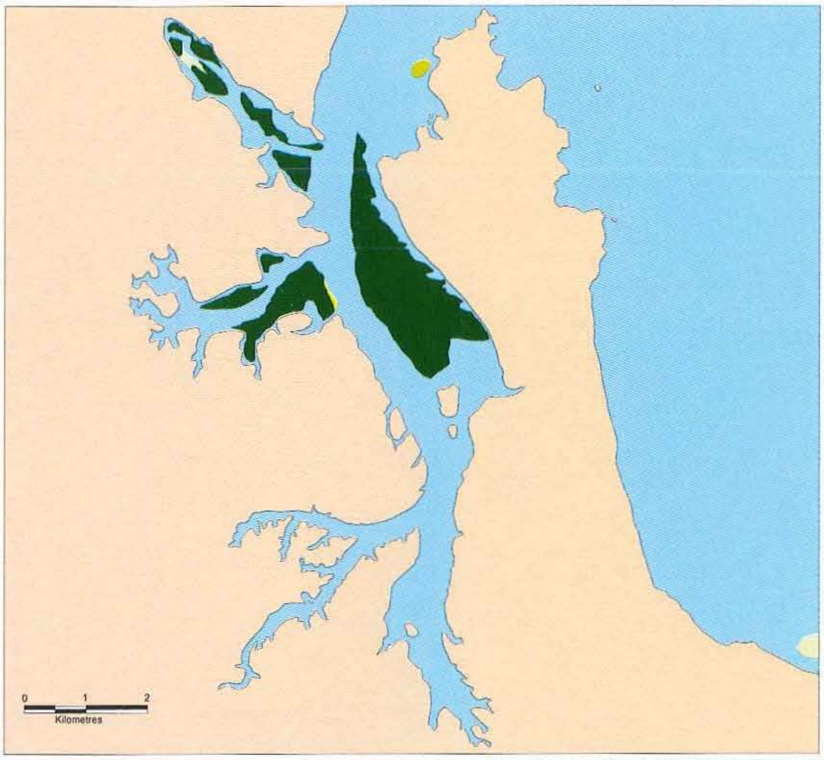
Produced by the Seagrass Group, QDPI, Northern Fisheries Centre, Cairns, 1997

MAP 11.

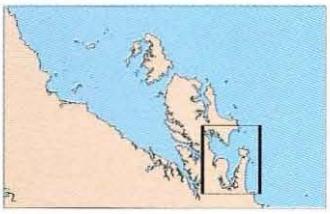
Seagrass distribution
- September 1995.

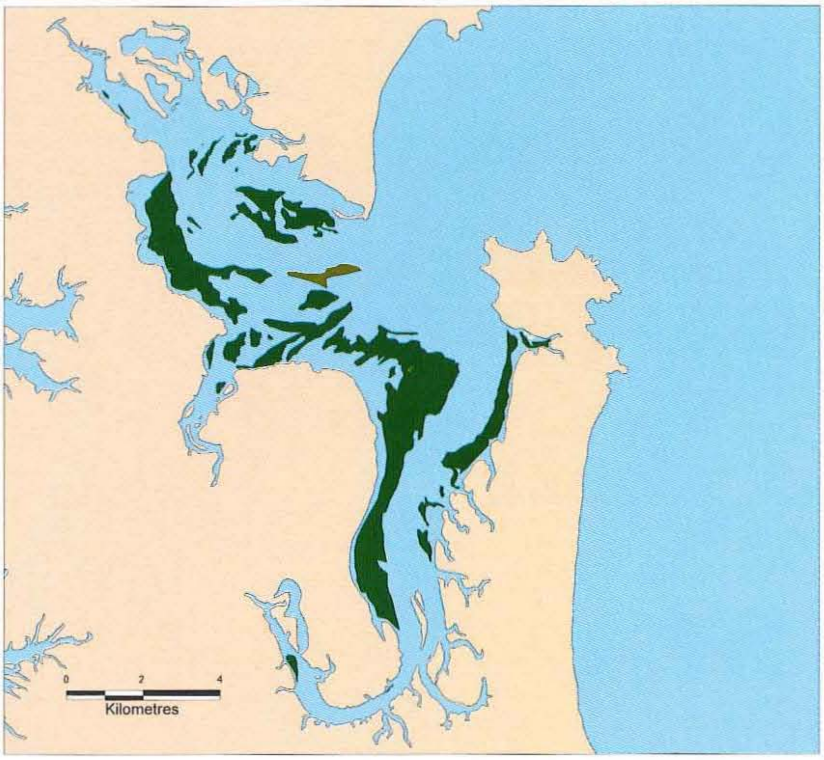
a. Island Head Creek





b. Port Clinton





Legend

- *Zostera capricorni*
- *Halophila/Mixed*
- *Halophila ovalis*
- *Halodule uninervis*
- *Halophila decipiens*

Source: Lee Long, W.J., McKenzie, L.J. and Coles, R.G. (1997) Seagrass communities in the Shoalwater Bay region, Queensland - Spring (September) 1995 & Autumn (April) 1996. QDPI Information Series QI96042 (QDPI,Brisbane) 38pp.

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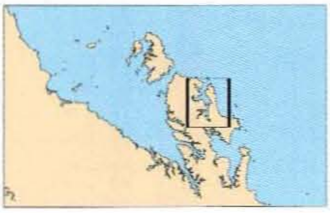
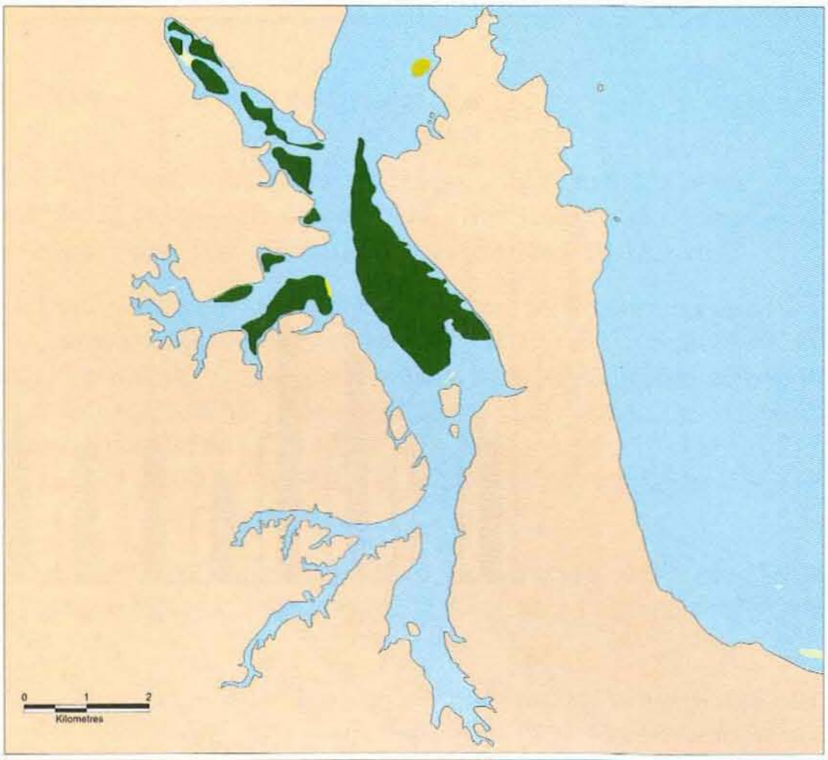
Produced by the Seagrass Group, QDPI, Northern Fisheries Centre, Cairns, 1997

MAP 12.

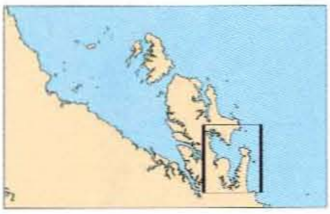
Seagrass distribution
- April 1996.

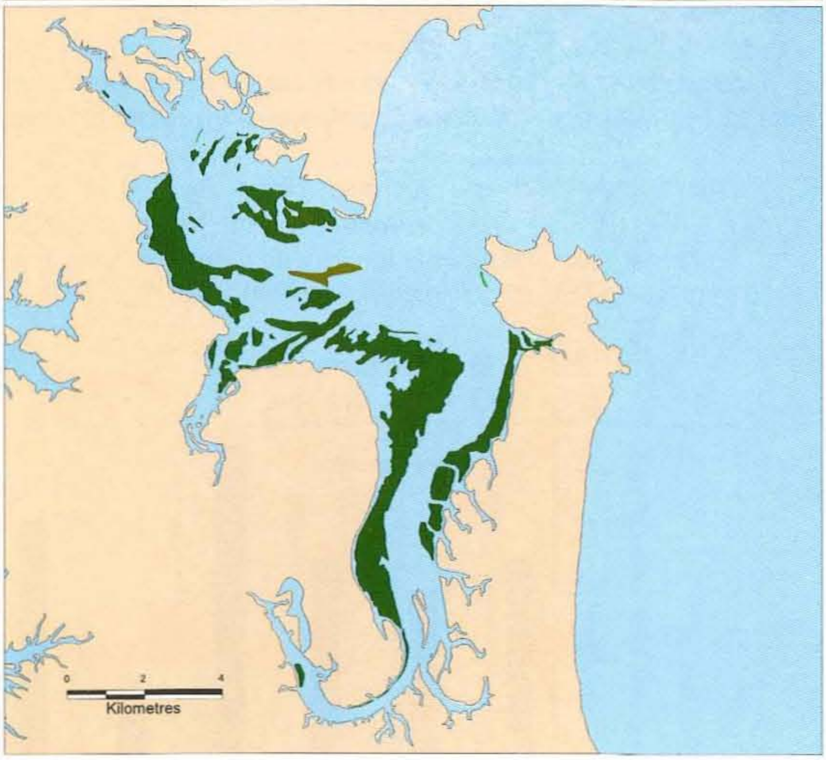
a. Island Head Creek





b. Port Clinton





Legend

- *Zostera capricorni*
- *Halophila/Mixed*
- *Halophila ovalis*
- *Halodule uninervis*
- *Halophila decipiens*

Source: Lee Long, W.J., McKenzie, L.J. and Coles, R.G. (1997) Seagrass communities in the Shoalwater Bay region, Queensland - Spring (September) 1995 & Autumn (April) 1996. QDPI Information Series QI96042 (QDPI,Brisbane) 38pp.

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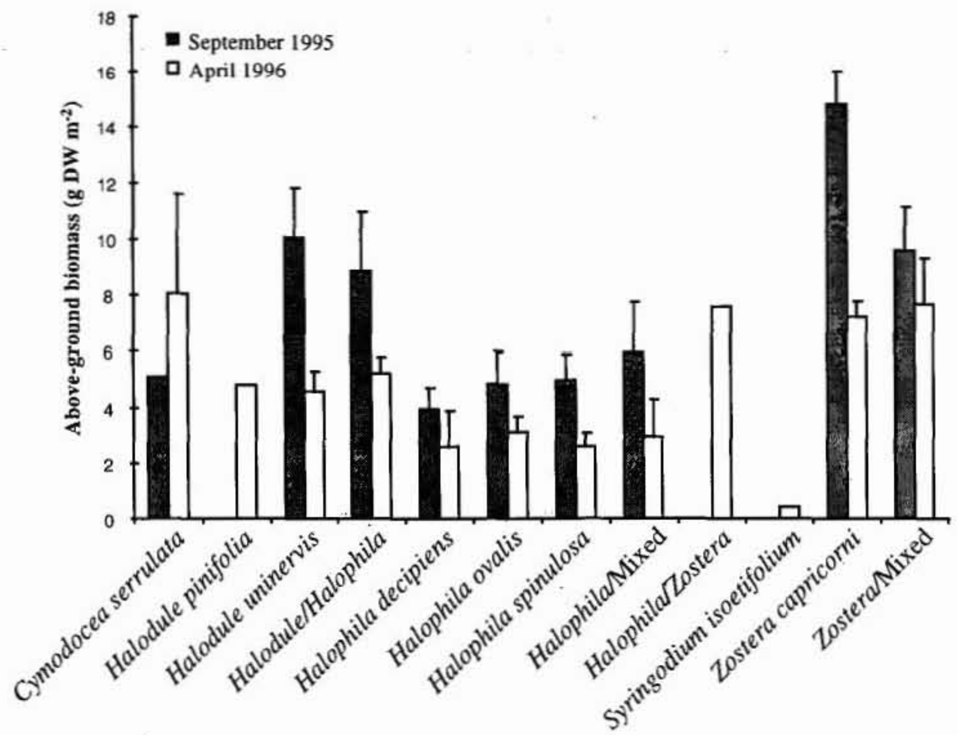


Figure 2. Above-ground biomass for each meadow type in September 1995 and April 1996 *(mean and +standard error displayed)*

Above-ground seagrass biomass varied from 0.04 g DW. m^{-2} (*Halodule/Halophila*) to 106.42 g DW. m^{-2} (*Zostera capricorni*) in September 1995. In April 1996, above-ground biomasses were significantly lower (with the exception of *Syringodium isoetifolium*) and ranged from 0.02 g DW. m^{-2} (*Halodule/Halophila*) to 25.48 g DW. m^{-2} (*Zostera capricorni*).

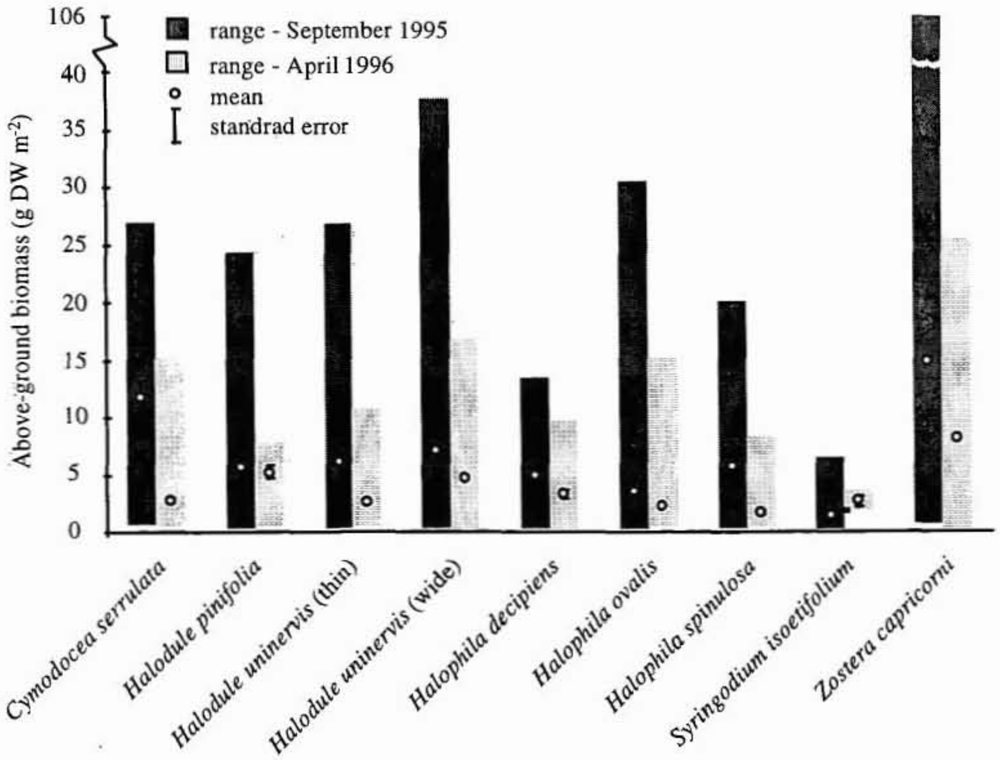


Figure 3. Mean and range of above-ground biomass for each seagrass species in the survey area (all sites pooled) in September 1995 and April 1996

Seagrass depth distribution

Seagrasses in Shoalwater Bay were found at depths from 0.7 m above MSL to 8.2 m below MSL in September 1995 and to only 6.5 m below MSL in April 1996. Most seagrass species occurred over large depth ranges and only a few species had restricted depth distributions (Figure 4).

In Shoalwater Bay, Island Head Creek and Port Clinton, *Zostera capricorni* occurred on intertidal flats (mean=1.5 ±0.1 m below MSL in September 1995 and 0.5 ±0.1 m below MSL in April 1996) and occasionally found down to 5.0 m below MSL in September 1995 (in April 1996 the deepest site was 3.7 m below MSL). At Pearl Bay, on a sand substrate and in good water clarity, *Zostera capricorni* occurred to 5.9 m below MSL in September 1995 and 5.5 m below MSL in April 1996 (mean=4.2 ±0.2 m and 4.2 ±0.2 m below MSL for September and April, respectively).

Halophila ovalis had the widest depth distribution range of all species found, maximum=7.6 m off Leicester Island and 6.2 m below MSL in Canoe Passage, in September 1995 and April 1996 respectively.

Halophila spinulosa and *Halophila decipiens* had the deepest mean depths of all species and occurred mostly sub-tidally in both surveys (Figure 4). In September 1995 *Halophila decipiens* was found at the deepest site where seagrass was present, 8.2 m below MSL at Leicester Island, however in April 1996 *Halophila spinulosa* was the deepest occurring species, at 6.5 m below MSL in Canoe Pass. *Cymodocea serrulata* had the most restricted depth distribution in September 1995 (<3.5 m range), however *Halophila decipiens* was the most restricted in April 1996 (<2.3 m range).

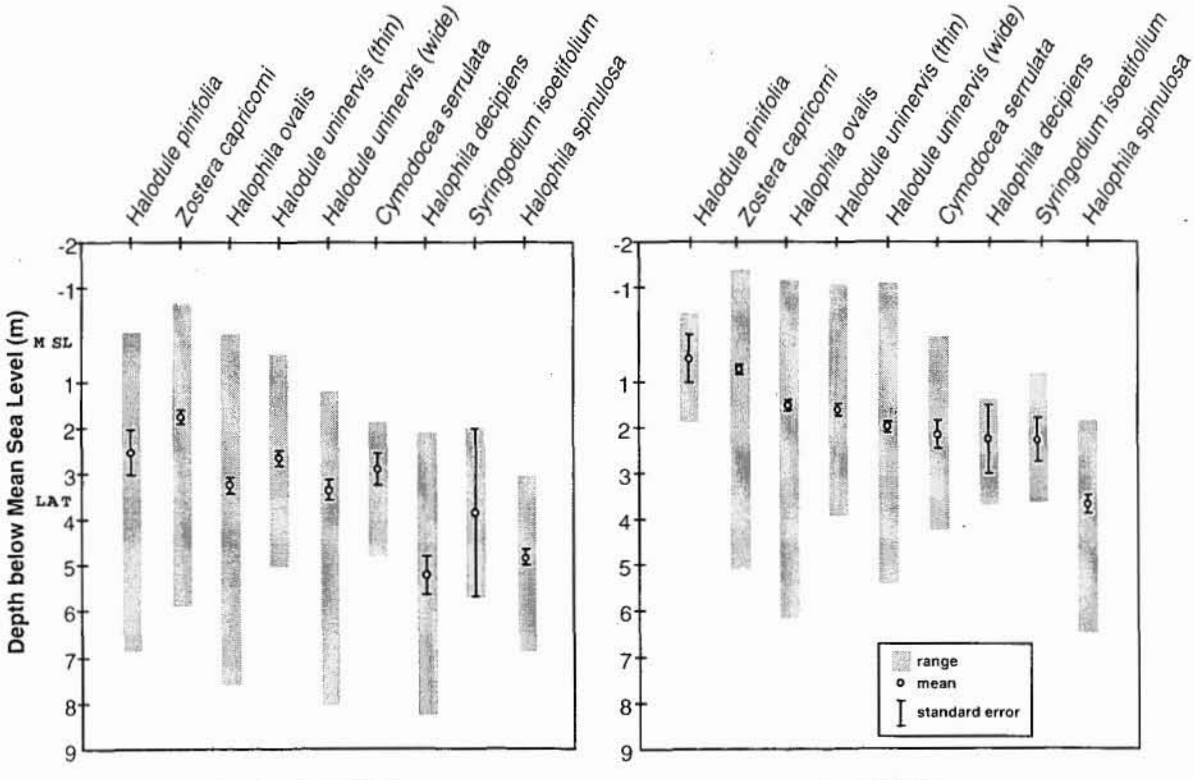


Figure 4. Means, standard errors and ranges of depth of occurrence for each seagrass species of Shoalwater Bay (MSL = Mean Sea Level, LAT = Lowest Astronomical Tide) *(Statistics calculated using only survey sites from transects which ran from shore to the seaward edge of meadows).*

Seagrass monitoring

Seven sites within seagrass meadows, which represented the major seagrass habitats found in the survey area, were identified as sites which could be used for future monitoring of seagrass abundance and distribution in spring (per wet-season). Measures of precision for the monitoring meadows were all «0.1 (Table 4).

Table 4. Number of sites sampled, mean above-ground biomass, precision and distribution of each monitoring meadow in Shoalwater Bay - September 1995.
Asterisks = site 200 m radius within meadow

Description	Meadow ID	Species	# sites present	Mean biomass ($\bar{x}$ ±SE) (g dry wt. m^{-2})	Precision ($SE/\bar{x}$)	Distribution (ha)
Aiken Island - intertidal	9	*Zostera capricorni*	20	15.09 ±0.90	0.06	7.3 ±0.9
Aiken Island - subtidal	12	*Halodule/Halophila*	20	7.90 ±0.49	0.062	68.3 ±12.3
Hideaway Bay	72	*Zostera capricorni*	46	8.43 ±0.51	0.061	77.7 ±2.8
Townshend Island	83	*Zostera capricorni*	43	15.64 ±0.59	0.038	37.1 ±2.7
Strongtide Passage	85+86	*Halophila*/Mixed	25	8.97 ±0.54	0.061	469.2 ±43.1
Strongtide Passage	86	*Halophila spinulosa*	11	9.71 ±0.79	0.081	365.9 ±36.6
Port Clinton	152	*Zostera capricorni*	27	22.11 ±0.82	0.037	25.1*

Six sites within seagrass meadows were identified as sites which could be used for future monitoring of seagrass abundance and distribution in autumn (post wet-season). Five of these sites were similar to those chosen in the spring survey. Measures of precision for the monitoring meadows were all <0.2 (Table 5).

Table 5. Number of sites sampled, mean above-ground biomass, precision and distribution of each monitoring meadow in Shoalwater Bay - April 1996.
Asterisks = site 150 m radius within meadow

Description	Meadow ID	Species	# sites present	Mean biomass ($\bar{x}$ ±SE) (g dry wt. m^{-2})	Precision ($SE/\bar{x}$)	Distribution (ha)
Aiken Island - intertidal	8	*Zostera capricorni*	33	7.18 ±0.34	0.05	36.2 ±7.9
Hideaway Bay	72	*Zostera capricorni*	24	4.28 ±0.33	0.08	78.1 ±2.0
Townshend Island	83	*Zostera capricorni*	28	8.26 ±0.58	0.07	36.5 ±2.7
Strongtide Passage	85+86	*Halophila*/Mixed	21	0.85 ±0.12	0.14	394.5 ±35.1
Strongtide Passage	86	*Halophila spinulosa*	17	0.70 ±0.11	0.16	300.6 ±30.0
Port Clinton	152	*Zostera capricorni*	50	13.32 ±0.54	0.04	14.1*

Associated Macrofauna

Invertebrates

Penaeid prawns

2909 and 2721 individual juvenile or sub-adult penaeid prawns were collected in September 1995 and April 1996 respectively. The total abundance of penaeid prawns was different between beam trawl sites. Penaeids were most abundant in samples from Island Head Creek and Port Clinton in both September and April (Figure 5).

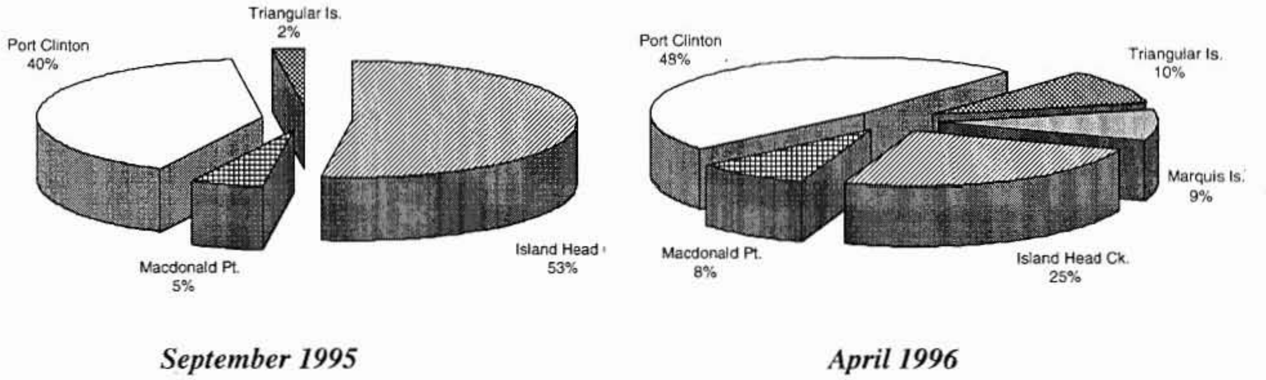


Figure 5. Percentage of total individual penaeids collected at each beam trawl site in September 1995 and April 1996.

Penaeid abundances in Shoalwater Bay and Port Clinton were not significant different between years (Appendix 2, Table 9). Island Head Creek had significantly higher abundances in September 1995 than in April 1996 (T-test, T=3.62; d.f.=5; P=0.02) (Figure 6).

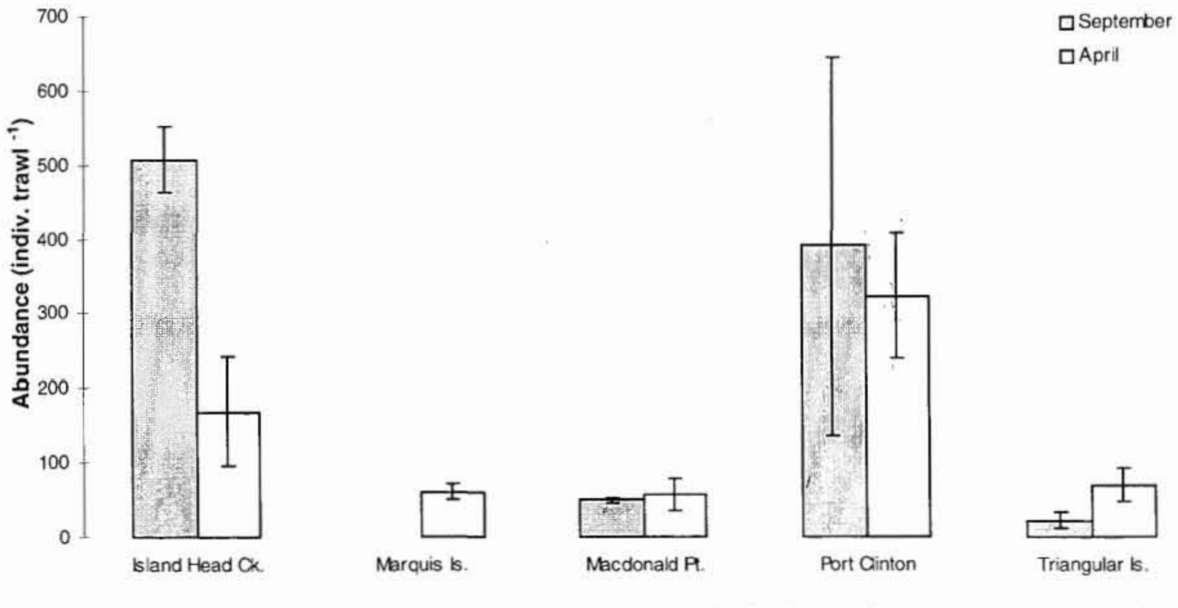


Figure 6. Abundance of penaeid prawns at each trawl site in September 1995 and April 1996 *(mean and standard error displayed)*.

10 species of penaeid prawn were identified from beam trawls in September 1995 and 16 species from April 1996 (Table 6). Although the number of species was not significantly different between sites each year, there were significantly more species in April 1996 than September 1995 (Appendix 2, Table 10). The additional species collected in April 1996 were mainly of the genera *Penaeus* (king, banana and tiger prawns) and *Metapenaeopsis* (coral prawns).

Table 6. Species, fishery code, carapace length and abundance of penaeid prawn species collected by beam trawl from Shoalwater Bay - September 1995 and April 1996.

Value codes: IV, important to north-eastern prawn fishery; III, component of fishery; II, minor to insignificant importance; I, no importance to fishery.

Species	Common name	Fishery code	September 1995		April 1996	
			mean CL ±SE (min - max)	n (%)	mean CL ±SE (min - max)	n (%)
Metapenaeopsis lamellata (de Haan)	Hunchback prawn	I	*absent*		3.88 ±0.08 (3.8 - 3.95)	2 (0.10)
Metapenaeopsis novaeguineae (Haswell)	Coral prawn	II	6.80 ±0.32 (5.1 - 8.2)	8 (0.28)	5.40 ±0.38 (3.05 - 9.9)	27 (1.36)
Metapenaeopsis palmensis (Haswell)	Southern velvet prawn	I	7.3	1 (0.03)	4.95	1 (0.05)
Metapenaeopsis rosea Racek & Dall	Rosy prawn	I	*absent*		8.81 ±0.34 (7.8 - 9.25)	4 (0.20)
Metapenaeus bennettae Racek and Dall	Greasyback prawn	I	13.3	1 (0.03)	11.13 ±1.37 (5.3 - 14.3)	6 (0.30)
Metapenaeus burkenroadi	School prawn	I	11.65 ±1.05 (10.6 - 12.7)	2 (0.07)	*absent*	
Metapenaeus endeavouri (Schmitt)	True endeavour prawn	IV	8.63 ±0.14 (4.2 - 14.0)	128 (4.40)	6.16 ±0.06 (1.6 - 26.1)	970 (48.72)
Metapenaeus ensis (de Haan)	Red endeavour prawn	IV	15.25 ±0.25 (15 - 15.5)	2 (0.07)	8.80 ±0.92 (4.82 - 17.8)	15 (0.75)
Penaeus esculentus Haswell	Brown tiger prawn	IV	5.03 ±1.51 (2.6 - 7.8)	3 (0.10)	8.19 ±0.55 (3.5 - 17.05)	48 (2.41)
Penaeus indicus Milne Edwards	Red legged banana prawn	II	*absent*		5.28 ±0.53 (3.25 - 8.85)	10 (0.50)
Penaeus latisulcatus Kishinouye	Western king prawn	IV	7.67 ±0.05 (2.3 - 17.1)	2756 (94.84)	5.05 ±0.09 (2.65 - 8.45)	160 (8.04)
Penaeus longistylus Kubo	Red spot king prawn	IV	*absent*		5.92 ±0.49 (4.05 - 21.8)	16 (0.80)
Penaeus merguiensis de Man	Banana prawn	IV	*absent*		20.99 ±0.82 (20.17 - 21.8)	2 (0.10)
Penaeus monodon Fabricus	Leader prawn	IV	*absent*		7.08 ±1.18 (3.95 - 11.3)	7 (0.35)
Penaeus semisulcatus de Haan	Grooved tiger prawn	IV	*absent*		8.04 ±1.45 (5.5 - 11.4)	4 (0.20)
Trachypenaeus curvirostrus (Stimpson)	Southern rough prawn	II	*absent*		9.1	1 (0.05)
Trachypenaeus fulvus Dall	Brown rough prawn	II	14.7	1 (0.03)	5.22 ±0.88 (3.5 - 6.4)	3 (0.15)
Trachypenaeus granulosus (Haswell)	Hardback prawn	II	8.10 ±0.38 (7.5 - 9.2)	4 (0.14)	*absent*	
Unidentified juvenile		-			4.38 ±0.09 (1.6 - 9.75)	210 (10.55)
Unidentified post-larvae		-			2.47 ±0.02 (0.75 - 4.3)	505 (25.36)
TOTAL			**7.73 ±2.67 (2.3 - 17.1)**	**2909**	**4.87 ±2.31 (0.75 - 26.1)**	**2721**

In September 1995 most species were *Metapenaeus* (4 species). In April 1996, the most diverse genus was *Penaeus* (7 species)

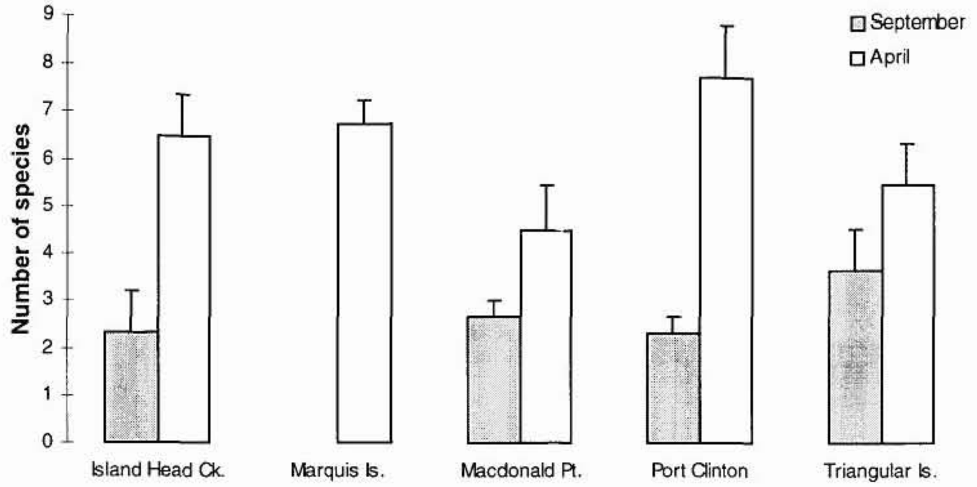


Figure 7. Number of species present at each site in September 1995 and April 1996
(means and standard error displayed)

The most abundant species collected in September 1995 was the Western king prawn *(Penaeus latisulcatus)* (94.8% of catch) (Figure 8). In April 1996, the most abundant species was the true endeavour prawn (*Metapenaeus endeavouri*) (48.7% of catch). Unidentified postlarvae were the largest proportion of catches, especially in Island Head Creek and at Macdonald Point in April 1996.

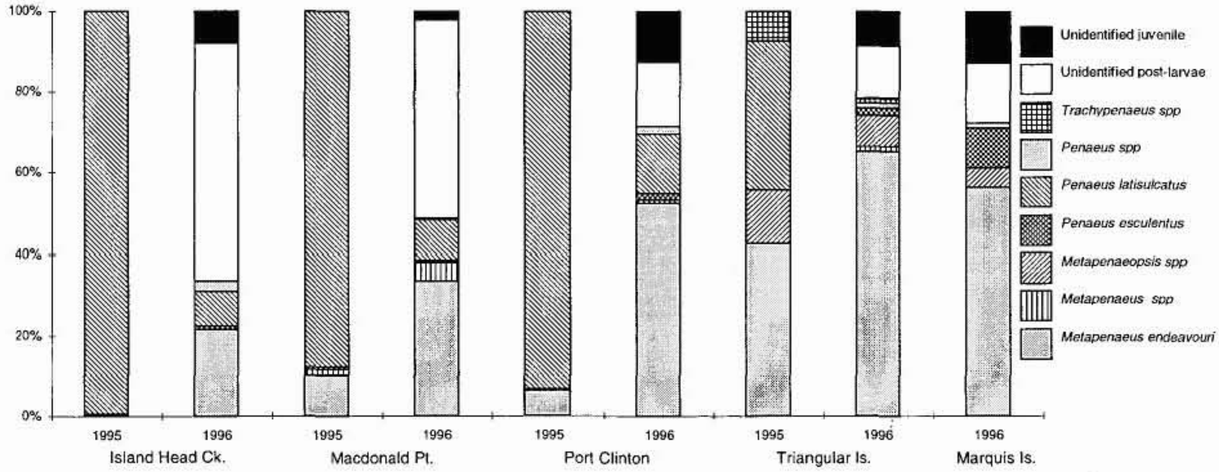
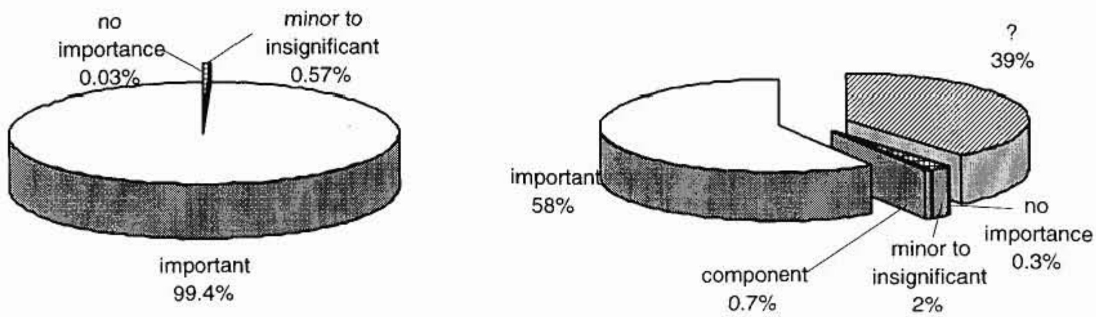


Figure 8. Percent species composition of penaeid prawns at each trawl site.

Penaeid species of commercial importance were numerically the most abundant prawn species in beam trawls (all sites pooled) (Figure 9).



September 1995

April 1996

Figure 9. Composition of fishery value for penaeids collected from beam trawls in September 1995 and April 1996 (all sites pooled).

Trawl sites at Island Head Creek and Port Clinton contained only species of commercial importance in September 1995, although in April 1996 unidentified post-larvae and juveniles were also abundant. Sites within Shoalwater Bay proper (Macdonald Point and Triangular Island) had a small percentage of individuals which were of minor/no commercial importance in September 1995, although commercially important individuals still continued to be the largest proportion of the catch in April 1996 (incl. Marquis Island) (Figure 10).

The Western king prawn *(Penaeus latisulcatus)* was the most common species of commercially important penaeids in September 1995, although the true endeavour prawn *(Metapenaeus endeavouri)* was the most abundant species in April 1996. The brown tiger prawn *(Penaeus esculentus)* and red endeavour prawn *(Metapenaeus ensis)* were common in both surveys.

Overall, penaeids contributed the greatest percentage to invertebrate biomass in both September 1995 and April 1996.

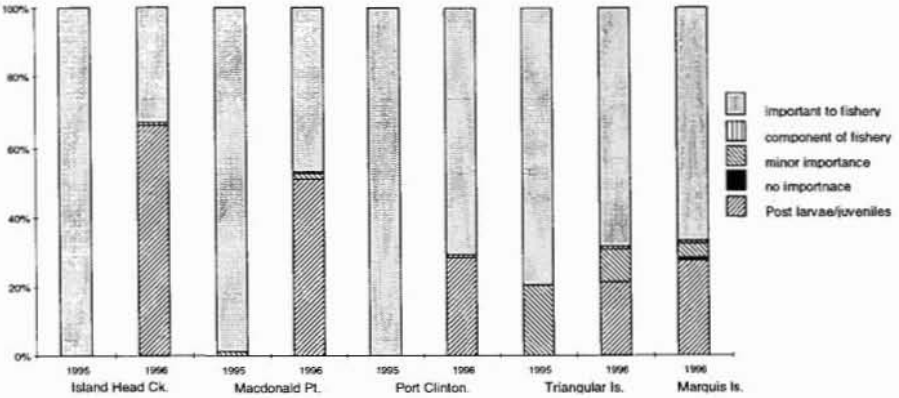


Figure 10. Percent fishery value composition of penaeids at each trawl site in September 1995 and April 1996.

Other invertebrates

Miscellaneous crustaceans (primarily caridean shrimps) were more abundant at Triangular Island and Macdonald Point sites in September 1995 (Figure 11). As no faunal counts were conducted for the April 1996 survey, no comparisons were possible between surveys. Crabs, squid and cuttlefish were collected only at Triangular Island and Macdonald Point trawl sites in September 1995, although no crabs were collected at Macdonald Point or Island Head Creek in April 1996. Other invertebrate fauna contributed between 1.4 - 67.3 % to the overall invertebrate biomass at trawl sites.

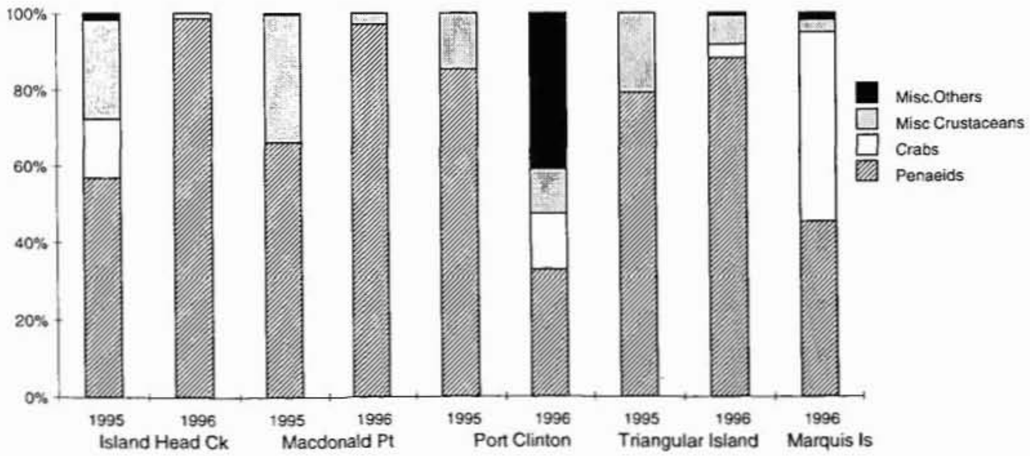


Figure 11. Percentage composition of invertebrate groups to the total biomass (g DW.) at each beam trawl site in September 1995 and April 1996.

Fish

1161 individual fish were collected from 12 beam trawls (all sites pooled) in September 1995 and 1568 from 20 trawls in April 1996. Fish abundances (all species pooled) were significantly different between sites (Appendix 2, Table 11), with most fish (84% of total catch in both September and April) being collected outside Shoalwater Bay proper (in Island Head Creek and Port Clinton) (Figure 12).

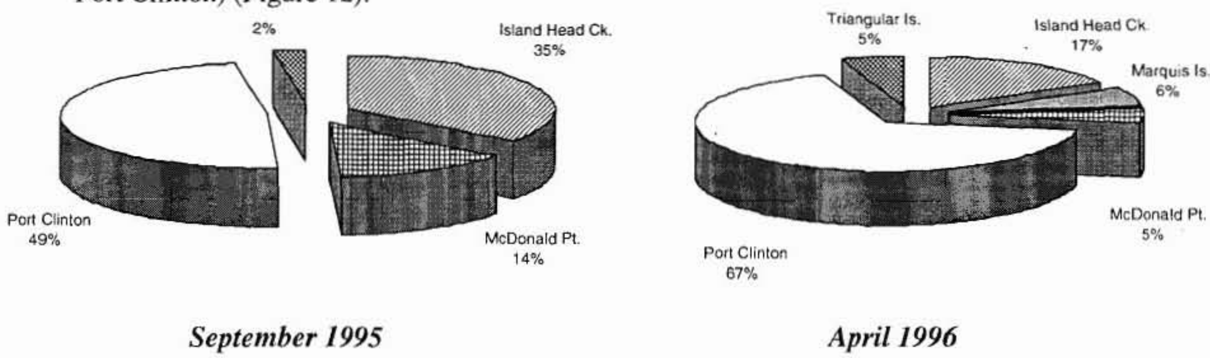


Figure 12. Composition of total beam trawl catch at each site in September 1995 and April 1996.

Fish abundances in Shoalwater Bay and Port Clinton were not significant different between years (Appendix 2, Table 11) (Figure 13). Island Head Creek had significantly lower abundances in April 1996 than September 1995 (T-test, T=2.87; d.f.=5; P=0.035).

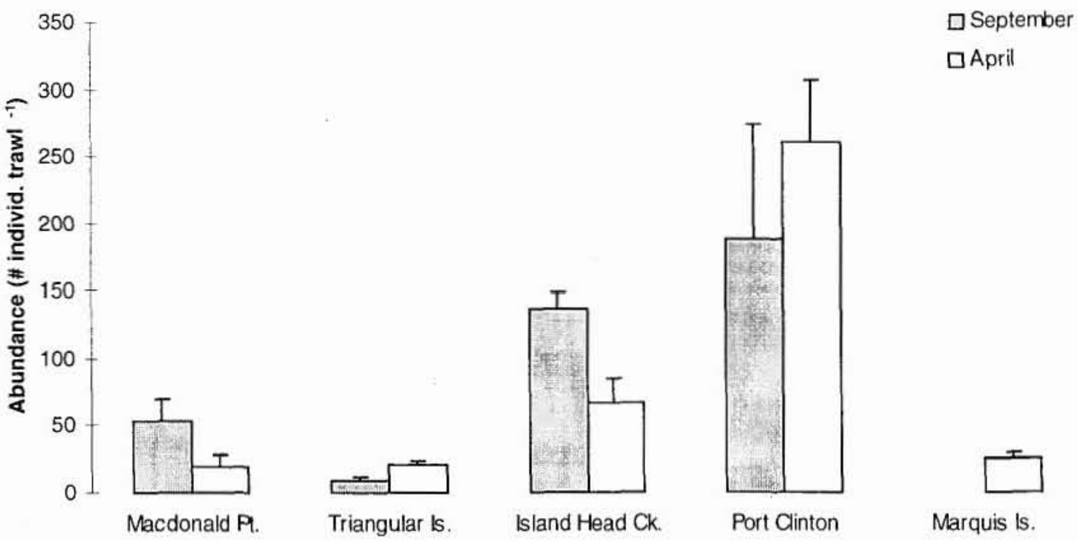


Figure 13. Abundance of fish at each trawl site in September 1995 and April 1996 *(mean and standard error displayed)*.

Fish collected were generally small sized and ranged in length from 5.20 to 170.0 mm SL. The most abundant fish taxa was the Gobiidae (83.2 % of total individuals in September 1995 and 77.75 % in April 1996) (Table 7) which was the largest proportion of catches in Island Head Creek and Port Clinton (Figure 14).

Table 7. Taxa, abundance, size data and value codes for fish collected from Shoalwater Bay beam trawl sites (all sites pooled).

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.

Family	Species	Code	September 1995			April 1996		
			Length range (mm)	#	Abundance %	Length (mm) ± SE (range)	#	Abundance %
Apogonidae	*Apogon nigripinnis*	?	absent	-	-	18.31 ± 2.37 (13.25 - 24.65)	4	0.26
Apogonidae	Apogonidae sp.	?	absent	-	-	12.92	1	0.06
Apogonidae	Apogonidae sp.a	a	absent	-	-	13.1	1	0.06
Blenniidae	Blenniidae sp.	br	59	1	0.09	15.2	1	0.06
Bothidae	*Arnoglossus* cf *dalgeish*	a	absent	-	-	23.83 ± 9.78 (14.05 - 33.60)	2	0.13
Bothidae	*Pseudorhombus elevatus*	a	88.5	1	0.09	absent	-	-
Callionymidae	Callionymidae sp.	A	41.3 - 43.0	2	0.17	8.35 ± 0.05 (8.30 - 8.40)	2	0.13
Callionymidae	*Callionymus* cf *grossi*	A	absent	-	-	48.05 ± 1.31 (46.74 - 49.35)	2	0.13
Carangidae	Carangidae sp.	c?	23.4	1	0.09	absent	-	-
Clupeidae	Clupeidae sp.		absent	-	-	13.30 ± 0.97 (8.48 - 17.54)	15	0.96
Cynoglossidae	Cynoglossidae sp.	a	27.3 - 72.5	3	0.26	absent	-	-
Cynoglossidae	*Cynoglossus* sp.	a	30.7 - 44.1	3	0.26	absent	-	-
Engraulidae	Engraulidae sp.	-	32.7 - 41.0	3	0.26	absent	-	-
Engraulidae	*Stolephorus* sp.	-	absent	-	-	24.21 ± 0.86 (16.60 - 34.41)	24	1.53
Gerridae	Gerridae sp.	-	absent	-	-	11.89 ± 0.18 (8.76 - 14.26)	30	1.91
Gerridae	Gerridae sp.a	-	absent	-	-	11.43 ± 0.12 (9.15 - 14.50)	78	4.97
Gobiidae	*Acentrogobius multifasciatus*	-	absent	-	-	30.33 ± 1.50 (24.00 - 34.25)	7	0.45
Gobiidae	*Arenigobius* cf *leftwichi*	-	absent	-	-	21.90 ± 0.87 (18.00 - 29.91)	12	0.77
Gobiidae	*Glossogobius* sp.	-	absent	-	-	14.21 ± 0.64 (5.33 - 158.00)	237	15.11
Gobiidae	*Gnatholepis* sp.	-	absent	-	-	17.25 ± 0.20 (5.20 - 26.25)	433	27.61
Gobiidae	Gobiidae larvae	-	absent	-	-	10.33 ± 0.18 (8.00 - 13.45)	54	3.44
Gobiidae	Gobiidae sp.a (Apr. 1996)	-	absent	-	-	12.50 ± 0.42 (7.95 - 42.80)	89	5.68
Gobiidae	Gobiidae sp.a (Sep. 1995)	-	8.8 - 60.6	428	36.86	absent	-	-
Gobiidae	Gobiidae sp.b (Apr. 1996)	-	absent	-	-	14.83 ± 0.32 (9.20 - 24.70)	125	7.97
Gobiidae	Gobiidae sp.b (Sep. 1995)	-	12.0 - 42.0	532	45.82	absent	-	-
Gobiidae	Gobiidae sp.c (Apr. 1996)	-	absent	-	-	13.94 ± 0.19 (6.60 - 23.85)	224	14.29
Gobiidae	Gobiidae sp.c (Sep. 1995)	-	8.8 - 25.7	6	0.52	absent	-	-
Gobiidae	Gobiidae sp.d	-	absent	-	-	11.13 ± 0.38 (8.60 - 14.10)	18	1.15
Gobiidae	Gobiidae sp.e	-	absent	-	-	18.52 ± 1.15 (16.50 - 20.50)	3	0.19
Gobiidae	Gobiidae sp.g	-	absent	-	-	32.35 ± 0.50 (31.85 - 32.85)	2	0.13
Gobiidae	Gobiidae spp.	-	absent	-	-	14.52 ± 1.81 (8.00 - 30.40)	15	0.96
Labridae	*Choerodon anchorago*	-	absent	-	-	29.66	1	0.06
Larvae	Unidentified larvae	-	0	1	0.09	absent	-	-
Larvae	Unidentified larvae	-	absent	-	-	15.52 ± 0.99 (8.20 - 31.50)	37	2.36
Leiognathidae	*Gazza* cf *minuta*	-	absent	-	-	29.45	1	0.06
Leiognathidae	Leiognathidae sp.	-	14.6	1	0.09	absent	-	-

Leiognathidae	*Leiognathus* sp.	-	absent	-	-	12.78 ± 0.03 (12.75 - 12.80)	2	0.13
Leiognathidae	*Secutor* sp.	-	absent	-	-	8.67	1	0.06
Lethrinidae	Lethrinidae spp.	c?	Absent	-	-	11.15 ± 0.30 (10.85 - 11.45)	2	0.13
Lethrinidae	*Lethrinus* cf *nematacanthus*	?	absent	-	-	20.83 ± 0.03 (20.80 - 20.85)	2	0.13
Lethrinidae	*Lethrinus* sp.	c?	absent	-	-	19.07 ± 1.02 (14.80 - 22.55)	6	0.38
Lethrinidae	*Lethrinus variegatus*	cr	absent	-	-	18.18	1	0.06
Monacanthidae	*Acreichthys tomentosus*	A	absent	-	-	26.32 ± 1.46 (21.50 - 29.00)	5	0.32
Monacanthidae	*Chaetoderma* sp.	A	absent	-	-	19.89 ± 0.73 (17.95 - 21.25)	4	0.26
Monacanthidae	Monacanthidae sp.	A	64.1	1	0.09	absent	-	-
Monacanthidae	Monacanthidae sp. cf *Acreichthys tomentosus*	A	absent	-	-	25.34 ± 1.47 (8.25 - 34.85)	20	1.28
Monacanthidae	Monacanthidae sp. cf *Chaetoderma swainson*	-	absent	-	-	17.43 ± 2.97 (11.60 - 21.30)	3	0.19
Monacanthidae	*Monacanthus oblongus otisensis*	-	absent	-	-	17.76 ± 2.08 (12.72 - 21.26)	4	0.26
Mullidae	*Upeneus* cf *tragula*	a	38.5	1	0.09	30.05	1	0.06
Ophichthyidae	*Ophisurus* sp.	-	absent	-	-	104.5	1	0.06
Ostaciidae	*Lactoria cornuta*	-	absent	-	-	54.75	1	0.06
Paralichthyidae	Paralichthyidae sp.	cR	absent	-	-	32.95 ± 3.69 (25.65 - 37.50)	3	0.19
Platycephalidae	*Cymbacephalus nematophthalmus*	cR	absent	-	-	49.17	1	0.06
Platycephalidae	*Inegocia* cf *japonicus*	cR	absent	-	-	55.83 ± 4.08 (51.75 - 59.90)	2	0.13
Platycephalidae	*Onigocia* sp	?	absent	-	-	10.44	1	0.06
Platycephalidae	Platycephalidae sp.	?	20.0 - 74.2	2	0.17	12.85	1	0.06
Platycephalidae	*Platycephalus indicus*	cR	170	1	0.09	absent	-	-
Platycephalidae	*Platycephalus* sp.	?	14.3 - 60.0	3	0.26	absent	-	-
Platycephalidae	*Thysanophrys* sp.	?	absent	-	-	74.83	1	0.06
Scorpaenidae	Scorpaenidae sp.	A	16.2 - 28.7	2	0.17	absent	-	-
Scorpaenidae	*Scorpaenodes* cf *scaber*	A	absent	-	-	47.2	1	0.06
Serranidae	*Centrogenys vaigiensis*	A	absent	-	-	30.1	1	0.06
Serranidae	*Epinephelus* sp.	cR?	absent	-	-	13.45	1	0.06
Sillaginidae	*Sillago* sp.	a	11.2 - 61.8	150	12.92	13.69 ± 0.33 (12.15 - 17.25)	24	1.53
Soleidae	*Aseraggodes cyaneus*	-	absent	-	-	25.1	1	0.06
Soleidae	*Aseraggodes* sp.	-	absent	-	-	28.75	1	0.06
Soleidae	Soleidae sp. cf *Aseraggodes cyaneus*	-	absent	-	-	30.5	1	0.06
Syngnathidae	Syngnathidae sp.	-	80.8 - 90.6	2	0.17	absent	-	-
Synodontidae	Synodontidae sp.	-	absent	-	-	22	1	0.06
Synodontidae	*Synodus macrocephalus*	-	absent	-	-	27.73	1	0.06
Teraponidae	*Pelates quadrilineatus*	-	20.4 - 36.1	6	0.52	16.54 ± 1.35 (10.50 - 41.10)	36	2.30
Teraponidae	*Pelates* sp.	-	17.8 - 37.8	11	0.95	absent	-	-
Teraponidae	Teraponidae sp.	-	absent	-	-	12.09 ± 0.18 (10.00 - 13.50)	20	1.28
Total			8.8 - 170.0	1161		15.59 ± 0.18 (5.20 - 158.00)	1568	

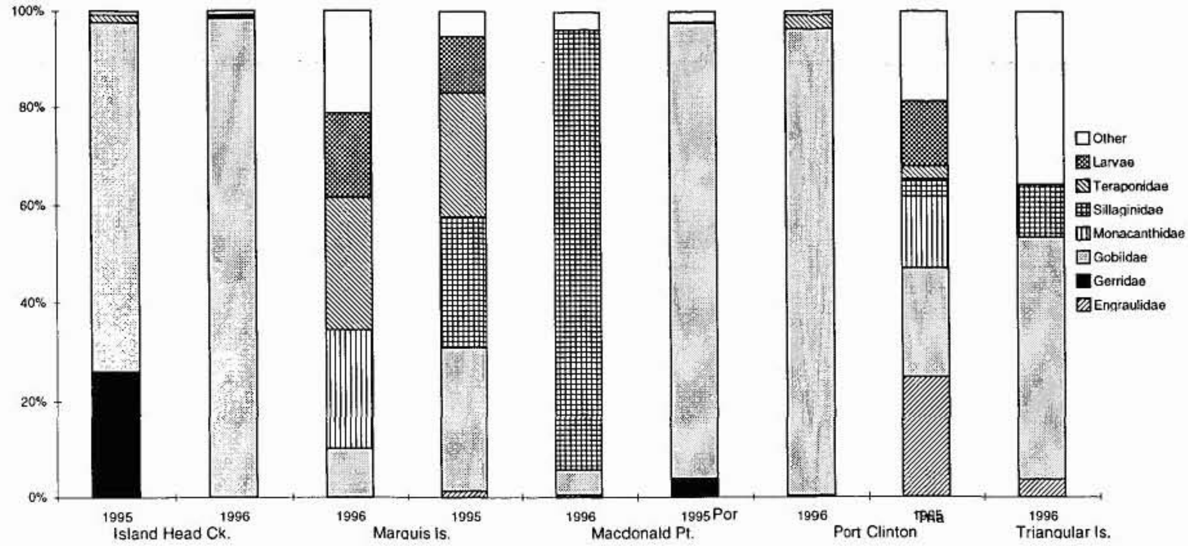
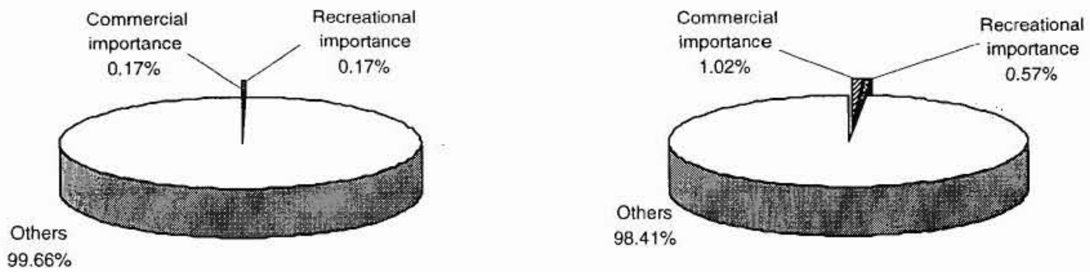


Figure 14. Percent composition of each family of fish collected at each trawl site in September 1995 and April 1996.

Only two species were of some commercial importance in September 1995 (Carangidae sp. and *Platycephalus indicus*) which represented only 0.17 % of total individuals collected (Figure 15). In April 1996 however, 7 species were collected which were of some commercial importance (Lethrinidae spp., *Lethrinus* sp., *Lethrinus variegatus*, Paralichthyidae sp., *Cymbacephalus nematophthalmus*, *Inegocia* cf *japonicus*, *Epinephelus* sp.), although they represented only 1.02 % of the total catch.



September 1995 ***April 1996***

Figure 15. Composition of fishery value for fish collected from beam trawls in September 1995 and April 1996 (*all sites pooled*).

Associated Megafauna

Dugongs were sighted during the helicopter reconnaissance survey, at the mouth of Keiver Creek and in Canoe Passage in September 1996 and in West Bight, Canoe Passage and Port Clinton in April 1996. Evidence of dugong feeding (feeding trails) were identified at several sites within the bay, in Port Clinton and Island Head Creek. Feeding trails were found mainly in meadows with mud/sand substrates dominated by *Zostera capricorni*, or *H. pinifolia*, *H. uninervis* (thin) and to a lesser extent *H. decipiens*.

Green sea turtles were found throughout the survey area. Many were either stranded at low tide on intertidal flats or swimming near the waters edge, although not always associated with seagrass meadows.

✎ DISCUSSION

Seagrasses

In the present surveys 13,076 ±800 ha of seagrass habitat was mapped in September 1995 and 13,001 ±890 ha in April 1996. Distribution patterns in these surveys were similar to those from the original post-wet broad-scale survey in March 1987 where an estimated 7,000 ha of seagrasses was mapped (Coles *et al.* 1987; Lee Long *et al.* 1993, corrigendum 1994). A number of intertidal meadows and most of the 1,300 ha of subtidal meadows were not mapped in the 1987 broad-scale survey, because of the sea conditions at that time.

The area of subtidal seagrass habitat found is only small, contributing approximately 10 % of the total seagrass resource. Strong tidal currents and associated high water turbidity in Shoalwater Bay proper limit light penetration and therefore the depth to which seagrasses can grow. The deepest seagrasses occurred in Shoalwater Bay was 8.2 m below MSL, although seagrasses have been recorded to 58 m below MSL at other localities (Lee Long *et al.* 1996). Runoff in Shoalwater Bay is from either Defence Reserve or grazing land; no urban runoff is likely. Soils are loose and probably easily eroded, and high water turbidities can occur during monsoonal runoff.

Most seagrass meadows in Shoalwater Bay were on intertidal banks often fringing the mangrove tree line (up to 0.7 m above MSL). Seagrass meadows in the southern section of the Bay were often in narrow strips which could only be mapped with extensive dive surveying and ground truthing. In contrast, northern parts of the Bay supported extensive meadows which were easily seen during aerial surveys. Seagrass distribution was greatly influenced by the topography of the tidal banks with small changes in level effecting drainage, exposure and consequently seagrass growth. In mid-western and eastern sections of the Bay, meadows occurred in a mosaic of patches where pools and channels allowed the growth of plants on otherwise exposed banks.

With large tidal ranges seagrasses are exposed for long periods during low tide, and appeared to have a large influence on where the upper limit of seagrass growth occurred. In places, water is retained on the flats at low tide and seagrasses are better protected against desiccation, extending the upper limit to around 0.7 m above MSL. Differences in the upper depth distributions between surveys could not be attributed to seasonality however, as they were probably an artefact of slight changes in sampling of the upper limits of distribution between surveys. During the September 1995 survey the upper limits of seagrass distribution were mapped mainly by aerial surveys, where very few depth measures could be taken. In April 1996, tidal conditions allowed divers to access the upper limits and obtain more depth measures, and this improved the information on upper depth distribution for each species.

The lower depth limits of seagrass growth were significantly lower in the April survey, particularly for species such as *H. pinifolia, H. decipiens, H. ovalis* and *H. uninervis*. *Halophila spinulosa* varied little in maximum depth between surveys. This seagrass species appears to be one of the most well adapted to low light environments in the Great Barrier Reef region (Lee Long *et al.* 1993; Coles *et al.* 1996).

Seagrass species biomasses were variable between habitat types within the study area (demonstrated by the large ranges in Figure 3). When all sites (from all habitat types) were pooled however, the variation in above-ground biomass was low (see Standard Errors for each species in Figure 3). This appears a consequence of the high number of sites surveyed on the large intertidal banks, of which the seagrass biomasses for most species were not highly variable.

Differences in the general morphology of *Zostera capricorni* and *Halophila ovalis* were also noted during both surveys. *Zostera capricorni* shoots on the large intertidal banks on the western side of the bay were much shorter and more densely clumped together than have been observed at other locations along Queensland's eastern coast. *Halophila ovalis* plants in the north-western section of the bay, from Sabina Point north to Stannage Bay, were more elongate than the typical round-to-oval shape of this species. Plants from Stannage Bay may be described as a new species (John Kuo pers. comm.). The causes of such morphological variation are unknown and requires further investigation.

The amount of algae present at sites was variable throughout the survey area. The amount of epiphytic green filamentous algae however, was very high at Triangular Island, particularly in Little Bang Bay on the northern side. Approximately half of the sites examined in Little Bang Bay had algal cover between 80 and 95 %. This bay is often used for undersea detonations, and it is possible that the high phosphate content of explosives may have elevated the available P in this area and allowed high growth-rates of filamentous green algae.

Approximately 62 % of the known seagrass resources in the Mackay/Capricorn section of the Great Barrier Reef Marine Park are located within the Shoalwater Bay survey area. The nearest other large seagrass meadows exist 150 km south at Gladstone, patchy meadows 50 km north at Clairview and extensive meadows 300 km north at the Whitsunday Island group (Coles *et al.* 1987b). This makes the Shoalwater Bay area regionally important as prawn and fish nursery habitat and as feeding area for dugongs and green sea turtles.

Prawns and Fish

Seagrass habitat in Shoalwater Bay is important regionally to commercial fisheries. Commercially important species of prawns dominated beam trawl samples at all sites. Juvenile penaeid prawns were more common at Port Clinton and Island Head Creek sites, where substrate types were mud and fine sand. Sites where western king prawns dominated beam trawl samples (in Shoalwater Bay) had mostly sandy substrates. This was also the pattern in beam trawl samples from the 1987 broad-scale survey (Coles *et al.* 1987b).

Large numbers of other invertebrates and juvenile fish from beam trawl samples indicate a rich food source for local marine food webs. The Shoalwater Bay seagrass meadows are likely valuable nursery habitats which provide food and shelter for juveniles of commercially and recreationally important species and the basis for very productive coastal marine communities.

Dugongs

The Shoalwater Bay area supports the most important dugong habitat in the Great Barrier Reef region south of Cape York (Marsh *et al.* 1995). In Shoalwater Bay, dugong numbers have declined from an estimated 765 ±161 animals in 1987 to 406 ±78 animals in 1994 (Marsh *et al.* 1995).

The pioneering seagrass species such as *Halophila* and *Halodule* which dominate much of the Shoalwater Bay seagrass communities are the preferred diet for dugong (Preen 1995). Although Preen has regularly sighted dugong at the upper limits of seagrass distribution, dugong feeding trails were most commonly seen along the seaward perimeter of meadows, and this may be because of the palatability, dietary value or accessibility of these seagrasses to dugong. Numerous feeding trails were also found in meadows dominated by *Zostera capricorni* in the present surveys. *Zostera capricorni* has since been confirmed as a major dietary component for dugong of the area (Tony Preen, pers. comm.). In the Shoalwater Bay area there is little subtidal seagrass, due to a combination of high tidal fluctuations and high turbidities, so much of the available seagrass resource is on large intertidal banks. Subtidal meadows may provide important feeding opportunities for dugongs during low tides, however biomass of these meadows was very low and productivity in these turbid, deep-water conditions may also be too low to support large food demands of dugong. Few, if any, dugong feeding trails were observed in these meadows.

Dugongs are known to feed throughout the day and night. Dugongs have been recorded to move throughout the bay and into the rivers in the lower section of Shoalwater Bay around the period of high tide (Tony Preen, pers. comm.). Narrow strips of seagrass found along creek banks had dugong feeding trails in September 1995, where the animals selected to graze on steep banks close to deeper water to avoid stranding. Almost no seagrass was found on river/creek banks in April 1996, and thin strips of habitat that were present had no feeding trails.

Gill netting is recognised as the most important fishing method in the Shoalwater Bay area (Fitzsimmons 1996) and is believed to be a significant source of anthropogenic mortality of dugong (Marsh *et al.* 1995). Gill nets set out from mangrove edges can accidentally capture dugongs, and records of bycatch of dugong in Shoalwater Bay increased in 1995 (Marsh *et al.* 1995). With very little sub-tidal seagrass in Shoalwater Bay available for feeding, dugongs are forced to utilise the same areas as gill-netters, increasing the chances of accidental capture of dugongs in nets.

Other areas within the Great Barrier Reef region which have high dugong populations (Marsh *et al.* 1995), also have substantial subtidal (deepwater) seagrass meadows. Extensive subtidal seagrass meadows have been found in the Starke River area (Lookout Point to Murdoch Point to the outer Great Barrier Reef) (Lee Long *et al.* 1989; Coles *et al.* 1995). Seagrasses were found to a depth of approximately 58 m and dugong feeding trails to a depth of 33 m (approx 18 km from the coast). In Hervey Bay the resident dugong population is dependent on extensive subtidal seagrass meadows within the bay, evidenced from a dramatic decline in dugong numbers following loss of approximately 1000 km^2 of the subtidal meadows (Preen *et al.* 1995).

In response to the decline of dugong and the high accidental catch of dugong in gill nets in the Shoalwater Bay area, a management plan has been developed which prohibits gill nets in the area (GBRMPA 1997).

Seagrass Monitoring

Monitoring programs should ideally be designed to quantify the causes of change; examine and assess acceptable ranges of change for the particular site; and to measure critical levels of impacting agents. Intensive monitoring of large areas or large suites of parameters is often prohibitively expensive and requires considerable expertise in the systems being studied. To measure regional changes, it is our view that mapping using qualitative information on spatial distribution and repeated biannually or at a suitable pre-determined time interval may provide a broad but sufficient indication of change. If changes in, for example, the area of seagrass measured this way continued in one direction for three or more sampling intervals, resources could be diverted to investigate the cause of change and, if possible, to take responsive action.

The present baseline surveys were designed to establish data sets on which monitoring programs could be based to investigate changes in seagrass biomass and distribution. These programs will enable measures of change in area of seagrass habitat and seagrass biomass within meadows.

Seagrass meadows can change in several ways. There can be a change in biomass without a change in area; a change in area, or shape, depth or location of a meadow; a change in species composition, plant growth and productivity, the fauna and flora associated with the meadow, or a combination of some or all of these. These changes will also occur naturally and on a regular seasonal basis. Environment monitoring programs require knowledge of these patterns of natural change. They also require cost-effective data collection, selection of appropriate parameters and scales, and measures of change which are statistically appropriate for determining if management action is required.

The present surveys provide a baseline suitable for developing a monitoring program, and where statistically valid measures of change can be gained. Sampling designs for monitoring, can now be developed to ensure that various levels of change can be detected.

It is difficult and expensive to accurately map and monitor large-scale and remote meadows. Satellite imagery and aerial photography are useful for mapping where dense seagrasses can be seen on very large scales (Kirkman, 1990; Hyland *et al.* 1989; Long, Skewes and Poiner, 1994), but cannot always be used successfully to map or monitor seagrass biomass (Walker, 1989) or identify seagrasses of low density, or in water too deep or too turbid for remote sensing (Hyland *et al.* 1989). In these instances ground surveys (walking, diving or grabs) are essential.

When the total seagrass resources of a locality are mapped, it is not necessary to monitor all of them in order to assess environmental impact. It is more cost effective to focus monitoring effort on priority areas or meadows. Selecting "monitoring meadows" requires some knowledge of the biology of species present and habitat/ ecological or economic value of the different meadows. From the present surveys the relative importance of different seagrass areas can be determined. Effort within long-term monitoring programs can then be focussed on the meadows which are important from ecological or economic points of view.

A "whole meadow" approach would be adopted as the monitoring unit and to enable detection of any change, a sampling design will require sites randomly (or haphazardly) spread across the whole meadow. If an adequate measure of spatial variability within the seagrass meadow is calculated from the baseline survey, it is possible to mathematically determine the required minimum number of randomly located sites, and sample units at each site, sufficient to detect any desired amount of temporal change for the meadow.

To resurvey the extent of seagrasses in the Shoalwater Bay area frequently would be logistically difficult and expensive. Although the information gained would be useful, we recommend that the most efficient method for monitoring would be to select "monitoring meadows" for monitoring at 1-2 year intervals and to resurvey the total area only every 3-5 years, preferably in Spring. Priority meadows for monitoring were determined from the seven meadows examined in the present surveys based on relevance to dugong management. We recommend monitoring intertidal meadows at Akens Island, Hideaway Bay (Triangular Island), Townshend Island and Port Clinton. *Subtidal meadows at Strongtide Passage (meadows # 85 & 86 combined)* or Canoe Pass would also be useful for monitoring.

↳ACKNOWLEDGMENTS

We are grateful to Glen Chisholm, Paul Leeson, Anthony Roelofs, Chantal Roder and Janet Slater for assistance during dive surveys; Anthony Roelofs, Chantal Roder, Emma Bradshaw, Shirley Veronise, Leane Makey, Wendy Baker and Sampson Hollywood for assistance with data entry/ management, and faunal sorting/identifications . We thank Ray Berkelmans (Research & Monitoring, GBRMPA), Brian Tunstall (CSIRO), Seonaid Philip (GIS Unit, QDNR, Mareeba) and Terry Webb (GIS Unit, QDNR, Mareeba) for assistance in establishing the GIS basemap and Peter Ludlow (SOKKIA) and Peter Rey (Remote Sensing Unit, CUQ) for assistance with differential position fixing. We also thank Phil Hales and Michael Rasheed (NFC, QDPI) for verifying fish identifications. Sea levels/predictions/residuals for port(s) are supplied by the National Tidal Facility, Flinders University of South Australia, copyright reserved. This survey was funded by the Great Barrier Reef Marine Park Authority, the Queensland Department of Primary Industries and the Australian Cooperative Research Centre Program through the CRC for Ecological Sustainable Development of the Great Barrier Reef.

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↬APPENDIX 1

Table 8. Results of linear regressions of each diver's biomass estimation with harvested above-ground biomass (g dry wt. m^{-2}) in September 1995 and April 1996.

Diver	September 1995			April 1996		
	r^2	F	p	r^2	F	p
G. Chisholm	0.95	113.29	«0.001	0.74	20.12	0.003
R. G. Coles	0.92	79.59	«0.001			
W.J. Lee Long	0.89	47.19	«0.001	0.85	38.56	«0.001
P. Leeson	0.92	70.50	«0.001			
L. J. McKenzie	0.94	104.52	«0.001	0.93	90.62	«0.001
C. Roder				0.88	53.49	«0.001
A.J. Roelofs				0.91	69.72	«0.001
J. Slater	0.84	37.96	«0.001			

↬APPENDIX 2

Table 9. Results of 2-way ANOVA for penaeid abundance between sites and years.

Source of Variation	SS	DF	MS	F	P
Main Effects	670917.7	5	134183.54	4.833	0.003
SITE	586063.7	4	146515.93	5.277	0.003
YEAR	52550.01	1	52550.012	1.893	0.181
Explained	670917.7	5	134183.54	4.833	0.003
Residual	721846.2	26	27763.314		

Table 10. Results of 2-way ANOVA for number of penaeid species between sites and years.

Source of Variation	SS	DF	MS	F	P
Main Effects	101.21	5	20.242	7.16	0
SITE	11.941	4	2.985	1.056	0.398
YEAR	75.241	1	75.241	26.613	0
Explained	101.21	5	20.242	7.16	0
Residual	73.509	26	2.827		
Total	174.719	31	5.636		

Table 11. Results of 2-way ANOVA for number of fish between sites and years.

Source of Variation	SS	DF	MS	F	P
Main Effects	213221.5	5	42644.3	11.325	0
SITE	210696	4	52674	13.988	0
YEAR	167.17	1	167.17	0.044	0.835
Explained	213221.5	5	42644.3	11.325	0
Residual	97905.01	26	3765.58		
Total	311126.5	31	10036.3		