AN ASSESSMENT OF THE LIKELY EFFECTS OF THE PROPOSED TRINITY POINT PROJECT IN THE MARINE ECOLOGY OF THE CAIRNS HARBOUR AND FORESHORE

A REPORT

by

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1.0 EXECUTIVE SUMMARY

This study was initiated to gather information about aspects of the marine life of Cairns Harbour and Trinity Inlet as it relates to the proposed reclamation of land for the Trinity Point project. This report updates findings of the October 1988 Interim Report. The following information is relevant:

1. The Olsen report (1983) by the Queensland Government stated that Trinity Bay was locally important but did not have national or international significance. The Cairns Tidal Wetlands are, however, listed in the register of the National Estate and by the National Trust.

2. In accordance with the Olsen report recommendations, a large portion of Trinity Inlet (Cairns Port Authority jurisdiction) is proposed as Fisheries Habitat Reserve. The Trinity Point Development lease site is outside these proposed boundaries.

3. Development, if it proceeds, would result in the loss of 25 hectares of seagrass fish and prawn nursery habitat and 56 hectares of mudflat, algae mat and isolated seagrass.

4. The marina basin and channels proposed in the Trinity Point Development would support marine flora and fauna different from and probably less abundant than at present, but which would also contribute to the productivity of the Cairns Harbour and Trinity Inlet.

5. The Development lease site would now be covered with a mangrove forest supplanting the mudflats and seagrasses (as has happened at Bessie Point) if mangrove seedlings were not regularly removed by human intervention. In this context the present intertidal mudflat habitats in the lease site region are artificial.

6. Sediment would be expected to accrete more quickly in lee areas if the proposed Development proceeds. This would probably cause short-term seagrass and algae mat losses. In the long-term it is highly likely that this area would be recolonized with algae, seagrasses and, if allowed, mangroves. Planting of marine vegetation would speed up this process.

7. Cairns Harbour and Mission Bay contain about 500 and 376 hectares respectively of seagrass nursery grounds for fish and prawns. Development of the lease site would effect the loss of 2.9% of these nursery grounds. The edge effect of reclamation work may increase this loss depending on construction techniques.

8. The seagrass beds are growing vigorously where there is adequate light, however, naturally high levels of turbidity restrict their growth in deeper water. Greatly increased turbidity during reclamation could destroy some of these deeper seagrasses even though they are adapted to life in a continuously muddy environment. Releasing high silt loads, during the wet season and at periods of high tidal range, could reduce the risks to these deeper beds.

9. Preliminary experimental work has shown that seagrasses can be transplanted in the Cairns Harbour. Although this may not be

economically viable, pressure from commercial and recreational fishermen may require that additional beds be created.

10. In the event of a predicted 0.9m sea level rise occurring in the next 50 years, seagrasses would be expected to recolonize mudflats where these occur in the same depth range as at present. There is no reason to suggest that the Trinity Point Development would magnify the effect on marine life caused by a Greenhouse sea level rise.

11. The Cairns Harbour seagrasses are amongst the most productive prawn nursery grounds on the eastern Queensland coast. The value of the lease site seagrasses in terms of commercial prawn production is estimated through computer modelling to be $3 467 per hectare per year and the mudflats $796 per hectare per year. As the lease site has only 25 hectares of seagrass prawn nursery ground and 56 hectares of mudflats, its loss would be of little consequence in monetary terms to an industry worth around $100 million annually.

12. The local annual production of prawns within Cairns Harbour and Mission Bay is estimated, through computer modelling, to be worth around $3 756 257. Of this, $131 263 (3.5%) may be lost through development of the lease site. This loss could be offset in the fishery's eye by rehabilitation of seagrass and allowing mangrove regrowth through funding of fisheries research and monitoring.

13. Very large numbers of fish (8 809 fish per hectare and 223 species, mainly juveniles) use the nursery grounds of Cairns Harbour and Trinity Inlet. Few of these (18%) are highly valued and are used directly by recreational and commercial fishermen. The rest probably serve as food for larger species.

14. There is a high level of year-to-year variability in prawn and fish numbers using the lease site. Caution is necessary in using year-to-year comparisons to assess the effect on marine life by the development. This high level of natural variation, combined with the relatively small lease area when compared with the entire Cairns Harbour, Mission Bay and Trinity Inlet, means that it would be difficult to detect any effect of the Development on fish and prawn numbers without a long-term and intensive study.

15. There has been a steady decline in dugong numbers over the last 20 years so that there are probably no dugong which are dependent on the seagrasses of Cairns Harbour. No turtles, crocodiles or dugongs were sighted during this study.

16. While pollution of the Cairns Harbour and Trinity Inlet is not a major factor in assessing the effect of the Trinity Point Development proposal, the current levels of bacterial, heavy metal and pesticide contamination of sediments, seagrasses and water are alarmingly high and warrant a more detailed study.

17. It is strongly recommended in the event of the proposed Development proceeding that both short- and long-term monitoring of the marine flora and fauna and physical parameters be undertaken. Replanting seagrasses and planting of mangroves in selected areas, and offsetting potential losses of fish and prawns by habitat modification, should be a priority consideration in the monitoring programme.

18. Section 8.0 of the report summarizes the principal findings and conclusions of this study.

2.0 INTRODUCTION

2.1 Background

In 1985 the Land Administration Commission granted Trinity Point Hotel Pty Ltd a special lease over some 81 hectares of tidal foreshore adjacent to the Cairns esplanade (Fig. 1). The lease was granted to enable a detailed investigation of the feasibility and likely impact of the proposed Trinity Point Development.

Construction of the Trinity Point Development would directly cause the loss of an area of existing habitat and replace it with another (Section 2.2).

This report details the investigations into the biological values of the present Cairns Harbour and Mission Bay environment in a local and regional context. The positive and negative aspects of the effect on the environment are assessed. Methods of offsetting both short-term and long-term negative effects are discussed and recommendations made.

2.2 The proposed Development project

The project would involve the reclamation of part of the lease site and dredging of a marina basin and channels to approximately 3.5m below Port Datum (Fig. 2). The perimeter of the reclamation will be bunded using imported quarry fill.

The enclosed area will be filled using sand pumped from a remote land site. Dredged spoil from the marina basin will be pumped to a suitably bunded land site. The finished project will be developed with a mix of marina support facilities, accommodation, recreational and commercial areas, plus a variety of public facilities.

2.3 Site description

2.3.1 General

The Trinity Point Development lease site occupies some 81ha of the Cairns mudflats (Fig. 1 and Fig. 2). The site consists of soft to very soft marine clay which has been accumulating since the Holocene period, overlying dense and stiff alluvial clay laid down in the Pleistocene era (companion report, Geotechnical Engineering). The depth of the upper layer ranges from 2 to 11 metres over the site.

The mud on the site is of geologically recent origin and were it not for the periodic removal of juvenile mangroves, would probably have developed mangrove forests similar to those to the north near the airport and to the south near Hills Creek. A large proportion of the lease site is unvegetated mud crisscrossed with natural ponds and drainage channels when exposed at low tide.

2.3.2 Flora and fauna

Parts of the mudflat are covered with marine vegetation ranging from dense stands of seagrasses through to fine filamentous algae which impart a green tinge to the mud surface (see Appendix 7).

Figure 1. Site of proposed Trinity Point Development adjacent to the Cairns Esplanade.

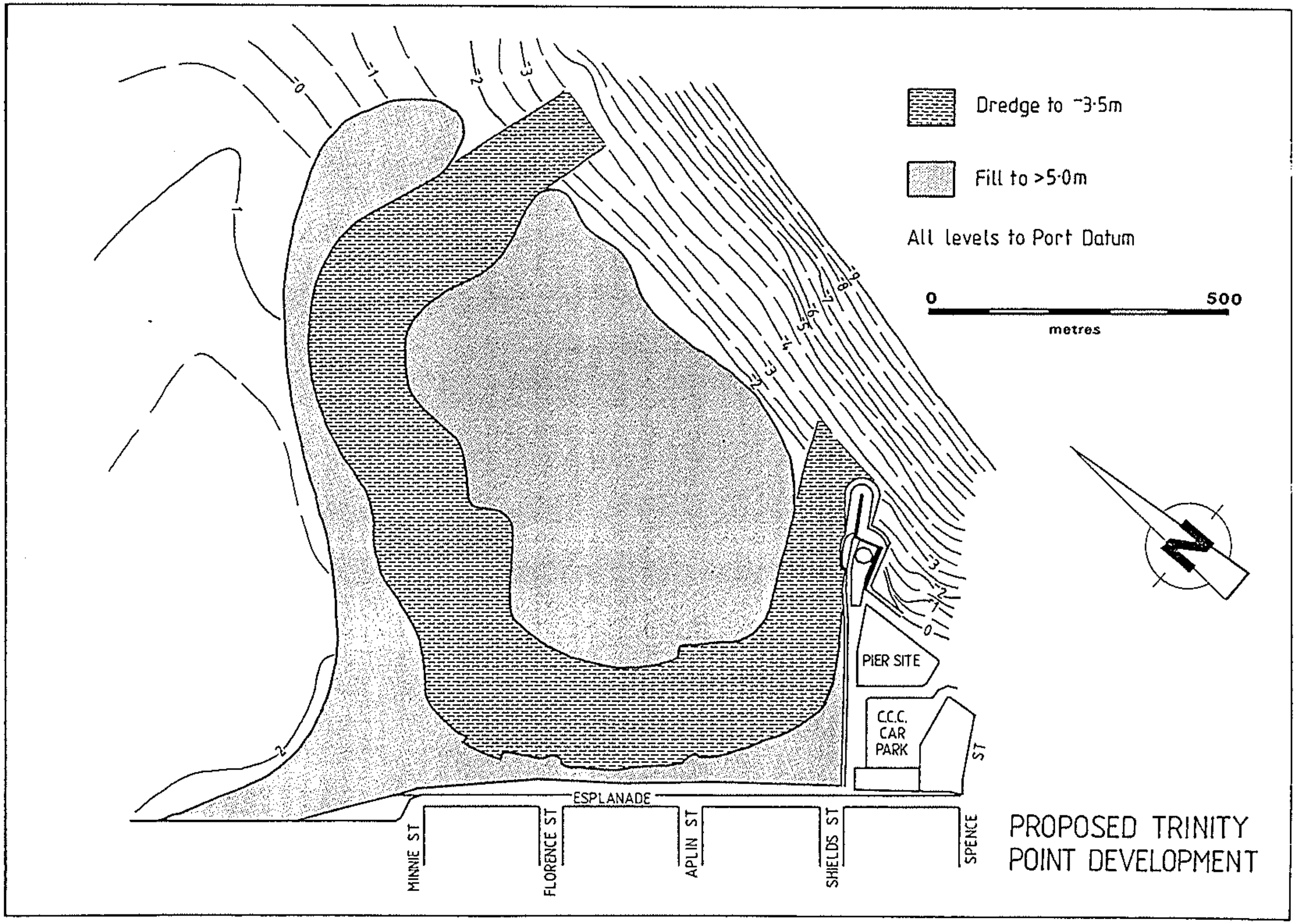


Figure 2. Site plan of proposed Trinity Point Development.

The marine animals found in the area include a wide variety of fish, crabs, prawns, other crustacea and at times, possibly turtles, crocodiles and dugong. Some of the species found have a commercial value or are important for recreational fishing.

The Cairns Harbour region surrounding the lease site is used regularly by local recreational fishermen and by a growing number of tourists involved in leisure time fishing activity. Cairns is Australia's largest commercial fishing port. Four hundred and nineteen trawlers operate out of Cairns although only about 16 rely on local prawn stocks (Beurteaux, 1986). The vast majority of commercial fishing activity in the region occurs in the coastal waters north of Cairns.

2.3.3 Olsen Report

An inventory of the biological resources of Cairns Harbour and Trinity Inlet undertaken by the Queensland Department of Primary Industries (Olsen, 1983) indicated that the Cairns Harbour area was important both as a nursery ground for juvenile fish and prawns and as a fishing ground for adult fish. Olsen's survey of juvenile prawn nursery areas revealed large numbers of juvenile brown tiger prawns, grooved tiger prawns and endeavour prawns over seagrass beds in shallow, mid-depth and deep water off the Cairns foreshore. These seagrass beds also support many species of juvenile and small adult fish and are therefore popularly regarded as a valuable resource.

The Olsen Report (1983) identified three "sensitive parameters"- shallow water feeding grounds for juveniles; the plankton; and finally the mangrove forest. While the proposed Development is unlikely to effect the last parameter, there is a possibility that there would be both direct and indirect effects on the first two parameters. In this regard, the Olsen Report (1983) sets the scene for further environmental studies where there could be:

a. "Destruction or alteration of intertidal or subtidal shallow areas. Thus further dredging of ecologically sensitive areas could drastically reduce the viability of the entire system."

b. "Alteration in the quality of effluent discharged into the estuary (which) could have serious consequences."

In the recommendations of the Olsen Report (1983) it is acknowledged that Trinity Bay and Inlet "do not constitute a pristine estuary of international or national significance for wetland conservation". Recognition is given to the regional and state importance of the system and in this regard it "has priority for conservation and management as reserves for fisheries purposes". The Cairns Tidal Wetlands are, however, listed in the Register of the National Estate by the Australian Heritage Commission and by the National Trust of Australia.

Core conservation areas were proposed in Olsen's inventory for declaration as Fish Habitat Reserves and adjoining buffer zones have been proposed for declaration as Wetland Reserves. These recommendations have been acted upon by the Queensland Department of Primary Industries and are the subject of a proposed declaration under the Fisheries Act 1976 - 1984. The lease site is not included within the boundaries of the core conservation areas proposed by Olsen (1983) or the boundaries of the proposed Reserves.

2.4 The purpose of the study and terms of reference

This study consists of an environmental survey and an assessment of the likely impact of the implementation of a foreshore development proposal. It extends previous research by documenting in detail the major flora and fauna of the Cairns Harbour region. It investigates major physical and chemical aspects of the local marine environment and evaluates the likely impact of the development on all these systems. The study also considers measures which may reduce any negative impact that may occur.

Included in the study area are the outer waters of Trinity Inlet north of a line between Hills Creek and the Marlin Jetty and the intertidal foreshore south of a line between Ellie Point to the west and False Cape to the east (Fig.3) (referred to in the text as the Cairns Harbour). Where relevant, information from the adjacent Mission Bay and the upstream continuation of Trinity Inlet are included.

Although other data are included, this study focuses on aspects of the fauna and flora of the Cairns Harbour that are related to local commercial and local recreational fisheries. It is within these terms of reference that the research has been conducted.

2.5 The consultants

The work included in this report was undertaken by the Queensland Department of Primary Industries, Fisheries Research Branch and Hollingsworth Consultants. The QDPI's major research facility in Cairns is the Northern Fisheries Research Centre. This Centre is well known within the scientific community and fishing industry as a centre for juvenile prawn and seagrass research aimed at the long-term conservation and management of the fishery resource. Research in these fields has been underway at the Centre since 1979 and encompasses work carried out in the Gulf of Carpentaria, Torres Strait and along Queensland's coastline from Karumba to Fraser Island.

Hollingsworth Consultants is a firm of consulting engineers, planners and environmental scientists with particular expertise in the assessment of the environmental impact of a wide range of development projects. Many of these projects have included coastal developments in tropical north Queensland.

2.6 Companion Reports

Information in this report is submitted in conjunction with the following reports:

(1) Coastal Processes
- Vol 1 Current and water height recordings
- Vol 2 Bathymetric survey
- Vol 3 Project impact and design criteria
  - a. Current and sediment analysis
  - b. Extreme water level prediction
  - c. Extreme wave climate
  - d. Normal wave climate
  - e. Protective structures
  - f. Marina wave climate

(MacDonald Wagner, 1988)

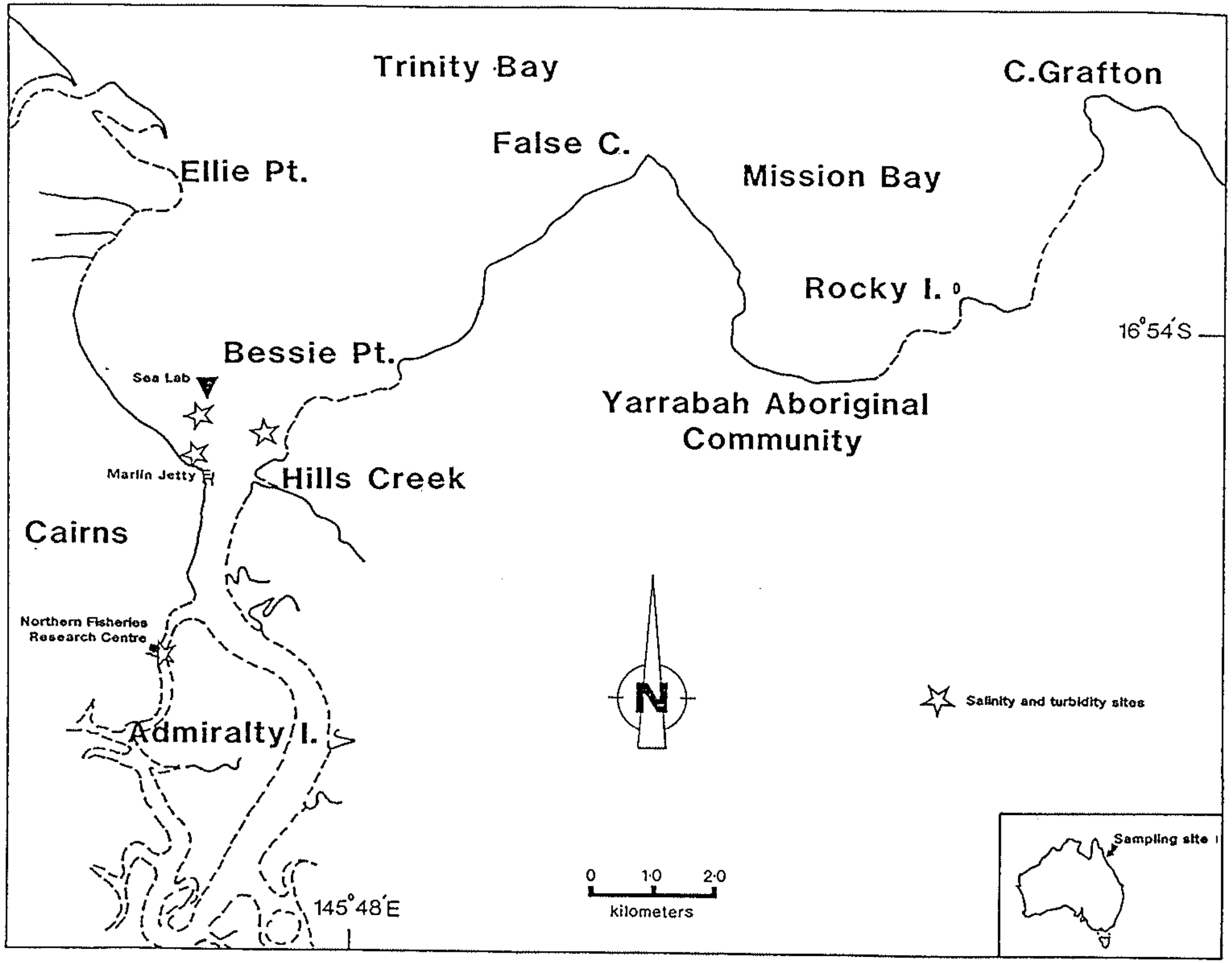


Figure 3. The study area.

(2) Environmental Assessment

a. Recreational and commercial fishing activities in Cairns Harbour and Trinity Inlet (Environmental Science and Services, 1988).

b. Migratory waders and other birds on the Cairns foreshore and implications for the Trinity Point Project (Environmental Science and Services, 1988).

c. Overview (Bunt, 1989).

(3) Geotechnical Engineering

Vol 1 Field investigation
Vol 2 Laboratory testing
Vol 3 Geotechnical model
Vol 4 Design of reclamation

(Vol 1-3, Hollingsworth Consultants, 1988).
(Vol 4, MacDonald Wagner, 1988).

3.0 RESULTS AND DISCUSSION

3.1 Physical parameters (QDPI)

3.1.1 Lease site profile and sediments

Included in the lease site is approximately 56ha of bare mudflat. This is divided into two separate zones. One zone of about 37ha is adjacent to the esplanade shore line and regularly exposed at low tide. The other 19ha is below Port Datum and borders the shipping channel at its outer edge, and is divided from the exposed mud region by a zone of algae and seagrasses (Fig. 1, Fig. 4a). The mud itself ranges from two to eleven metres thick with a gradient of about 1/500 (see companion report, Geotechnical Engineering Vol 1: Field investigation) (Fig. 4b). The exposed mudflat has two distinct zones: an area that dries completely at low tide and an area that at low tide is crisscrossed with depressions, standing pools of water, and drainage channels (Fig. 1). The 37ha of intertidal unvegetated mudflats within the lease site is part of an estimated 600ha of this habitat in Cairns Harbour.

At times of the year the mudflat immediately adjacent to the esplanade and extending out up to 250m (particularly the area adjacent to the carpark at the eastern end) is covered with a fine encrusting yellow-green algal mat (family Xanthophyceae, Pseudodichotomosiphon sp., Section 3.2 and Appendix 7). Saltcouch also occurs at times in a narrow band (0-15m wide) along the esplanade shore line (Fig. 4a).

The mudflat sediment is predominantly clay and fine silt mud in places with fine to medium sand particles, shell fragments and some organic material. Sand banks overlay a silt clay substrate adjacent to the lease site where the "Sea Lab" is stationed. Particle size analysis at a range of depths is detailed in Appendix 3. Except where vegetation occurs the mud is oxygenated for approximately the surface 50mm.

On one occasion only, as a routine analysis, single samples of the surface sediments at five sites on the lease site were tested for the presence of heavy metals and pesticides. We have included data from identical analysis of sediment in coastal waters of the Great Barrier Reef lagoon (near Fitzroy Island, Cairns) as a comparison and data from vegetation growing on the lease site (Table 1). The test laboratory report is included in Appendix 4.

The results indicate high levels of lead and aldrin in the lease site sediment and some contamination with dieldrin and mercury. There appears to be no established Australian standards for levels in marine muds. The results strongly suggest, however, that independently of this study, a comprehensive survey should be undertaken of the pollutants in the sediments, water and marine life of Cairns Harbour. Of further concern is the appearance of heavy metals and pesticides in the coastal site near Fitzroy Island. In Cairns Harbour sediments, heavy metals and pesticide contamination levels and low oxygen levels make this environment a harsh one for most animals. It is possible that some animals, including commercial and recreational fish and prawn species, may be accumulating these pollutants to levels dangerous for human consumption. The consequences of these alarming contamination levels should be investigated further.

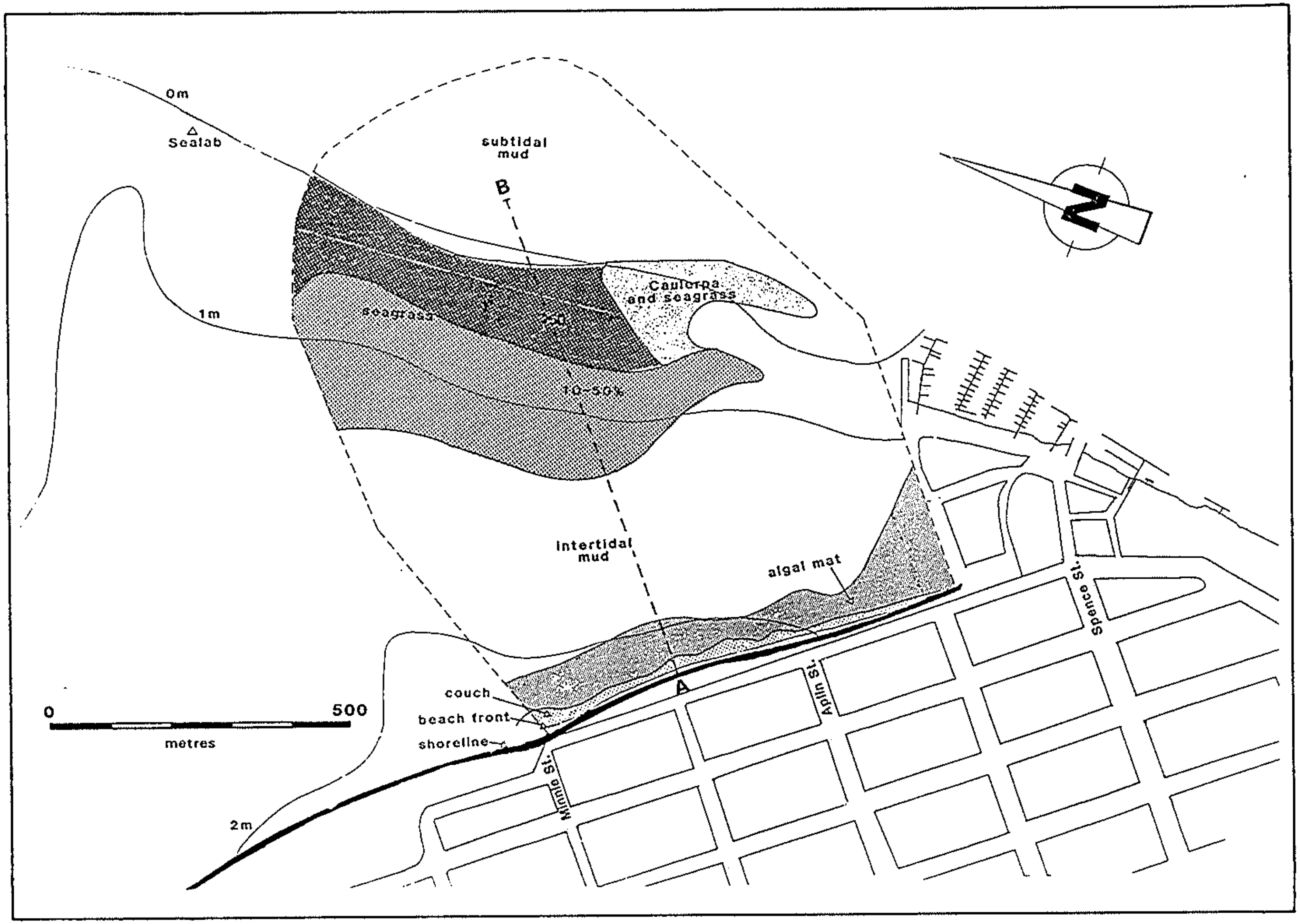


Figure 4a. Areas of major habitat types in the lease site of the proposed Trinity Point Development, showing profile transect:A - B.

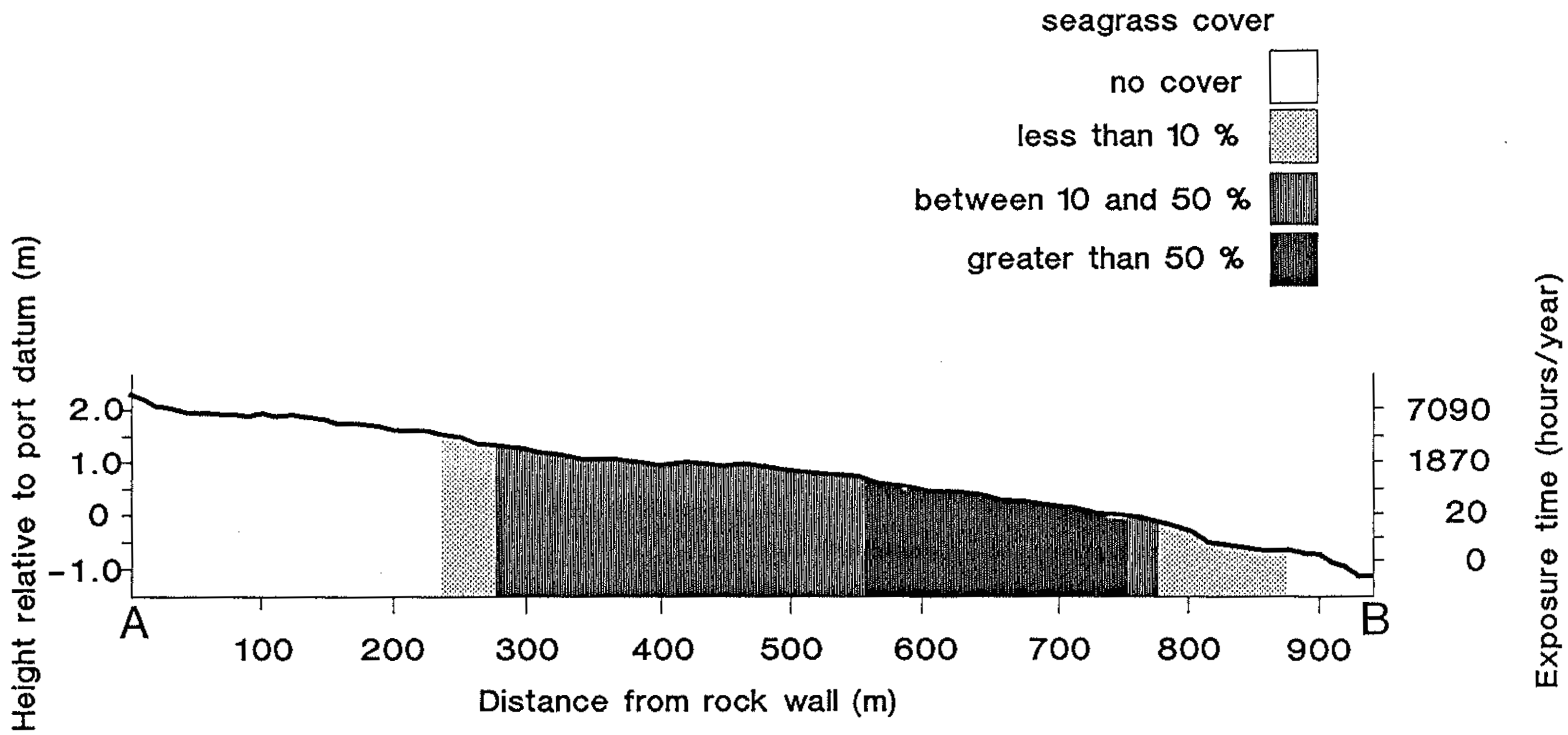


Figure 4b. Representative mudflat profile on lease site showing percentage seagrass cover.

Table 1. Analysis of heavy metal and pesticide levels in mud and seagrass samples from Cairns Harbour and Fitzroy Island.

Heavy Metal	SITE					
	Fitzroy Is. mud	Esplanade mud	Saltwater Ck mud	Sealab Seagrass	Saltwater Ck Seagrass	Sealab Seagrass
Mercury	0.04 ppm	0.29 ppm	0.18 ppm	0.07 ppm	0.04 ppm	0.04 ppm
Cadmium	<0.50 ppm	<0.10 ppm	0.10 ppm	<0.01 ppm	0.20 ppm	<0.01 ppm
Lead	4.40 ppm	0.26 ppm	0.18 ppm	4.70 ppm	5.20 ppm	7.50 ppm
Pesticide						
Endrin	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm
DDT	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm
DDE	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm
DDD	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm
TOTAL DDT	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm
Lindane	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm
Methoxychlor	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm
Dieldrin	<0.002ppm	0.006ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm
Aldrin	0.033ppm	0.271ppm	0.103ppm	<0.002ppm	<0.002ppm	<0.002ppm
Benezene Hexachloride	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm
Oxychlordane	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm
Heptachlor	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm
Heptachlor Epoxide	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm
Hexachlorobenezene	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm	<0.002ppm
Bromophos Ethyl	<0.01 ppm	<0.01 ppm	<0.01 ppm	<0.01 ppm	<0.01 ppm	<0.01 ppm
Chlorpyrifos	<0.01 ppm	<0.01 ppm	<0.01 ppm	<0.01 ppm	<0.01 ppm	<0.01 ppm
Ethion	<0.01 ppm	<0.01 ppm	<0.01 ppm	<0.01 ppm	<0.01 ppm	<0.01 ppm
2,4 D	<0.01 ppm	<0.01 ppm	<0.01 ppm	<0.01 ppm	<0.01 ppm	<0.01 ppm
2,4,5 T	<0.01 ppm	<0.01 ppm	<0.01 ppm	<0.01 ppm	<0.01 ppm	<0.01 ppm

The "<" sign denotes that the concentration in the sample was below detectable amounts.

ppm = parts per million

3.1.2 Water quality - samples

Various indicators of water quality were measured in the study area. Coupled with longer term data from other studies, these will provide a series of base measurements which define the current situation and to which post-development values could be compared.

Water quality was measured at four stations; three at the mouth of the Inlet where salinity and turbidity were measured near the lease site; and one in Smiths Creek which is well within the confines of Trinity Inlet and where salinity, temperature and turbidity were measured (Appendix 2). Because of the high degree of mixing produced by wind driven currents and waves, only surface samples were collected from the shallow water near the lease site. Both surface and bottom samples were collected at Smiths Creek (adjacent to the Northern Fisheries Research Centre) (See Figs 5a, 5b, 6a, 6b, 7a and 7b).

Samples were collected from the lease site and the Smiths Creek site from 20 January 1988 through 30 November 1989. Longer term data collected from the lease site and near Hills Creek on a monthly basis between 1980 and 1987 are also included (Fig. 8).

3.1.3 Salinity

Salinity was highly variable in Smiths Creek and much less variable near the bottom (Figs 5a and 5b). As would be expected, all of the variability was associated with freshwater run-off in the wet season. The greater density of the sea water and reduced mixing in this area maintained a high degree of separation between these water masses. Salinity was more stable near the lease site (Figs 5a and 5b) and became increasingly so with the onset of the south-easterly trade winds and the end of the wet season around March/April. Unseasonal heavy rainfall in November 1989 resulted in a reduction in salinity at all sites (Fig. 5b). Trends over the entire year are shown from data collected between 1980 and 1987 (Fig. 8).

3.1.4 Temperature

Temperature was moderately variable at both surface and bottom sites in Smiths Creek. Temperatures ranged from 32.2°C down to 25.2°C (Figs 6a and 6b) and tended to decrease with the approach of the winter months. This trend is shown more clearly from measurements taken between 1980 and 1987 (Fig. 8). Temperatures as low as 21.5°C were recorded in Cairns Harbour surface measurements between 1980 and 1987 (Fig. 8).

3.1.5 Turbidity

Turbidity during the wet season was highly variable at both the surface and bottom sites of Smiths Creek. Both the variability and level of turbidity decreased during the sampling period with the passing of the wet season and the onset of winter.

Turbidity as measured near the lease site was generally lower than Smiths Creek measurements during the wet season and stabilized about one month earlier at about 10 NTU (Figs 7a and 7b).

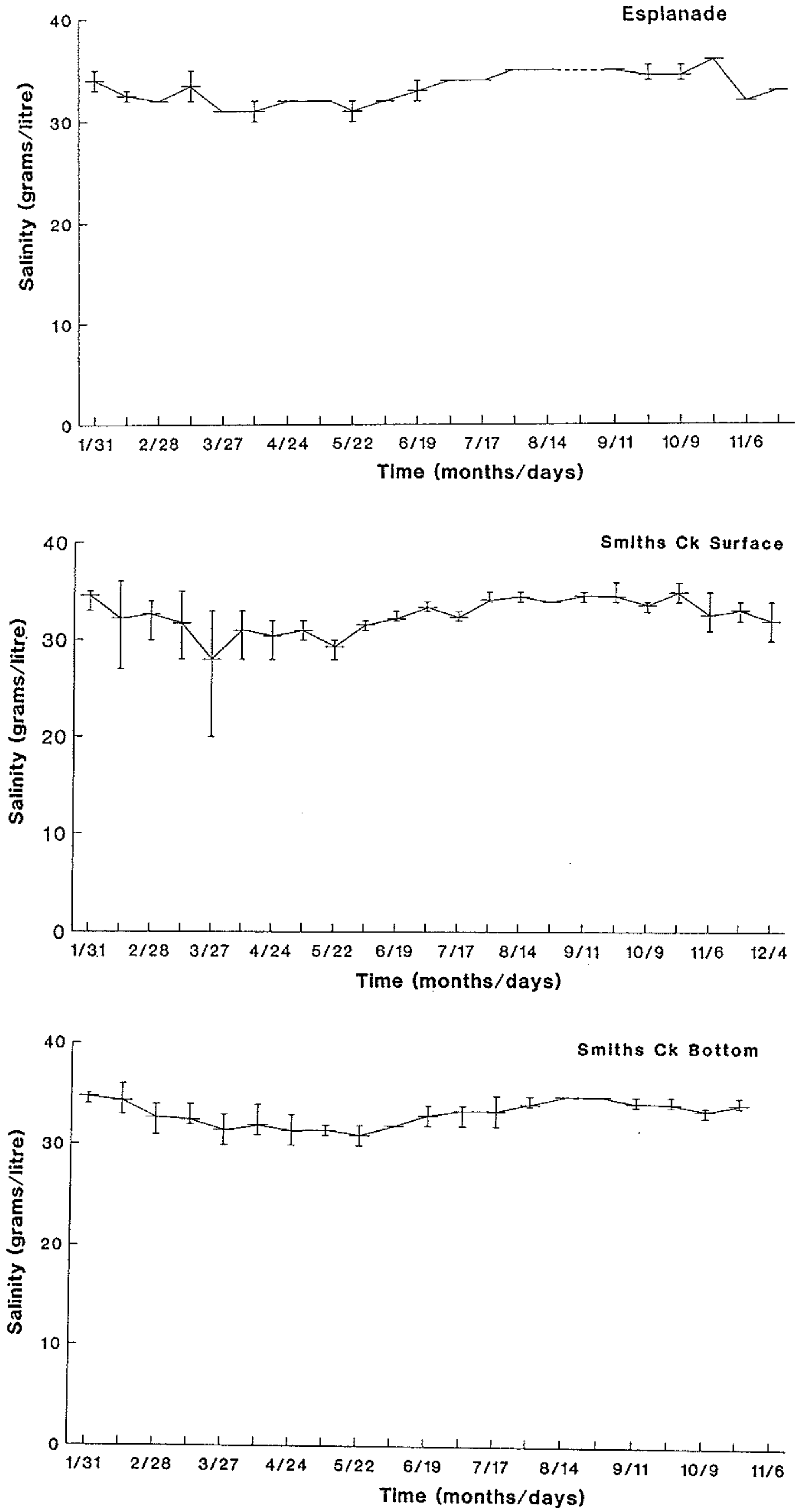
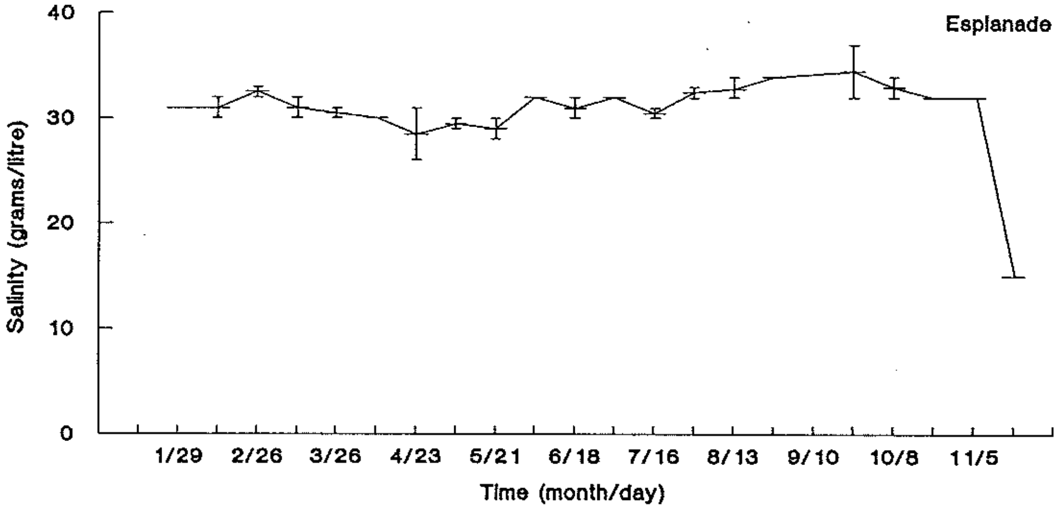
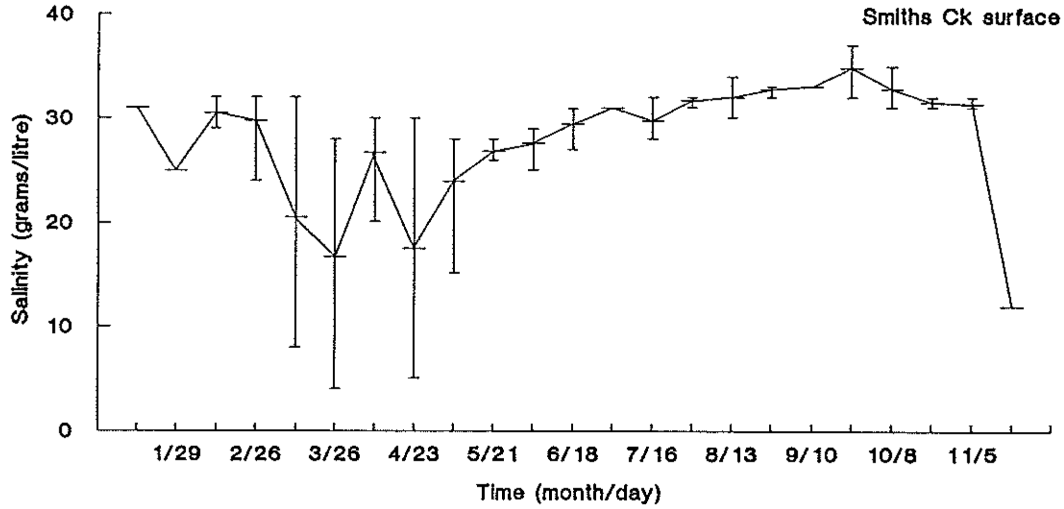


Figure 5a. Fortnightly means and ranges of the water salinity (grams/litre) for the Esplanade Lease site, Smiths Ck surface site, and the Smiths Ck bottom site, 1988





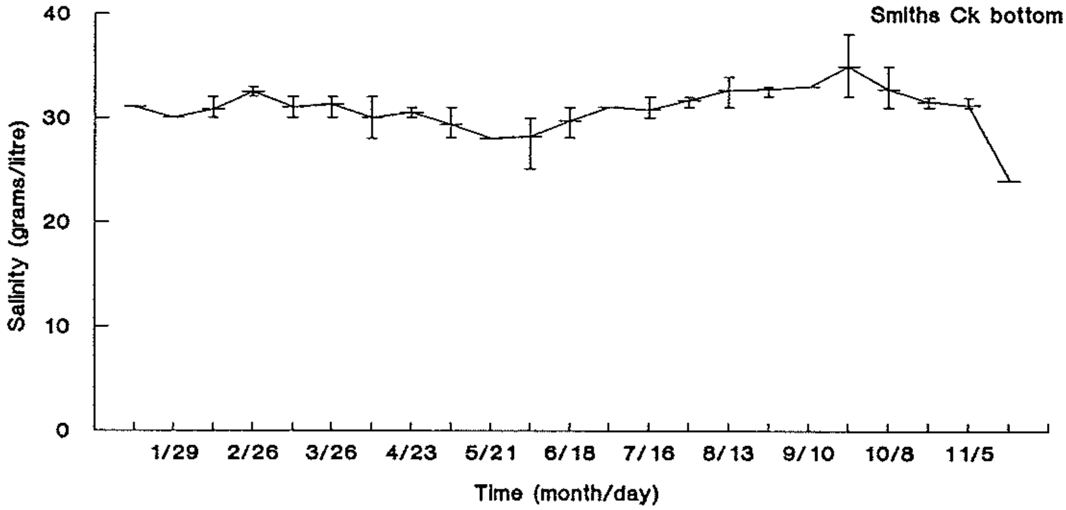


Figure 5b. Fortnightly means and ranges of the water salinity (grams/litre) for the Esplanade lease site, Smiths Ck surface site, and the Smiths Ck bottom site, 1989.

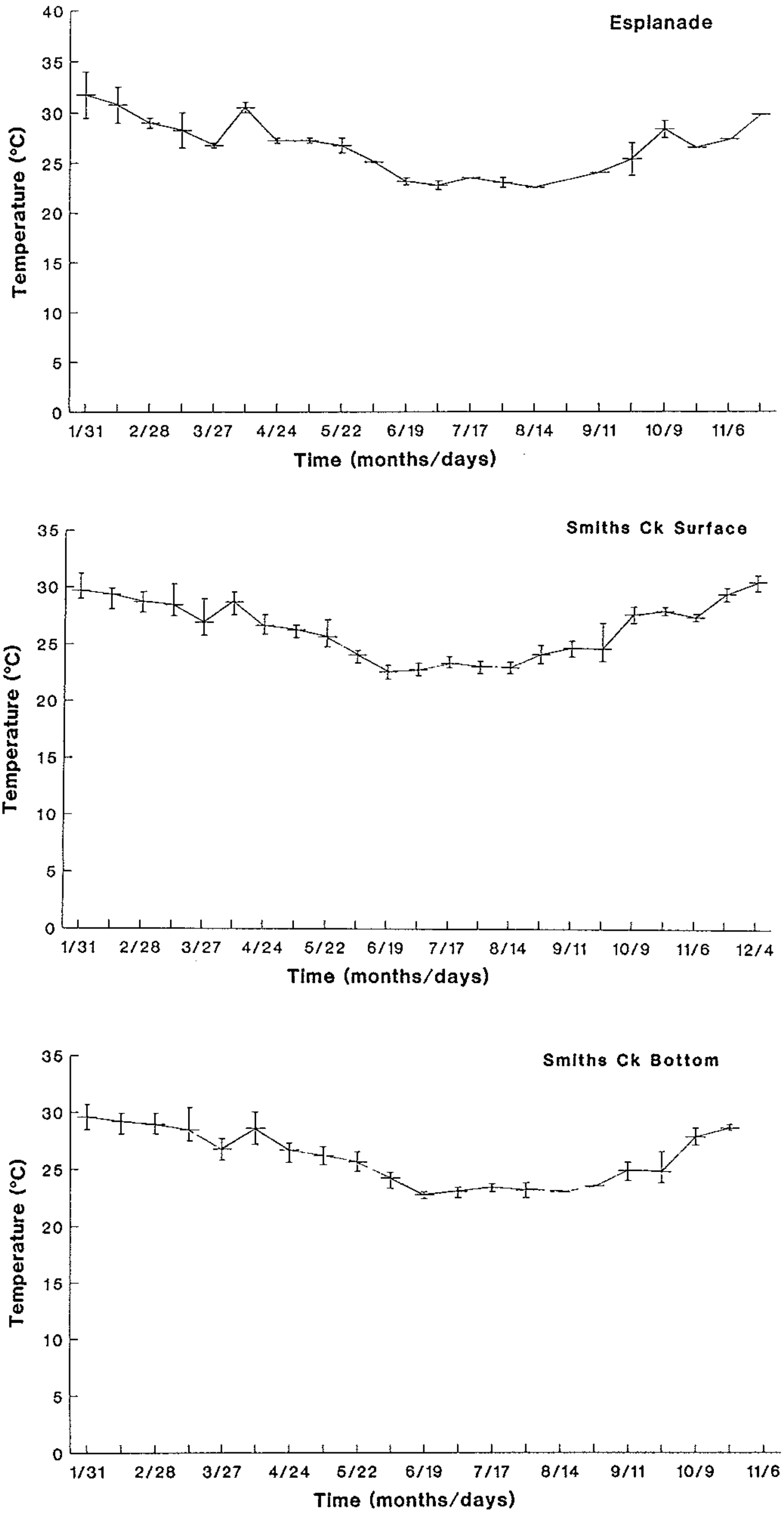


Figure 6a. Fortnightly means and ranges of the temperature (°C), for the Esplanade Lease site, Smiths Ck surface site, and the Smiths Ck bottom site, 1988

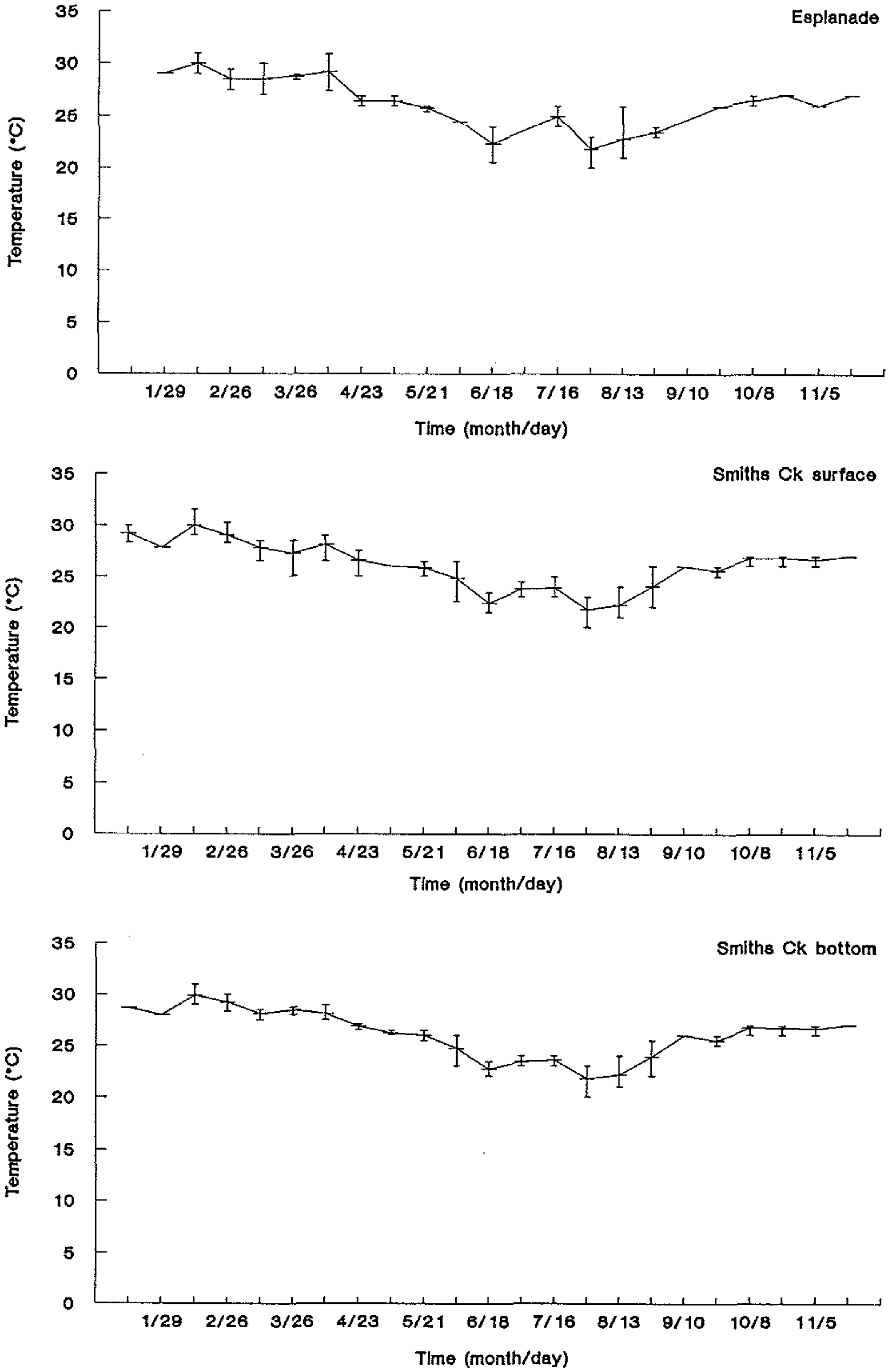


Figure 6b. Fortnightly means and ranges of the temperature (^{o}C), for the Esplanade lease site, Smiths Ck surface site, and the Smiths Ck bottom site, 1989.

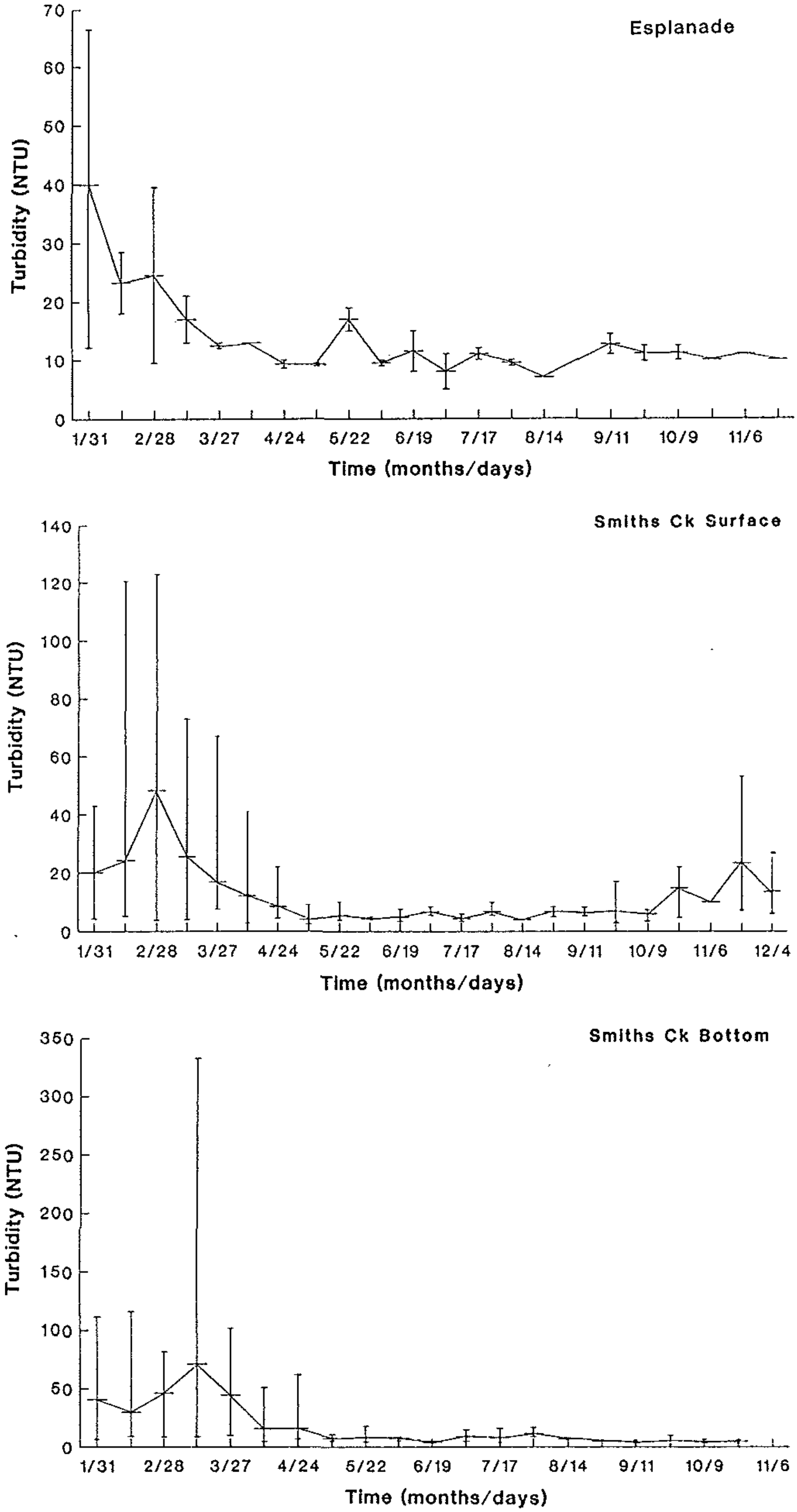


Figure 7a. Fortnightly means and ranges of the turbidity (NTU), for the Esplanade Lease site, Smiths Ck surface site, and the Smiths Ck bottom site, 1988. The inlet was dredged between 3 July and 26 July 1988.

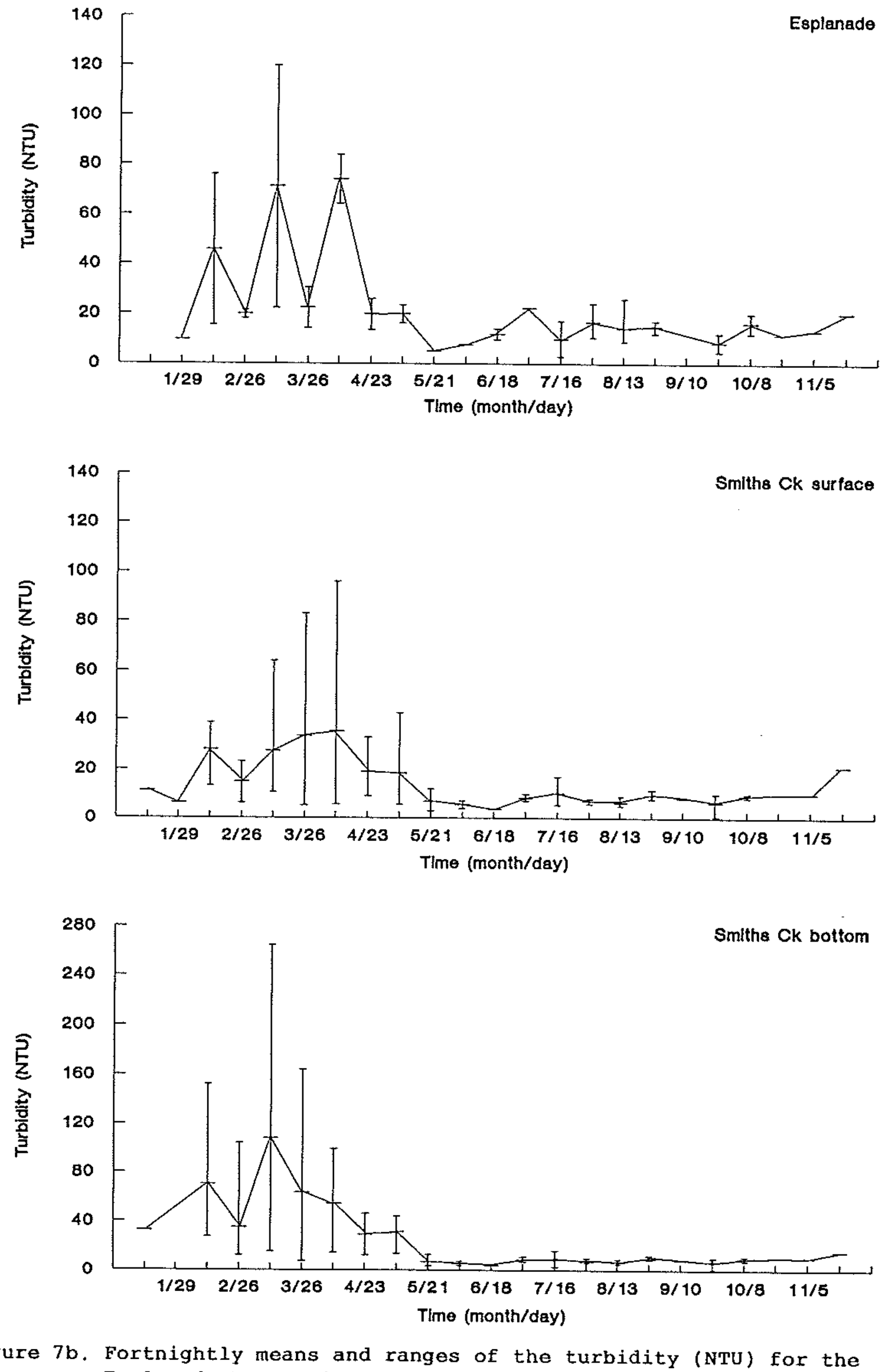
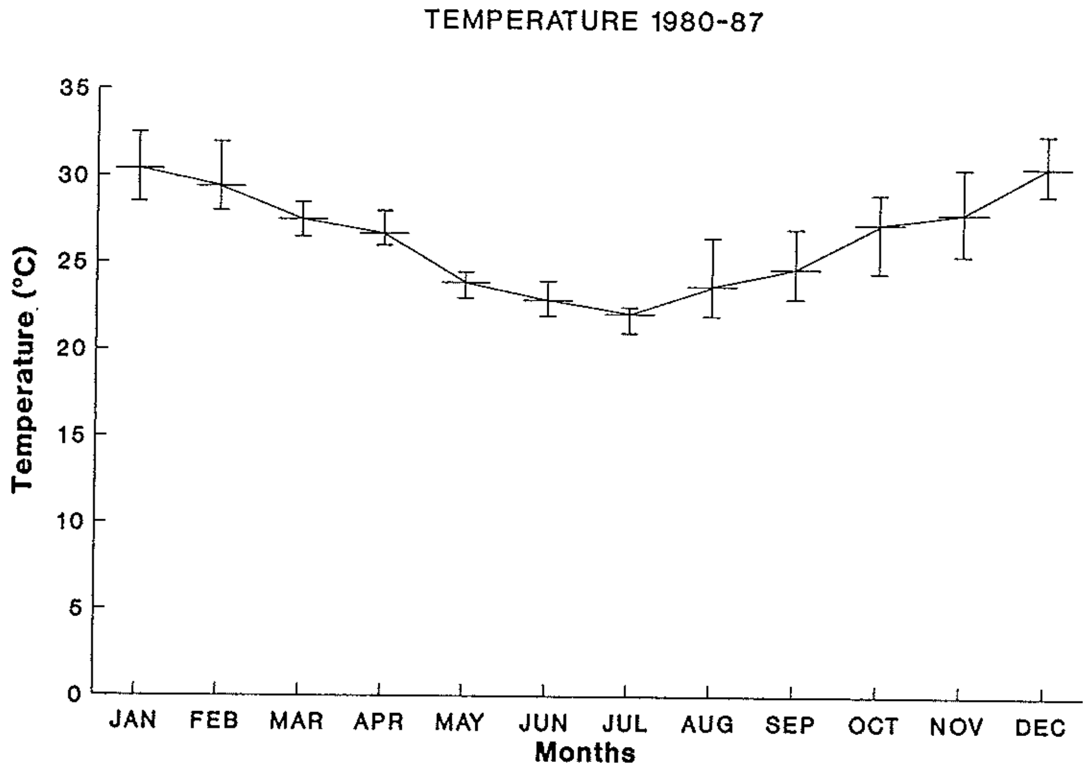


Figure 7b. Fortnightly means and ranges of the turbidity (NTU) for the Esplanade Lease Site, Smiths Ck surface site and the Smiths Ck bottom site, 1989



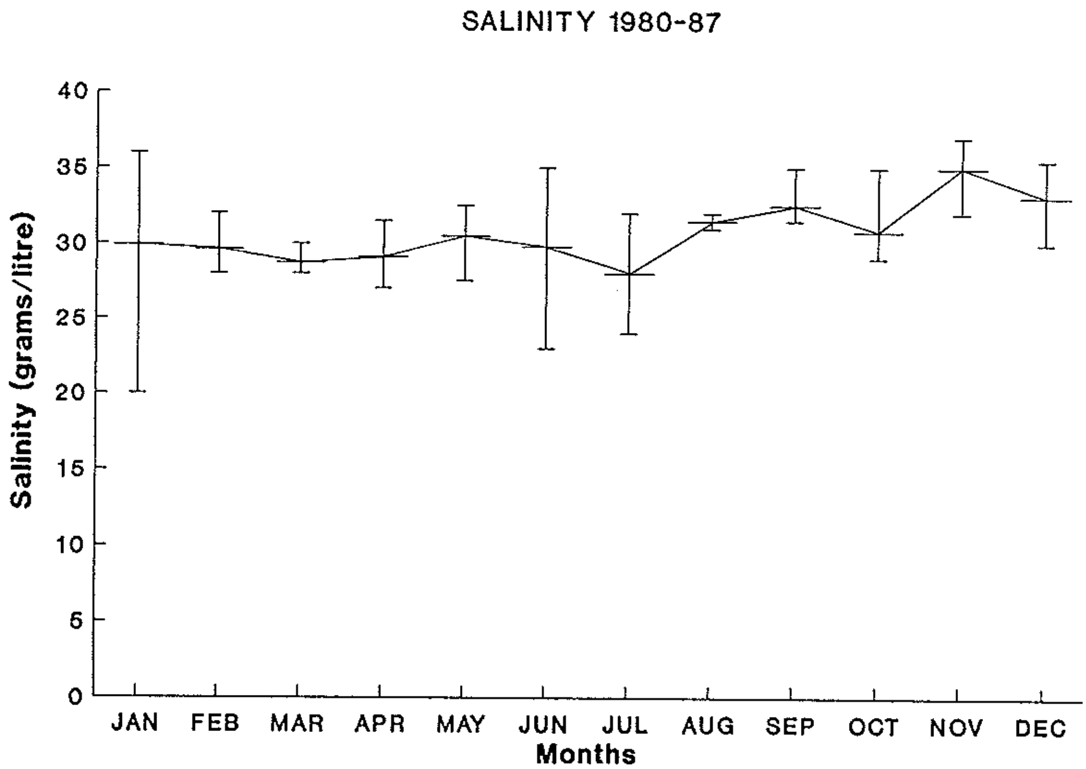


Figure 8. Averages and ranges of surface salinity and temperatures, measured in Cairns Harbour between 1980 and 1987.

3.1.6 Water quality - general

Although the period investigated was too short to establish a comprehensive profile of the water mass of Cairns Harbour, it is possible to draw some conclusions of relevance to the proposed development of the lease site.

Cairns Harbour is a highly variable environment in terms of salinity, temperature and turbidity. This variability is brought about by the "conflicting" influences of a regular seawater influx and egress resulting from tidal action, and seasonal but apparently transitory (because the estuary is small) inputs of turbid fresh water run-off.

Organisms which inhibit use the Cairns Harbour are likely to be rather tolerant of the highly variable nature of their environment. They will, however, have upper and lower physiological limits beyond which growth and behaviour may be affected or their very existence threatened (Section 3.2).

Of potentially greater importance to the marine life are changes in water quality caused by pollution. The introduction of chemicals foreign to natural marine environments can cause damage in even very small quantities. The growing concern over very low levels of tributyl tin (used in some antifouling paints on boats) is a case in point. Water pumped routinely from Smith's Creek for fish hatchery purposes is high enough in tributyl tin to be implicated in chronic poisoning of captive barramundi at the Northern Fisheries Research Centre (Appendix 5).

A one-off analysis of bacterial levels in the seagrass and in the water overlying the lease site at high tide (19-12-88) revealed very high coliform counts and several marine fish pathogens (Appendix 6). This contamination may be localized but its source needs further investigation.

3.2 Seagrass and algal beds

3.2.1 General

Nearshore and estuarine seagrass and algal vegetated areas are important habitats for commercial penaeid prawns (Coles et al., 1987b) and for juvenile fish (Burchmore et al., 1984). Seagrass and algae probably increase the abundance of estuarine fauna by increasing the complexity of the habitat and add to the natural productivity (Heck and Orth, 1980).

Seagrasses provide habitat and food sources for animals (both directly and indirectly), reduce current flow and enhance substrate development. Seagrass roots bind the sediment and reduce erosion, preserving the sediment microflora.

The 13 seagrass species found on Queensland's east coast represent nearly a quarter of the world's seagrass species (Coles et al., 1987b). Those found in the inshore and estuarine regions of the Cairns Harbour are generally species able to withstand fluctuations in the physical and chemical nature of the water and able to colonize unstable muddy substrates. The intertidal seagrasses of Cairns Harbour are interspersed with stands of a Caulerpa algae. There is very little information available on the role algae play in our tropical coastal marine environment. As the Caulerpa algae stands occur only in conjunction with seagrasses they are included with the seagrasses in this discussion.

Mapping of the seagrass and algal beds was performed twice during the course of this study. The first measurement in 1987 used mainly aerial photographs for determining the extent of the beds and was backed up by field observations. These provided a base for comparison with older aerial photographs to determine historical changes. Aerial photographs were only available only for the area of Cairns Harbour between Ellie Point and Bessie Point and for Mission Bay. The second survey was in 1988 and was based on detailed diver records and profile measurements made in the field, and included all of Cairns Harbour and Mission Bay.

3.2.2 Mapping of seagrasses from aerial photographs (Greenway/Hollingsworth)

Cairns Harbour

Figure 9 shows the extent of intertidal mudflats and seagrass beds between Ellie Point and Bessie Point based on colour aerial photography taken in July 1987. At the time the photographs were taken the tide ranged from 0.5m to 0.8m. Due to the highly turbid waters in Cairns Harbour at that time, it was impossible to map the full extent of intertidal seagrass cover. An indication of the seaward extent of intertidal seagrass was obtained by conducting a field survey during the extreme spring tides of August 1987 when low water mark was below 0.0m. The seaward extent of the intertidal seagrass approximated the 0.0m contour (Fig. 9). A full bathymetric survey was performed in April 1988 to produce detailed contour information (see companion reports).

At several field sites established during the August 1987 survey, seagrass cover extended down to a depth of between 0.25-0.5m below Port Datum. (Detailed dive surveys by QDPI in February and June 1988 (Fig. 15 Section 3.2.3) placed the lower range of seagrasses at 3.7m below Port

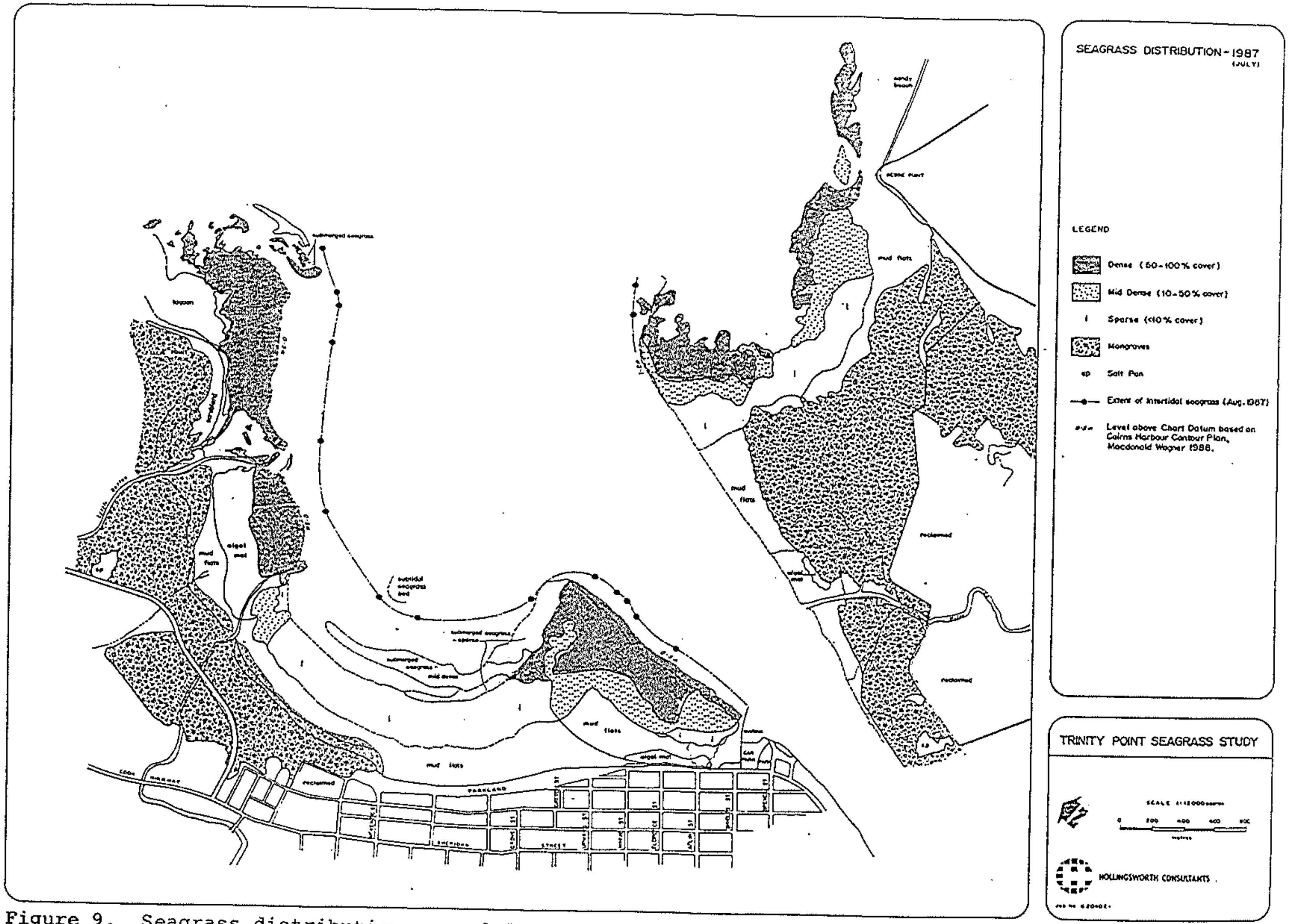


Figure 9. Seagrass distribution mapped from 1987 aerial photographs.

Datum although only one seagrass species (Halodule pinifolia) reaches this lower depth). The most extensive seagrass meadows in subtidal waters between Ellie Point and Bessie Point in 1987 were off Bessie Point, east of the shipping channel. The dominant seagrass species in this region was Halodule pinifolia which formed pure stands. Halodule pinifolia also occurred subtidally along the western side of Trinity Bay between Minnie Street and Ellie Point in both sandy and muddy substrates. Halophila ovalis extended to a depth of 0.25-0.5m below Port Datum in the vicinity of the Trinity Point Development lease site. The distribution of this seagrass however was patchy and individual specimens were small.

In an attempt to quantify abundance, three categories of seagrass have been mapped from aerial photographs based on percentage cover (Fig. 9) of the sediment surface.

The most luxuriant seagrass beds categorised as dense occurred at the four locations of Ellie Point to Little Barron River, Little Barron River to Saltwater Creek, offshore from Grove Street to Florence Street, and off Bessie Point. The total area of these dense beds between Ellie Point and Bessie Point, measured seaward to approximately 0.5m above Port Datum, was about 177ha.

While the August 1987 field measurement (Fig. 9) showed that seagrass occurred at 0.0m and in some places to 0.5m below Datum, at least another 167ha of seagrass could be expected to occur between the -0.5m contour level and the 0.0m contour. 0.0m was the deepest seagrass could be mapped from the 1987 photographs. Areas of submerged dense seagrass visible in the 1987 photographs and mapping from 1952, 1971 and 1974 aerial photographs (see Figs. 10, 11 and 12, see also Appendix 8) indicated that a continuous band of dense seagrass may have occurred below the 0.0m level between Saltwater Creek and offshore from Grove Street. Thus at least 100ha of dense seagrass may have been present in the Cairns Harbour (between Ellie Point and Bessie Point) between -0.5m and 0.0m contours in 1987.

Sparse and mid-dense seagrass beds are characterised by patchy seagrass cover amongst bare mud or sand. These sparser beds generally occurred landward of the denser beds. The 1987 aerial photographs also indicated the presence of submerged sparse seagrass in tidal flats between Gatton Street and MacKenzie Street.

Bare mudflats characterise the uppermost intertidal areas which are exposed daily. A conspicuous algal mat covered the mud between Little Barron River and Saltwater Creek and offshore areas between Upward Street and Shields Street, and probably results from receiving drainage runoff rich in nutrients.

Isolated clumps of seagrass occurred in small depressions and drainage channels in the mudflats between Saltwater Creek and Shields Street, and the shipping channel and Bessie Point. These isolated clumps represent the landward extent of seagrass.

Mission Bay

The extent of exposed intertidal seagrass beds in Mission Bay was also measured from July 1987 aerial photography. Again it was impossible to map seagrass much beyond the level of the tide at the time of the aerial photographs due to poor visibility through the turbid water. The area of

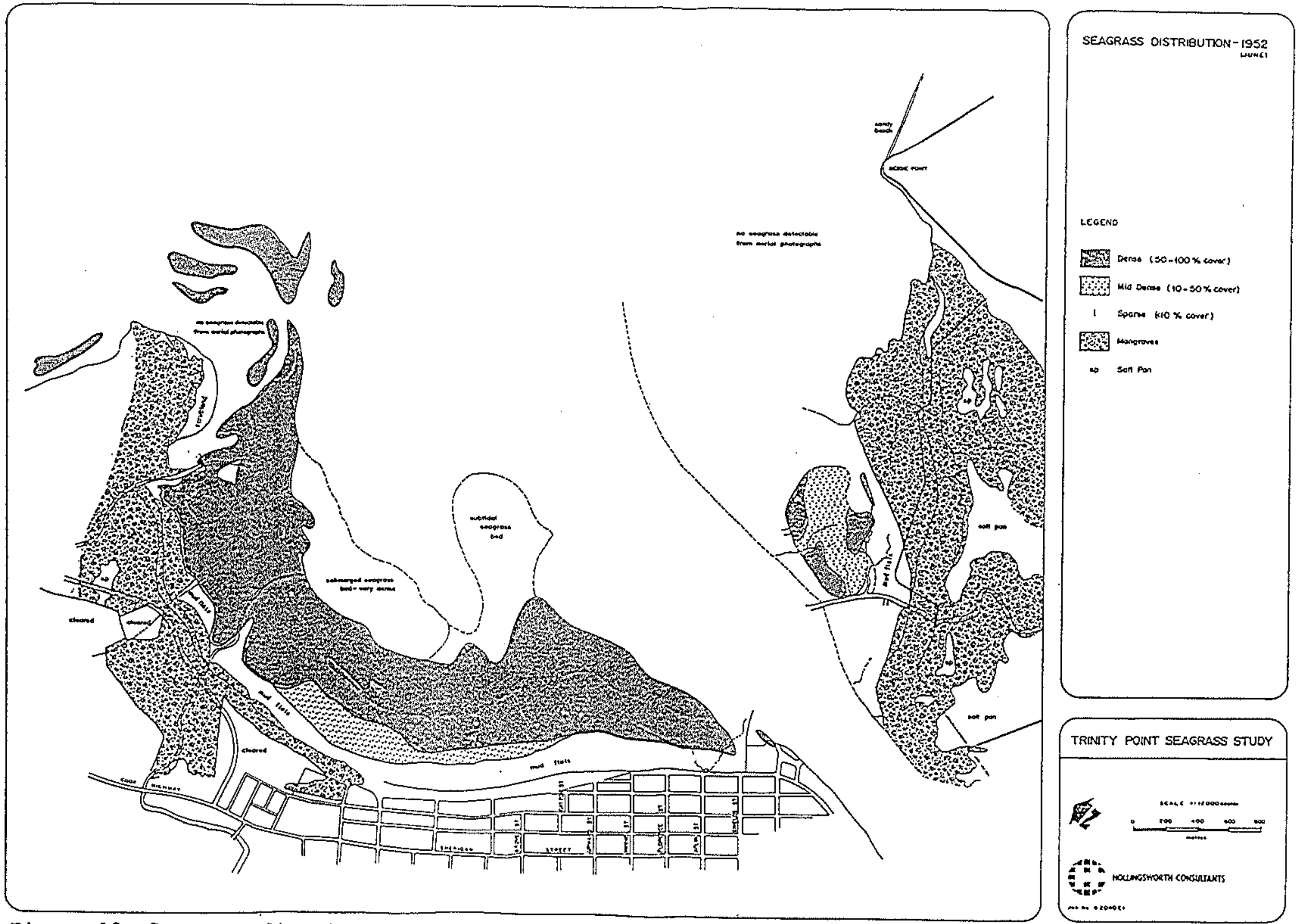


Figure 10. Seagrass distribution mapped from 1952 aerial photographs.

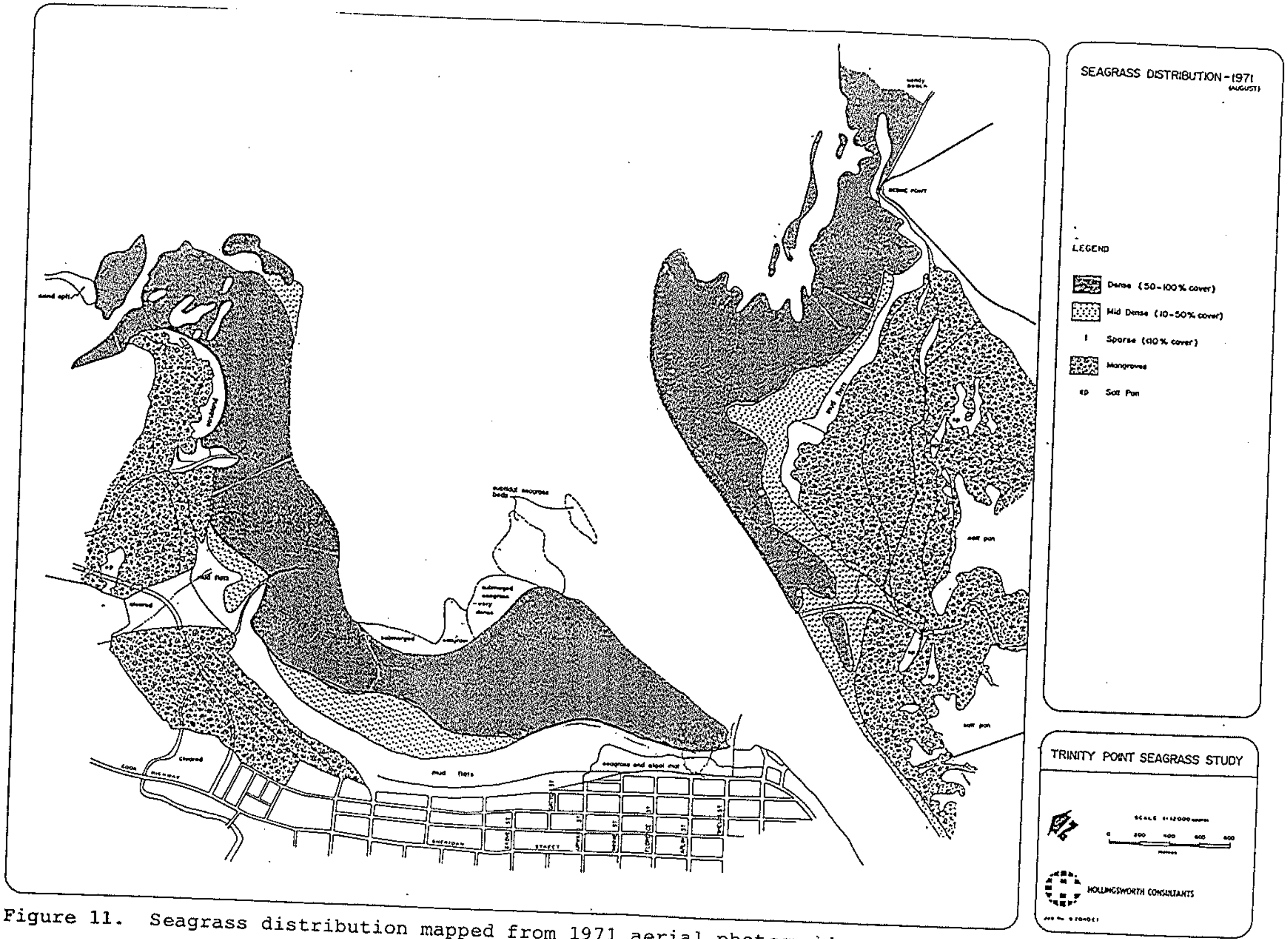


Figure 11. Seagrass distribution mapped from 1971 aerial photographs.

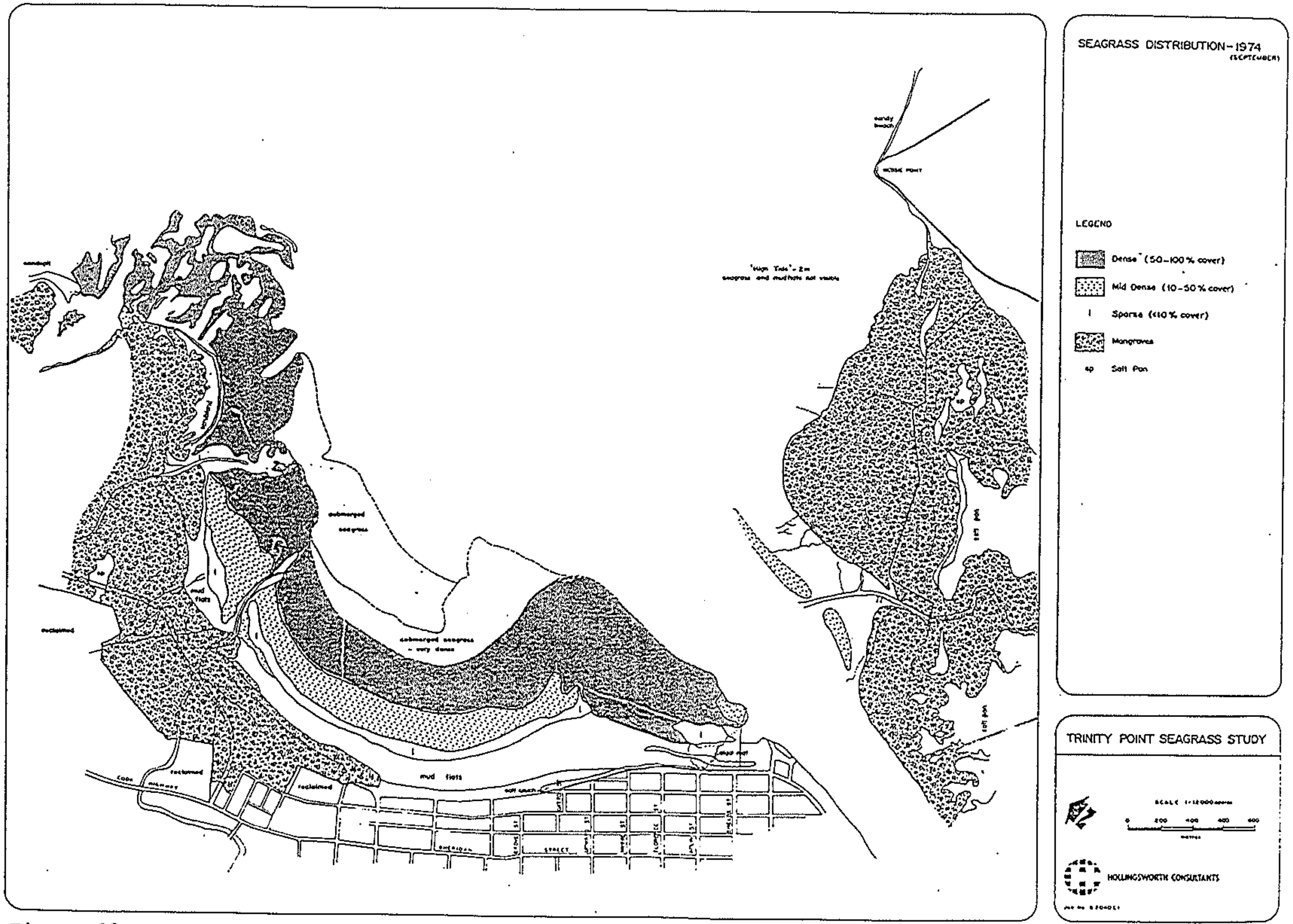


Figure 12. Seagrass distribution mapped from 1974 aerial photographs.

visible dense seagrass cover in Mission Bay was estimated from aerial photographs to be 206ha.

Lease Site

Mid-dense seagrass (10-50% cover) within the Trinity Point Development lease site in 1987 was estimated from aerial photographs to be 12.7ha. Dense seagrass (50-100% cover) within the Trinity Point Development site was estimated as 22.0ha.

3.2.3 Diver estimates and field surveys of seagrass - 1988 (QDPI)

Eight species of seagrass were collected in the Cairns Harbour by divers on survey transects and by collection at low tide (Fig. 13). A shallow water seagrass mimic, the algae Caulerpa sertularioides, was found in algal beds amongst predominantly seagrass communities. It possesses features similar to those of some seagrass species and quite different from the algal mat (Pseudodichotomosiphon sp.) found covering much of the exposed mud flats in the Cairns Harbour.

Of the specimens collected, Zostera capricorni was the most common, being found in 22 of the 59 sample sites that contained seagrasses (Fig. 14). The depth range of the seagrass species overlapped. All of the seagrass species found in the Cairns Harbour were also found on the lease site. The only species that was found in deeper water in the Cairns Harbour was Halodule pinifolia, a pioneering seagrass common to estuaries and often associated with prawn nursery grounds (Fig. 15).

While all but the thin form of Halodule uninervis occurred at depths above Cairns Port Datum, Zostera capricorni appeared to be the most resistant to exposure and was found as much as 1.0m above Port Datum.

Seagrasses in the Cairns Harbour were more restricted in depth range than at any other locations surveyed along the tropical eastern Queensland coast (Coles et al., 1987b). Cairns Harbour seagrasses ranged from 1.0m above Port Datum to a maximum depth of 3.7m below Port Datum. These same species occupied a depth range from 0.0m to 10.0m below mean sea level at other sites along the coast (Coles et al., 1987b). It is likely that the reason for this difference in depth range is the reduced light levels at depth in Cairns Harbour due to turbidity.

The total areas of seagrass cover were recorded in February and March 1988 by diving and by recording the presence or absence of seagrass on the bottom (Appendix 2). Distribution maps prepared using these methods were verified by re-examining subtidal areas in June 1988 and by low level observation from a helicopter in May 1988.

Using divers to check for presence of seagrass, the areas of seagrass cover on the lease site, in Cairns Harbour and in Mission Bay were estimated (Table 2). This was compared with estimates of seagrass areas between Townsville and Cape York made by QDPI using similar methods (Coles et al., 1987a; Coles et al., 1987b). The lease site seagrasses were 0.04% of the estimated total area of 69 398ha of seagrass between Townsville and Cape York. Cairns Harbour seagrasses were 0.7% of this total and Cairns Harbour and Mission Bay together were 1.3% of the total area. Seagrass areas in the Cairns Harbour estimated by divers to have 10% or greater cover of the bottom in 1988 are shown in Figure 16.

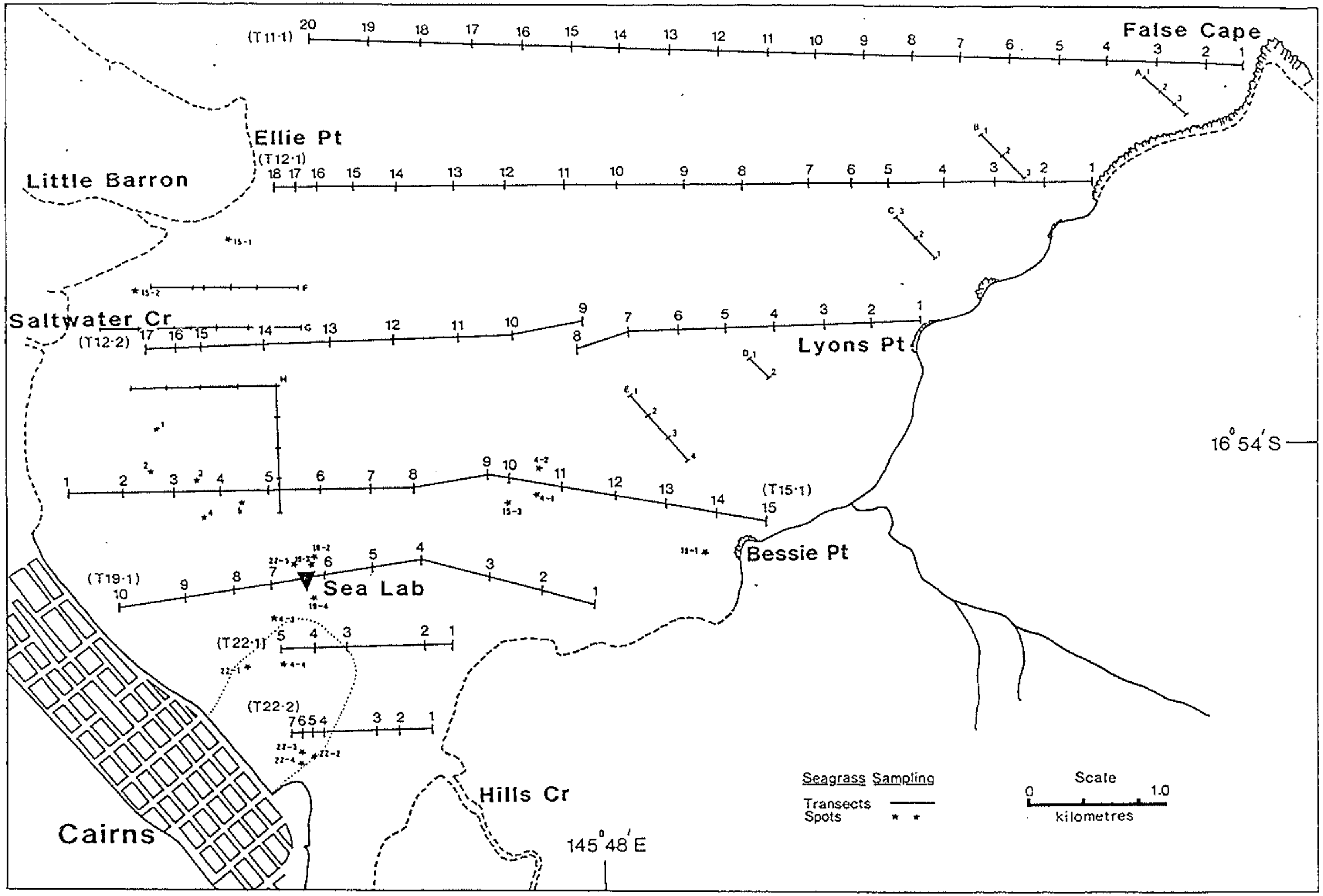


Figure 13. Seagrass sampling sites in Cairns Harbour.

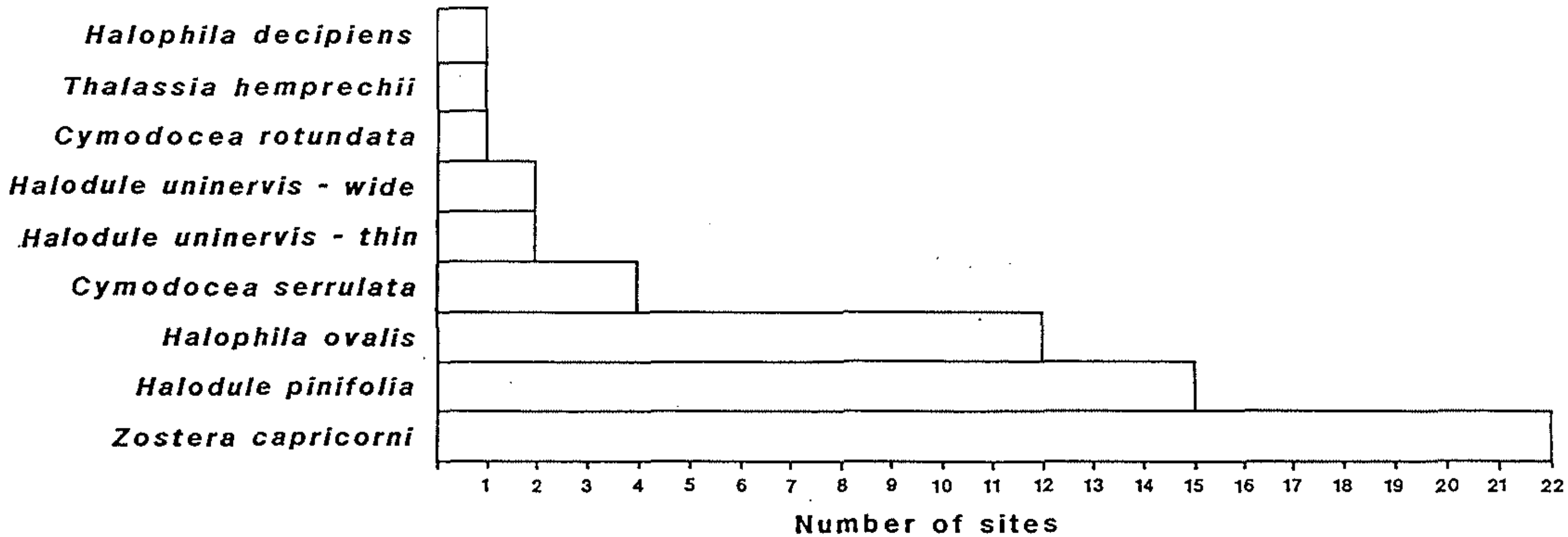


Figure 14. The number of sites at which each seagrass species was found in Cairns Harbour.

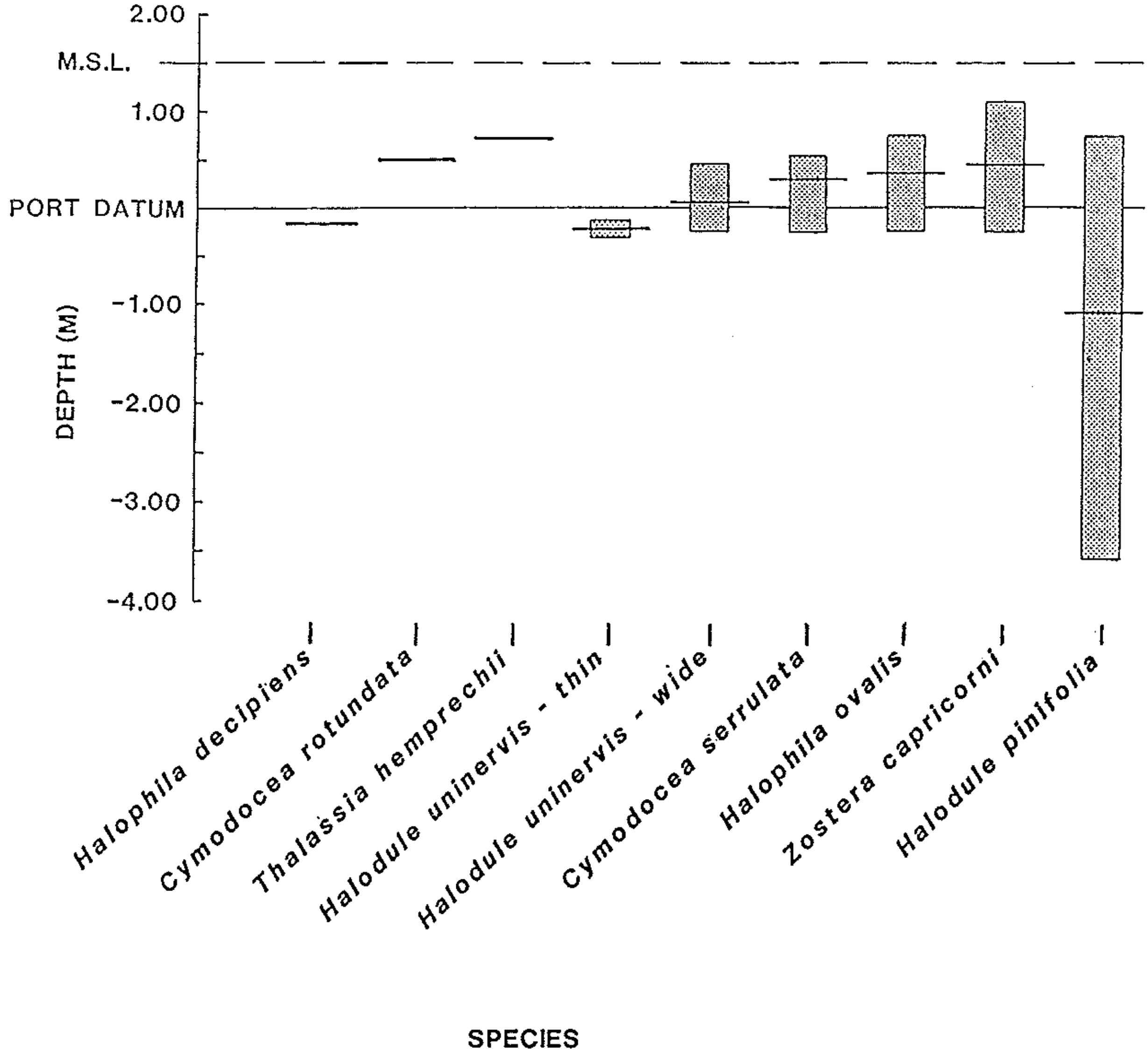


Figure 15. Depth range of seagrass species in Cairns Harbour.

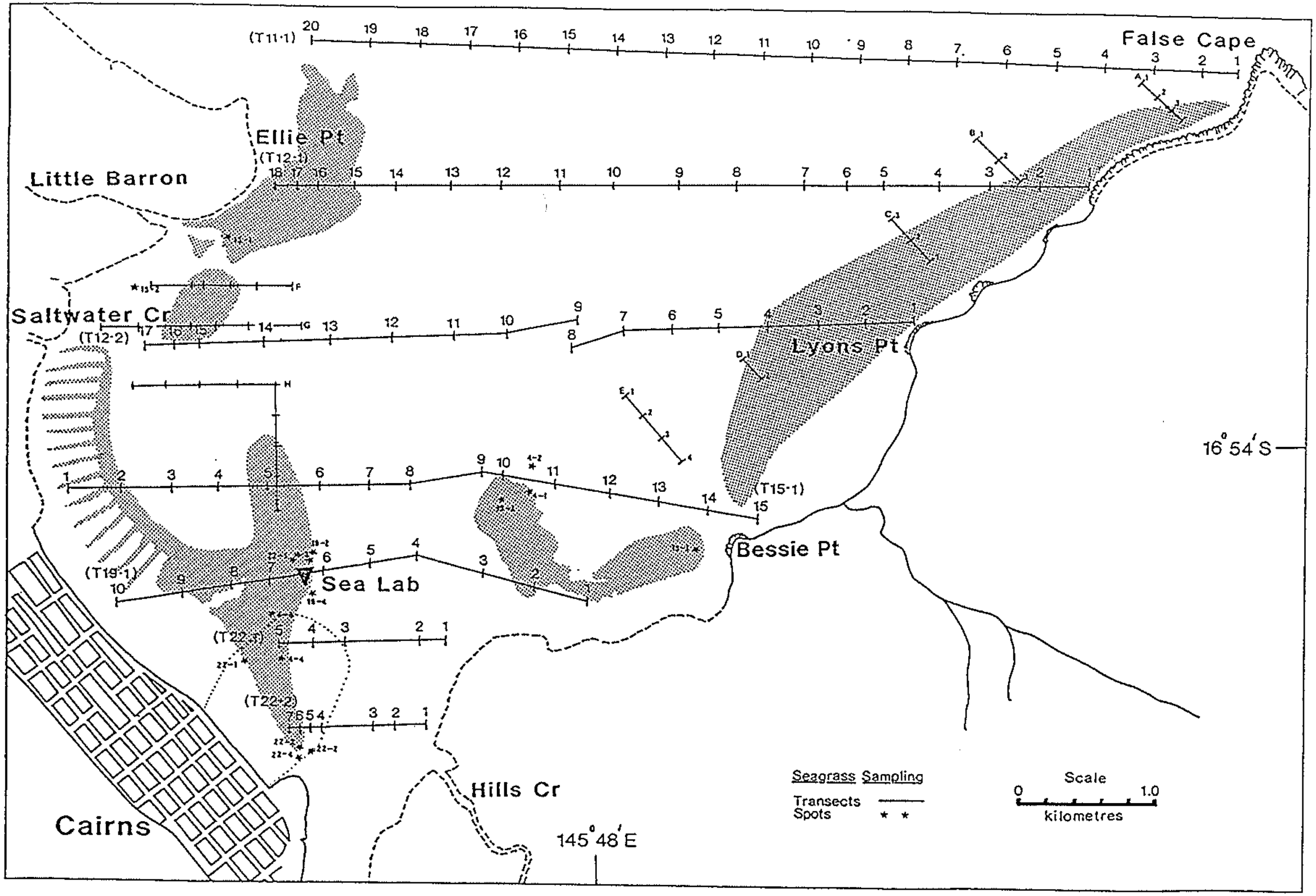


Figure 16. Distribution of seagrass density greater than 10% in Cairns Harbour.

Table 2. Estimates based on QDPI surveys of seagrass areas for Cairns Harbour and the coastal region between Townsville and Cape York. Only areas with seagrass bottom cover between 10% and 100% are considered.

Location	Area (ha)	Seagrass Cover % of Cairns Harbour	Seagrass Cover % Of Cairns + Mission Bay	Seagrass Cover % Of Townsville to Cape York
Lease Site	25	5.0	2.9	0.04
Esplanade	88	17.6	10.0	0.13
Channels (Esplanade)	22	4.4	2.5	0.03
Ellie Point	99	19.8	11.3	0.14
Number 18 Lead	36	7.3	4.2	0.05
Bessie Point	21	4.2	2.4	0.03
Bessie Point - False Cape	209	41.8	23.8	0.3
CAIRNS HARBOUR TOTAL	**500**	**NA**	**57.1**	**0.72**
MISSION BAY	**376**	**NA**	**42.9**	**0.54**
CAIRNS HARBOUR AND MISSION BAY	**876**	**NA**	**NA**	**1.26**
TOWNSVILLE TO CAPE YORK	**69 398**	**NA**	**NA**	**NA**

3.2.4 Discussion of photographic and diver surveys of seagrass

There are small differences in areas calculated from aerial photographs taken in 1987 and those calculated from diver surveys in 1988. Three factors contribute to this:

a. Natural year-to-year variations in seagrass cover have resulted in slightly different total areas.

b. Seagrass and algal mats, and discoloured muddy areas are difficult to distinguish using high altitude aerial photographs.

c. Diving surveys included some intertidal seagrasses not included in aerial photograph analysis. This is particularly so for Bessie Point to False Cape (not included in aerial photographs) and in Mission Bay.

In calculating areas for seagrass prawn nursery grounds we have included all but the areas of isolated seagrass plants (<10% cover). We have used QDPI 1988 estimates in Cairns Harbour and QDPI and Hollingsworth data for seagrasses in Mission Bay.

Both the 1987 and 1988 surveys suggest most seagrasses are found between one metre above Cairns Port Datum to 0.5m below the Port Datum. Halodule pinifolia is found down to 3.7m but only outside False Cape where the water is less turbid.

While it is easy to understand why seagrasses are limited in their upper depth range by exposure and dehydration, the factors which control the deeper end of their distribution are more complex. Coles et al. (1987b) have shown that most tropical seagrasses have maximum densities between two and six metres below mean sea level. They also suggest that depth limitation is likely to be a consequence of photosynthetic requirements. Turbid coastal waters quickly filter out sunlight so that photosynthetic activity may only occur occasionally or only at the lower tidal levels. The results of Greenway's work (Section 3.2.6) demonstrated that photosynthesis fell away quickly for seagrass in Cairns Harbour as light intensity was reduced. Light levels of about 100uE/m^2/sec probably represent the limit for photosynthesis detectable by seagrass species.

The restricted maximum depths of the Cairns Harbour seagrasses indicate that turbidity levels are likely to be high and sustained for longer periods of time. This supposition is consistent with high levels of turbidity caused by tidal activity in a muddy tropical mangrove estuary in a high rainfall area. It can also be aggravated indirectly by agricultural activities within the estuary's catchment, and directly by dredging and reclamation works within the Cairns Harbour because both of these processes are likely to increase turbidity. If silty agricultural run-off or dredging and reclamation activities occur at a time when the estuary would normally have been less turbid, then the long-term photosynthetic production of the seagrasses is likely to be reduced. With time, the deepest beds will be unable to meet their metabolic requirements and will be lost. The width of the seagrass strip will become narrower.

The impact of dredging and reclamation works on seagrass productivity could be reduced by co-ordinating these activities with the seasonally high periods of turbidity which coincide with the wettest months of the year (Section 3.1.5).

3.2.5 Seagrass biomass and shoot density (QDPI)

The seagrass species were identified and the biomass quantified for the Cairns Harbour. This information was collected to: (i) compare values found on the lease site with those elsewhere in Cairns Harbour; and (ii) to compare values found in the Cairns Harbour with those found elsewhere on the eastern Queensland coast. The methodology of seagrass collection and analysis is set out in Appendix 2.

Shoot density and above ground biomass are two measures of the spatial complexity of a seagrass community and consequently of the availability of shelter and food for the number of species that use seagrass as a habitat.

Shoot density in Cairns Harbour ranged up to a maximum of 4 798 shoots per square metre of bottom for Halodule pinifolia (Fig. 17). Shoot density on the lease site reached a maximum of 1 416 for Zostera capricorni in a square metre of bottom.

The largest biomass recorded was for Zostera capricorni with 78.8g dry weight of stems and leaves per square metre of bottom. The largest biomass recorded within the lease site was 54.5g dry weight of stems and leaves per square metre, also of Zostera capricorni.

These biomass figures are amongst the largest that have been previously recorded in tropical Queensland coastal waters (Coles et al., 1987a and 1987b). The implication is that the seagrass beds with the greatest above ground biomasses are living well within their range of limiting conditions and were growing well for some time prior to the time of sampling.

Similarly, shoot density within Cairns Harbour was high when compared with samples collected by Coles et al. (1987a and 1987b) from other sites along the tropical Queensland coast.

Figure 17 also shows the below ground biomass. This measure is also indicative of the vigour of the seagrass community and is directly related to the ability of the seagrass to bind and stabilize the substrate. Zostera capricorni had the greatest below ground biomass. It occurred in the greatest number of sample sites and, with the exception of Halodule pinifolia, had the greatest depth range (Fig. 15).

3.2.6 Seagrass productivity (Greenway/Hollingsworth)

Production measurements for shoots of Zostera capricorni, Thalassia hemprichii and Cymodocea serrulata were obtained between 17 and 22 January 1988 using in situ marking techniques. Eight stations were selected (Fig. 18) and at each station a $0.063m^2$ quadrat was marked off. The blades of 20-50 shoots within each quadrat were marked at the base (blade-sheath junction) either with a metal staple or a hole. After three to five days the shoots within each quadrat were harvested and the new growth (ie. between blade base and staple or hole) over that period measured. The number of shoots in each $0.063m^2$ quadrat was counted then an estimate of production per square metre was calculated (Table 3).

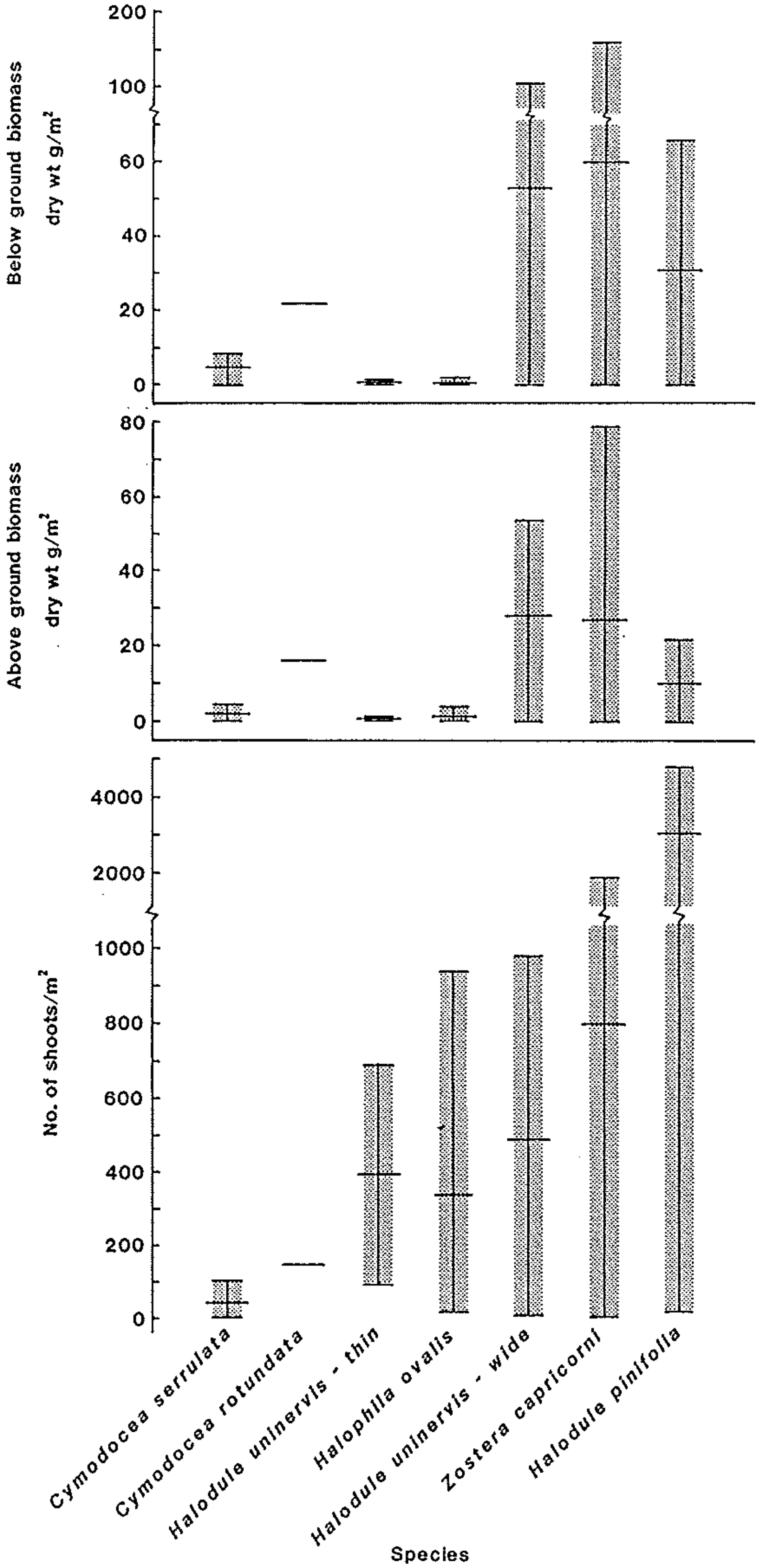


Figure 17. Shoot density, above ground biomass and below ground biomass for seagrass species in Cairns Harbour.

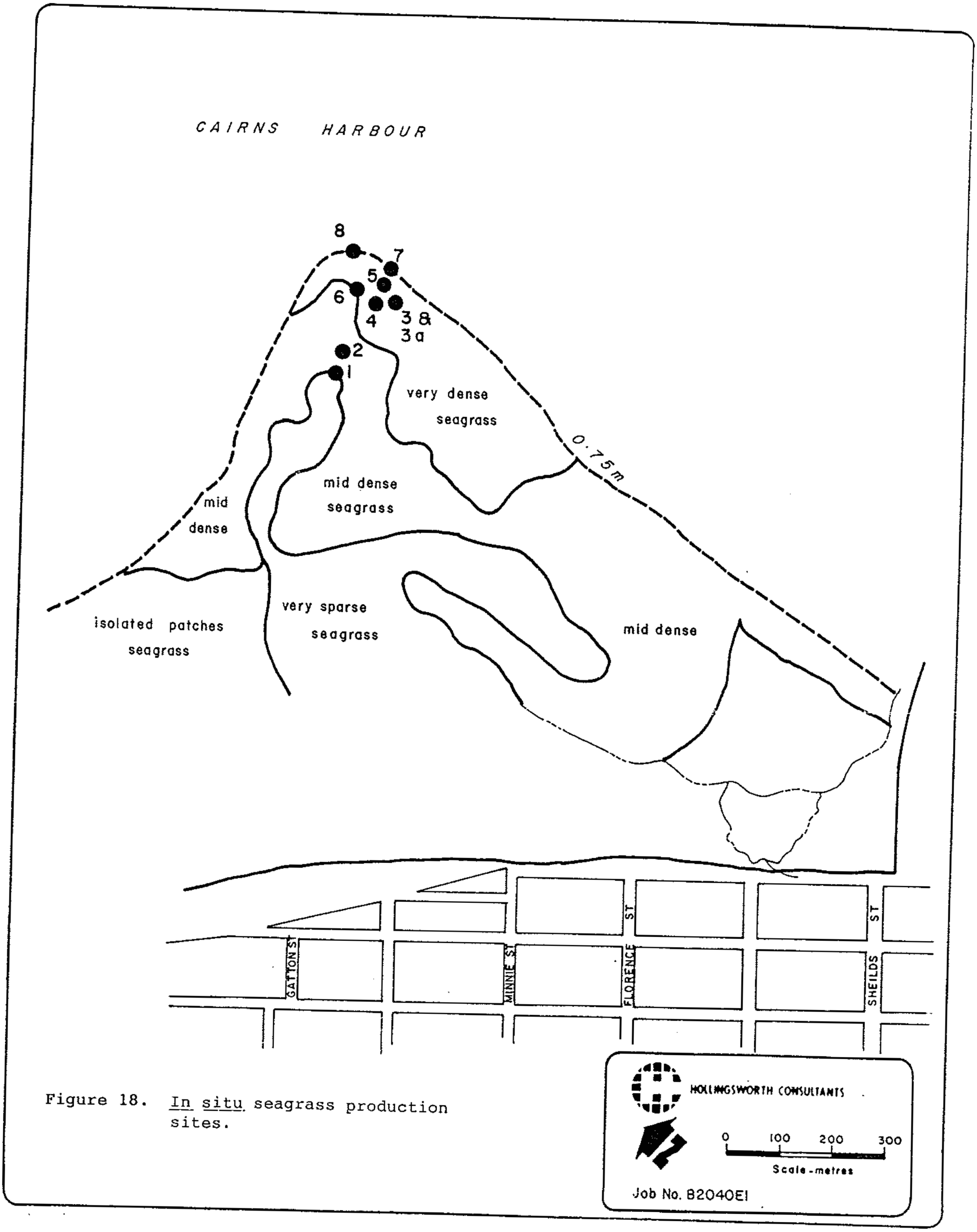


Figure 18. *In situ* seagrass production sites.

Table 3. Seagrass shoot production in Cairns Harbour (marking technique January 1988).

Station Number	Genus	Dry wt increase (mg)/shoot/day $X \pm SD$	No. of shoots per 0.063 m^2 quadrat	Estimated dry wt g/m^2
1 - Isolated clump exposed at 0.98m tide level	Zostera	0.99 ± 0.42	116	1.84
2 - In drainage channel exposed at 0.96 tide level	Zostera	0.91 ± 0.46	120	1.75
3 - In tidal pool, exposed at 0.95m tide level	Zostera	1.53 ± 0.41	90	2.20
3a - In tidal pool, exposed at 0.95m tide level	Thalassia	1.94 ± 0.75	64	1.99
4 - In tidal pool, exposed at 0.90m tide level	Thalassia	1.94 ± 0.75	64	1.99
5 - In tidal pool, exposed at 0.85m tide level	Thalassia	2.18 ± 0.82	56	1.95
6 - In tidal pool, exposed at 0.85m tide level	Thalassia Zostera	1.42 ± 0.65 0.64 ± 0.18	70 12	1.71
7 - Exposed at 0.85m tide level; sandy substrate	Thalassia Cymodocea	1.98 ± 0.72 0.97 ± 0.34	40 26	1.79
8 - In tidal pool, exposed at 0.77m tide level	Cymodocea Zostera	1.99 ± 0.70 0.63 ± 0.29	46 20	1.67

In addition, production measurements for shoots of Zostera capricorni, Thalassia hemprichii, and Cymodocea serrulata were determined under different light intensities by the lacunal gas discharge method (Roberts and Moriarty, 1987). Shoots were subjected to varying light intensities in the field and the amount of gas discharged, which is a measure of photosynthesis (Roberts and Moriarty, 1987), was plotted against irradiance. Figures 19a, 19b and 19c are the resultant photosynthetic saturation curves for Zostera capricorni, Cymodocea serrulata and Thalassia hemprichii respectively. They indicate the relationship between photosynthetic activity (lacunal gas-ml/hr/shoot) and increasing light intensity (irradiance - uE/m^2/s).

Table 4 gives irradiance values recorded immediately above the seagrass at Station 4 with a falling tide on a sunny day. With complete cloud cover, however, irradiance values above the seagrass were reduced by as much as 90%.

These irradiance values serve to illustrate how little light is reaching the seagrass, nevertheless the dry weight production values obtained show that these seagrasses must be able to photosynthesise under very low light intensities. This is verified by Figures 19a, 19b and 19c which show that the photosynthetic saturation point for all three species is around 150 uE/m^2/sec. Shoots would receive higher irradiance only when exposed at low tide.

The densest stand of Thalassia hemprichii occurred in bottom depressions which at low tide become pools of clear water. Thus maximum photosynthetic activity would be expected to occur in these pools. Thalassia hemprichii production values given in Table 3 are from shoots in tidal pools.

Leaf production rates were highly variable and would be expected to change both seasonally and with different tidal regimes. Carbon production figures are within the ranges found for other species of the same genera in tropical and sub-tropical regions (McRoy and McMillan, 1977).

Direct measurements of algal productivity were not obtained for Cairns Harbour due to sampling difficulties. Data are available (although limited in quantity and quality) for comparable nearshore, tropical marine algae beds. Figures range from less than 30g to more than 400g of carbon/m^2/year (Bunt, 1982). Figures of around 0.53g of carbon/m^2/day are common (Qasim, 1973). Bunt (1982) recorded sub-tidal micro-algae productivity in a Florida estuary comparable to Cairns Harbour at a range of 0.01 - 3.1g of carbon/m^2/day.

3.2.7 Seasonal and spatial changes in seagrass distribution along a transect (QDPI)

Seasonal changes were expected in the extent and biomass of Cairns Harbour seagrass. To fully describe the seagrass communities some quantification of the changes is necessary.

A 50m transect was marked out on the lease site and photographs of two 0.25m^2 quadrats side by side were taken at 5.0m intervals. The number of shoots of seagrass in each quadrat was counted and the means and ranges were plotted (Fig. 20). The five months analysed show an increase in the number of shoots between March 1988 and July 1988, followed by a decline during and after the 1989 wet season.

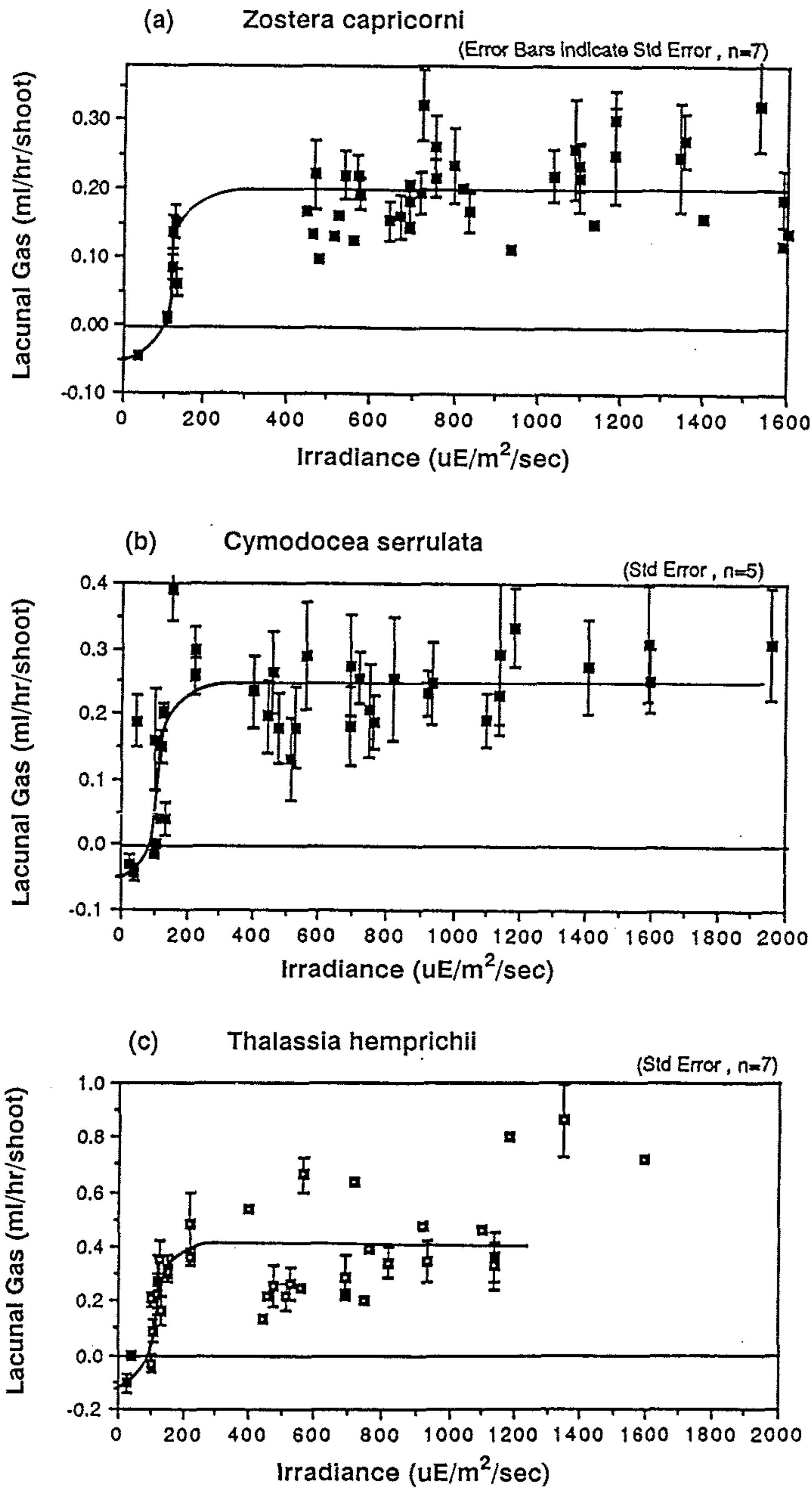


Figure 19. Photosynthetic Saturation Curves for (a) Zostera capricorni; (b) Cymodocea serrulata; (c) Thalassia hemphrichii; based on lacunal gas transport rates at given irradiance values.

Table 4. Irradiance immediately above seagrass bed in Cairns Harbour (Station 4; sunny day over a 20 minute period).

Time of day 18.01.88	Depth of water (m) above seagrass	Irradiance uE/m^2/sec.
11.10	1.75	21
11.40	1.25	38
12.00	1.00	22
12.20	0.75	109
12.40	0.50	54
13.00	0.25	109
13.20	0.10	121
14.00	Exposed	2000

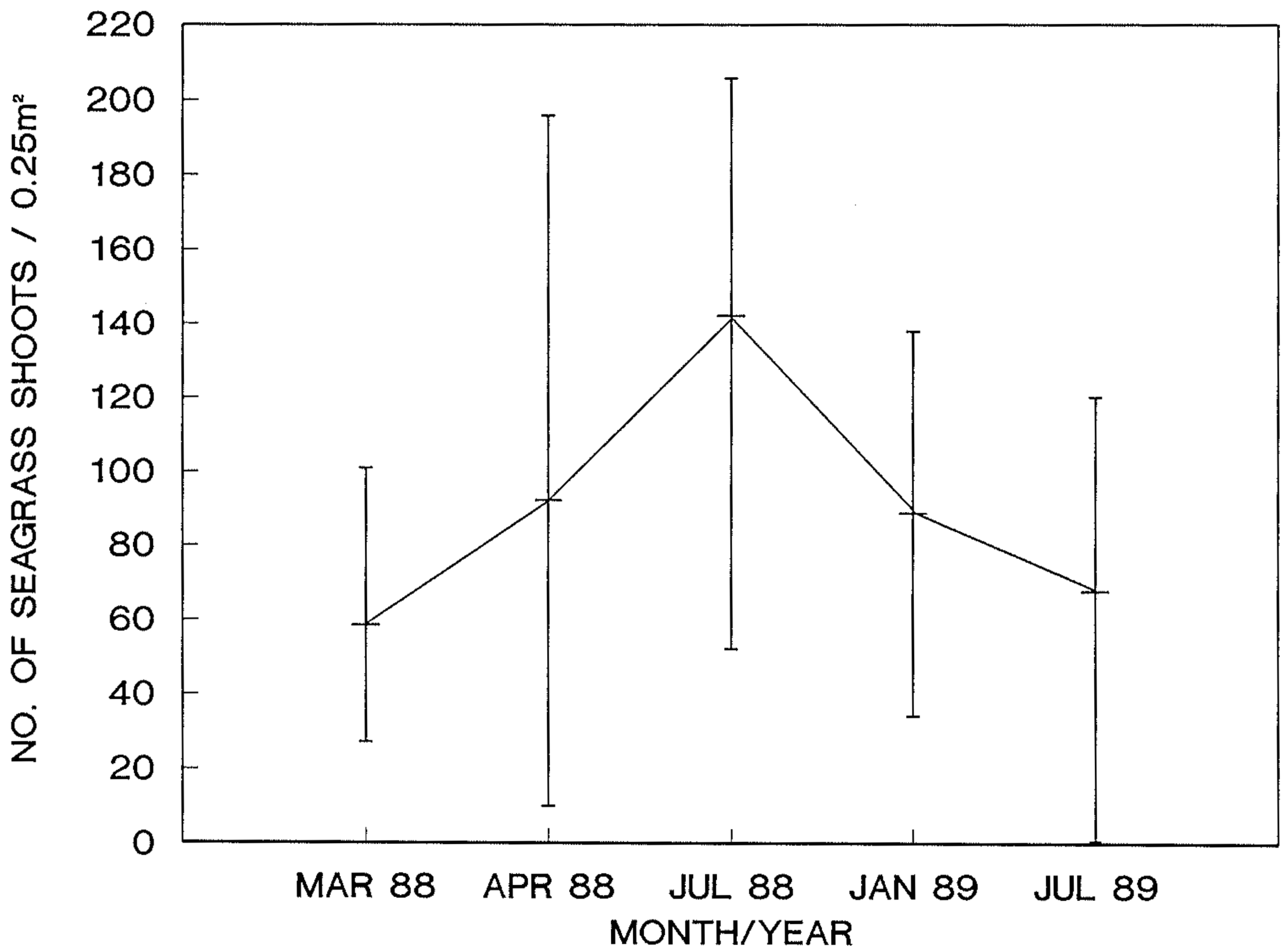


Figure 20. Temporal change in seagrass shoot density (mean and range) measured on a permanent transect in Cairns Harbour.

Analysis of aerial photographs taken in October 1989 suggest that seagrass cover and density has increased on the lease site and density is now at July 1988 levels. It is likely that there is a marked wet season-dry season change in seagrass cover and density and possibly in species composition. There is very little recorded data a seasonal change of tropical Australian seagrasses and more extensive research is required to determine levels of natural change.

3.3 Marine fauna of the Cairns Harbour (QDPI)

Data on fauna were collected to establish, in a quantitative manner, the overall importance and relative contribution of the mudflats and seagrass beds of the Cairns Harbour and of the Trinity Point Development lease site. Molluscs, worms and other non-commercial crustacea etc. were collected in one-off sampling programmes. The methodology by which this was achieved is set out in Appendix 2. Other fauna, eg. birds, found on the Cairns Harbour foreshore are discussed in a companion report (Environmental Assessment).

3.3.1 Penaeid prawns

Twenty-three species of penaeid prawns have been found in the Cairns Harbour and Trinity Inlet region. Nine of these species are marketed commercially (Table 5). The landed value of the east coast Queensland prawn fishery is worth in excess of 100 million dollars each year to the Queensland economy (Coles et al., 1987a).

Eight of these commercially valuable species are commonly found in estuaries during their early juvenile phase. Their life cycles, which are mostly estuary dependent, have a similar pattern (Fig. 21). Adults spawn offshore on the fishing grounds giving rise to very large numbers of eggs. These hatch, probably in less than 24 hours, and develop through a series of planktonic stages which are carried to inshore areas by wind-driven and tidal currents. In these shallow inshore and often seagrass-covered nursery grounds, they settle out on the bottom and grow until, as larger juveniles, they begin to move back into the fishery. On the east coast of north Queensland, this life cycle takes approximately one year.

Of the species which appear to be highly dependent on the presence of seagrasses during their juvenile phase, the most common and economically valuable as adults in the commercial fishery of the Cairns region are the tiger prawns Penaeus esculentus and Penaeus semisulcatus, and the endeavour prawn Metapenaeus endeavouri.

The other major inshore commercial prawn species is the banana prawn Penaeus merguiensis. The banana prawn juveniles were generally found on bare mud substrates associated with mangrove fringed estuaries between 1980 and 1987, and are rarely found amongst seagrass.

Of the 23 penaeid prawn species previously recorded in QDPI studies of the Cairns Harbour, 14 were found in samples taken between November 1987 and November 1988 (Table 5). The species most sought after by the east coast trawl fishery, the two tiger prawns and the endeavour prawn, were the most abundant of the penaeids caught in the Cairns Harbour (Table 14). All of these prawns were juveniles, confirming that the adults had followed the generalized life cycle presented in Figure 21 and had moved offshore and into the fishery. The range of sizes for these three species (Fig. 22) shows that the majority had carapace lengths (C.L.) of less than 10mm.

The tiger prawns and endeavour prawns are accepted by domestic markets in the size range 19-26mm C.L. and for export above 26mm C.L., all well above the sizes of prawns taken during the Cairns Harbour sampling.

There were differences in species composition and significant differences in abundance depending on substrate type (Table 6). There were significant differences between the number of prawns caught on seagrasses on the lease site and on other seagrasses in Cairns Harbour (Kruskal-Wallis

Table 5. Species of penaeid prawns and the number caught in beam trawl samples in the Cairns Harbour and Trinity Inlet between 1980 and 1989.

Species		Total number	Total number	Total number
Common Name	Scientific Name	(414 trawls) 1980 - 1987	(64 trawls) Nov. 1987 - Nov. 1988	(96 trawls) Dec 1988 - Dec 1989
Brown tiger prawn	*Penaeus esculentus* *	2153	478	259
Grooved tiger prawn	*Penaeus semisulcatus* *	1759	611	510
Western king prawn	*Penaeus latisulcatus* *	44	18	-
Banana prawn	*Penaeus merguiensis* *	19	12	28
Leader prawn	*Penaeus monodon* *	6	-	1
Red spot king prawn	*Penaeus longistylus* *	3**	-	-
Red legged banana prawn	*Penaeus indicus* *	2**	-	-
True endeavour prawn	*Metapenaeus endeavouri* *	2307	1051	507
York prawn	*Metapenaeus eboracensis*	713	568	1517
Red endeavour prawn	*Metapenaeus ensis* *	269	50	35
Western school prawn	*Metapenaeus dalli*	74**	12	-
Greasyback prawn	*Metapenaeus bennettae*	46**	138	75
Brown rough prawn	*Trachypenaeus fulvus*	246	113	22
Hardback prawn	*Trachypenaeus anchoralis*	11	-	4
Southern rough prawn	*Trachypenaeus curvirostrus*	-	8	-
Coral prawn	*Metapenaeopsis novaeguineae*	15	1	-
Southern velvet prawn	*Metapenaeopsis palmensis*	12	9	-
Coral prawn	*Metapenaeopsis rosea*	1	1	-
Orange prawn	*Atypopenaeus formosus*	6	-	-
Periscope prawn	*Atypopenaeus stenodactylus*	1	-	-
Coral prawn	*Parapenaeopsis cornuta*	1	13	-
Smoothshell prawn	*Parapenaeopsis tenella*	-	2	22
Total		7725	3085	2980

* Species of major economic importance in Northern Australia

** Identification uncertain due to small size

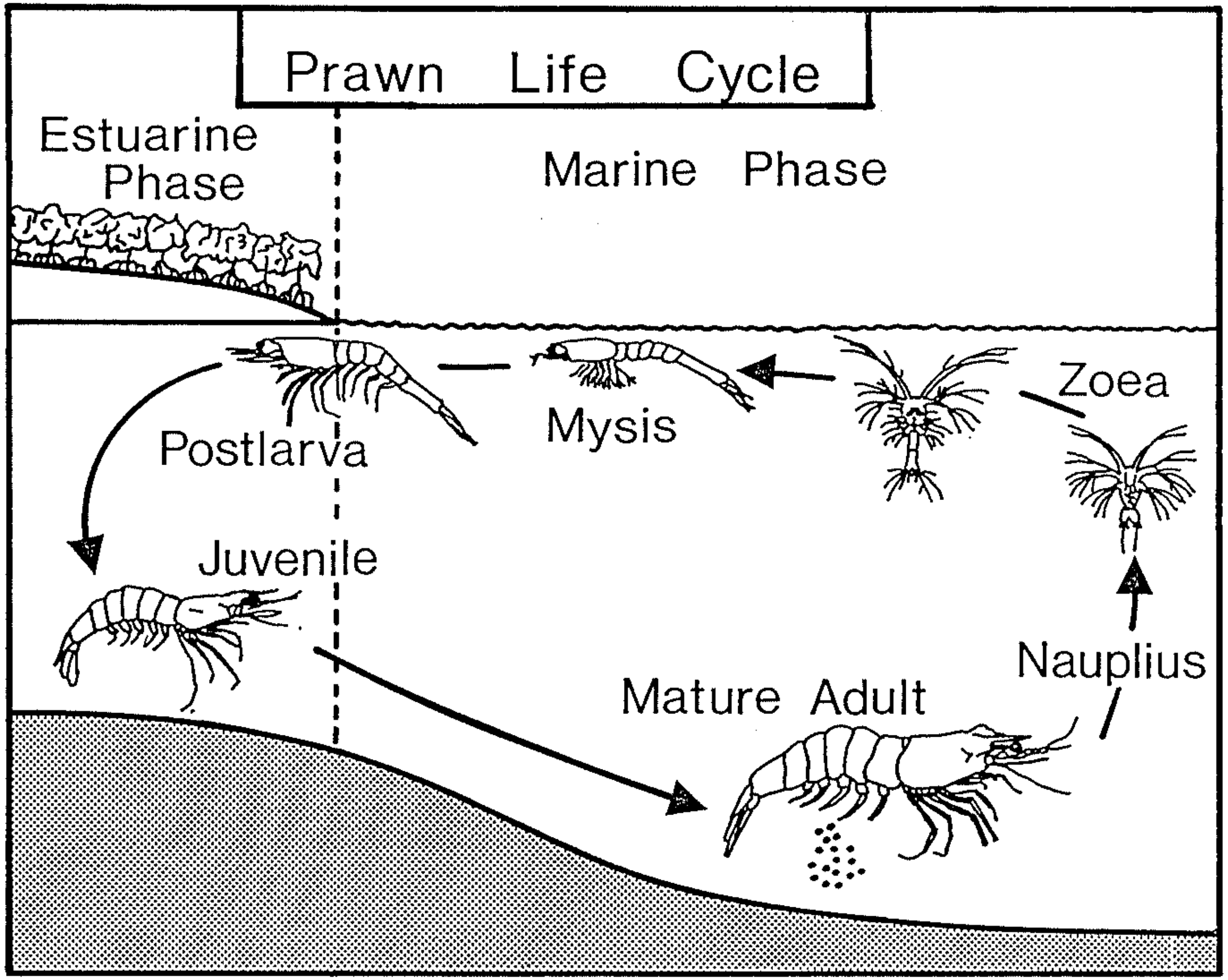


Figure 21. The generalized life - cycle of a penaeid prawn.

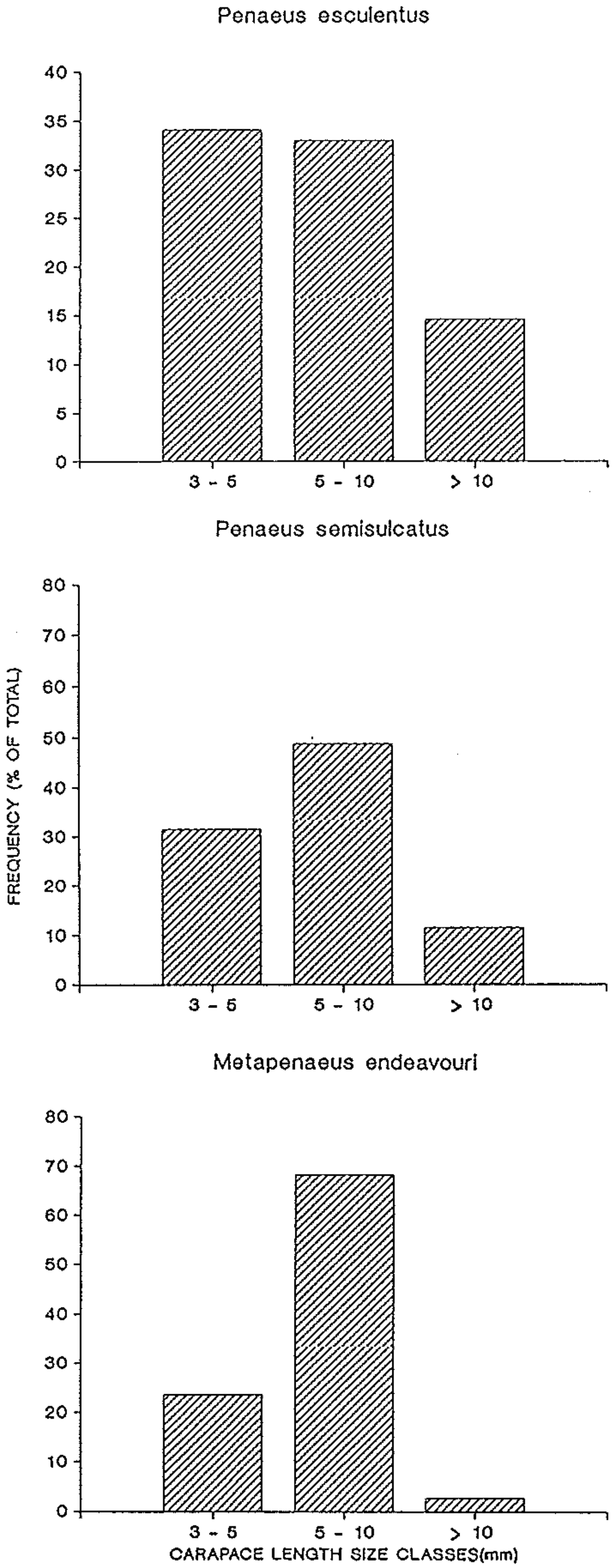


Figure 22. Size range of the three most common commercial species of prawns found in Cairns Harbour. Data are from 1980 to 1987.

$P<0.05$) (Siegel, 1956). The number of commercially important prawns was not significantly different between seagrass vegetated areas and Caulerpa algae and seagrass vegetated areas. Bare mud substrates supported the smallest numbers of commercially valuable prawns. The number of prawns found in these samples is larger than expected. Previous research (Coles and Lee Long, 1985) showed very low numbers of commercial prawn species on non-vegetated bottoms. It is likely that the trawls over bare mud substrates include prawns moving off the adjacent seagrass beds.

Density measurements of prawns on the lease site gave a total density for the three main commercial species of 23 143 prawns per hectare of bottom. Density estimates were completed on the 29 April 1988 at a time following the peak in maximum density of juvenile prawns in Cairns Harbour (Fig. 23b).

The maximum density of prawns recorded on the lease site during sampling by the QDPI (1980 - 1988) shows greater densities have been recorded in the past for brown tiger prawns and endeavour prawns (Table 7). It should be noted that those prawns were younger than the prawns sampled during this survey. Although their numbers were greater, low survival rates mean that fewer of the younger prawns actually reach maturity. In terms of the number of commercial juvenile prawns caught, Cairns Harbour is amongst the most productive of the known seagrass nursery grounds of the north-eastern Queensland coast (Table 8).

The banana prawn Penaeus merguiensis comprises an important fishery in coastal waters near Cairns for several months each year. It is known to penetrate well upstream in estuaries and to be found on bare mud substrates adjacent to mangrove forests (Staples et al., 1985). It is poorly represented in our samples (Table 5).

3.3.2 The commercial value of Cairns Harbour prawns

The productivity of a nursery ground in terms of eventual commercial prawns to the industry may not be directly related to the peak number of juvenile prawns found during surveys. Natural mortality of juvenile prawns would be expected to increase as prawn density approaches peak values. This is not surprising since many prawns may be unable to find optimum protection from predation and because other biological resources, some of which may serve as food for the prawns, are likely to be very limited.

The difference in the density of penaeid prawns between samples taken from seagrass on the Trinity Point Development lease site and seagrass elsewhere in the harbour probably results from the range of sites included. The samples on the lease site are all from dense or mid-dense seagrass beds on a muddy substrate. Seagrass sites sampled elsewhere in the harbour include areas of sparser seagrasses in deeper water and sandy substrates.

To estimate the value to the commercial prawn fishery of prawns living in seagrasses in the Cairns Harbour, a computer model was developed based on a standard von Bertalanffy growth model (Bertalanffy, 1938). This model incorporates from each month the number of juvenile prawns that had settled on the seagrass beds since the previous months' samples. These prawns are allowed to grow in the model at rates based on published and measured estimates for each species and each sex (Appendix 10). As growth occurs, size dependent rates of natural and fishing mortalities are applied (Appendix 10). Prawns caught by the fishing industry are given a size dependent value based on a purchase price quoted by Cairns processors in

Table 6. Penaeid prawns caught on different substrate types within and outside the Trinity Point Development lease site.

Number of trawls	Substrate	Commercial species	Total number of individuals	Average number/ trawl ($75m^2$)
8	Seagrass-lease site	Penaeus esculentus	103	12.9
		Penaeus semisulcatus	347	43.4
		Metapenaeus endeavouri	97	12.1
		Metapenaeus ensis	1	0.1
		Penaeus merguiensis	1	0.1
		Total	549	68.6
10	Seagrass-off lease site	Penaeus esculentus	24	2.4
		Penaeus semisulcatus	117	11.7
		Metapenaeus endeavouri	52	5.2
		Metapenaeus ensis	32	3.2
		Penaeus merguiensis	2	0.2
		Total	227	22.7
2	Algae *	Penaeus esculentus	16	8.0
		Penaeus semisulcatus	84	42.0
		Metapenaeus endeavouri	145	72.5
		Metapenaeus ensis	4	2.0
		Total	249	124.5
10	Mud ++ adjacent to sea-grass beds -sub tidal	Penaeus esculentus	1	0.1
		Penaeus semisulcatus	50	5.0
		Metapenaeus endeavouri	26	2.6
		Metapenaeus ensis	10	1.0
		Penaeus latisulcatus	1	0.1
		Penaeus merguiensis	1	0.1
		Total	89	8.9
5	Mud on lease site-intertidal	Penaeus esculentus	34	6.0
		Penaeus semisulcatus	10	2.0
		Metapenaeus endeavouri	1	0.2
		Metapenaeus ensis	5	1.0
		Total	50	10.0

* Caulerpa algae found within seagrass beds on lease site.
++ Both lease and off-lease sites included.

Table 7. Maximum density of juvenile prawn per hectare in samples from Cairns Harbour seagrass beds taken between 1980 and 1988.

Species	Density (number)	Date of occurrence
Penaeus esculentus (brown tiger)	18 400	January 1986
Penaeus semisulcatus (grooved tiger)	13 803	April 1988
Metapenaeus endeavouri (endeavour)	9 200	May 1986

Table 8. Distribution and number of juvenile commercial penaeid prawns occurring per hour of beam trawling over seagrass beds, comparing Cairns Harbour with other seagrass beds on Queensland's eastern coast.

After Coles et al. (1987b).

April 1988. A closure to trawling occurs in north Queensland coastal waters in January and February and the model incorporates this with zero fishing mortality for these months. Prawns that settled in the last months of the twelve month sampling period and still survive, are carried through for a further 12 months with no new recruits and the value added on. For example, catch values in April (Appendix 10) are those surviving from March (the bottom line of Table 9). Details of the model and the parameters are given in Appendix 10. Appendix 10 lists for each month estimated fishing effort, the number of prawns remaining, female to male ratio, new recruits on the seagrass beds of Cairns Harbour, deaths ascribed to natural and fishing mortality, cumulative and incremental catch value, catch weight, average weight and value of each prawn, and the proportion of fishing and natural mortality. Dollar values are for a hectare of prawn nursery ground.

The model was re-run to estimate the value to the fishing industry of prawns on bare intertidal mudflats in the Cairns Harbour. Monthly data for mudflats were not collected. Values for the model were generated by assuming the seagrass-bare mud proportion of comparative trawls (Table 6) remained constant throughout the year. The results of the model calculations are in Appendix 10). The value to the fishing industry of the Cairns Harbour prawn nursery grounds is collated in Table 9. Banana prawns are not included in these calculations. This species is found in mangrove bordered areas and was not well represented in our Esplanade and Cairns Harbour samples. Banana prawns are found in Trinity Inlet in large numbers at certain times of the year and are targeted by trawler fishermen in a specific daytime trawl fishing. Data used to calculate the value of prawns were collected each month between November 1987 and November 1988. The monthly sampling sites represent the densest level of seagrass cover found on the lease site and in Cairns Harbour. We have assumed for the purpose of the model that prawn numbers are similar on all densities of seagrass greater than 10% cover.

Table 9. The value of penaeid prawns per year in Cairns Harbour, Mission Bay and the lease site.

Region	Area (hectares)		$ Value		
	Intertidal Mudflat	Seagrass	Intertidal Mudflat $	Seagrass $	Total Value $
Lease site	56	25	44 577	86 686	131 263
Cairns Harbour	604	500	480 790	1 733 710	2 214 500
Mission Bay and Cairns Harbour*	903	876	718 797	3 037 460	3 756 257

* Cairns Harbour values extrapolated to include Mission Bay.

The value of prawns from intertidal mudflats and seagrass beds calculated in the model is an estimate based on a range of assumptions, all of which are subject to variation. Penaeid prawns are a luxury food item and the market price can vary enormously depending on economic conditions. Excluding all the biological variables, this single factor can result in variations in value estimates of 50% or more within a year. Penaeid prawn populations are noted for year-to-year fluctuations in commercial catches and these changes in population numbers on the fishing grounds may result in similar variations in the numbers of prawns settling in coastal prawn nursery grounds such as in the Cairns Harbour. This background variation or noise in the system makes estimating the value of prawns in seagrass nursery areas difficult without many years of sampling to provide estimates of year-to-year variability from several sampling sites.

The value given here is considered a reasonable estimate when compared to the catch value of vessels operating in the region. Based on the number of trawlers and days spent at sea in the Cairns region (Beurteaux and Coles, 1988), the catch value estimated for prawns recruiting to the fishery from Cairns Harbour and Mission Bay would be $1 174 per night per boat, a realistic figure for the trawlers in the night-time tiger and endeavour prawn fishery.

The value of prawns found on mudflats and seagrasses within the lease site boundary make up 5.9% of the total value of Cairns Harbour prawns and 3.5% of the value of Cairns Harbour and Mission Bay.

The seagrasses sampled within the lease site produced significantly more juvenile commercial penaeid prawns than many of the other sites in the Cairns Harbour. Little information is available on the factors which determine abundance of prawns within a seagrass bed. In the lease site it is likely to be combination of dense seagrasses providing shelter and soft, nutrient-rich substrates, low water current velocities, and compression of the bed due to a narrowing of contours as the bed slopes into deeper water.

3.3.3 Fluctuations in prawn populations

Prawn population numbers and their species composition vary considerably through a year. The comprehensive survey described in this report is based mainly on data collected between November 1987 and November 1989. These provide a detailed picture of the prawn and fish community over a short time frame that is insufficient for assessment of seasonal changes. We have therefore included additional data on prawns collected on the lease site and in Cairns Harbour from previous research programmes. Monthly trawls to update this database are scheduled to continue.

Previous work (QDPI unpublished) has shown that the greatest numbers of juvenile Penaeus esculentus were found on the lease site each year in January. Penaeus semisulcatus numbers reached their peak in February. Metapenaeus endeavouri do not appear to have a well defined population density peak (Fig. 23a). These results are based on data collected each year from 1980 through 1986.

Results of the current study (November 1987 through December 1989) showed that both tiger prawn species reached their peak abundance in the seagrass beds between November and May (Figs 23a and 23b). Again, the endeavour prawn continued to recruit to the Cairns Harbour over several months (Figs 23b and 23c).

The numbers of juvenile prawns using Cairns Harbour as a nursery area vary greatly from year to year. This phenomenon is best illustrated by the standard error measurements around the monthly averages for prawn numbers shown in Figure 23a. It is clear that there is a normally high level of unpredictability in prawn density and that if changes occur in their numbers, these changes have to be either very large or occur over a relatively long period before they can be detected using statistical analysis.

This conclusion has implications for the proposed Development. Should the lease site be reclaimed, there is a risk that modification of that environment may affect prawn production in Cairns Harbour. Even with an elaborate monitoring programme, however, it may take many years for the change to be detected and proven statistically. The converse is also true; reclamation of the area may well be credited with a reduction in juvenile prawn numbers in the Cairns Harbour when the variation is the result of other factors and should be described as natural.

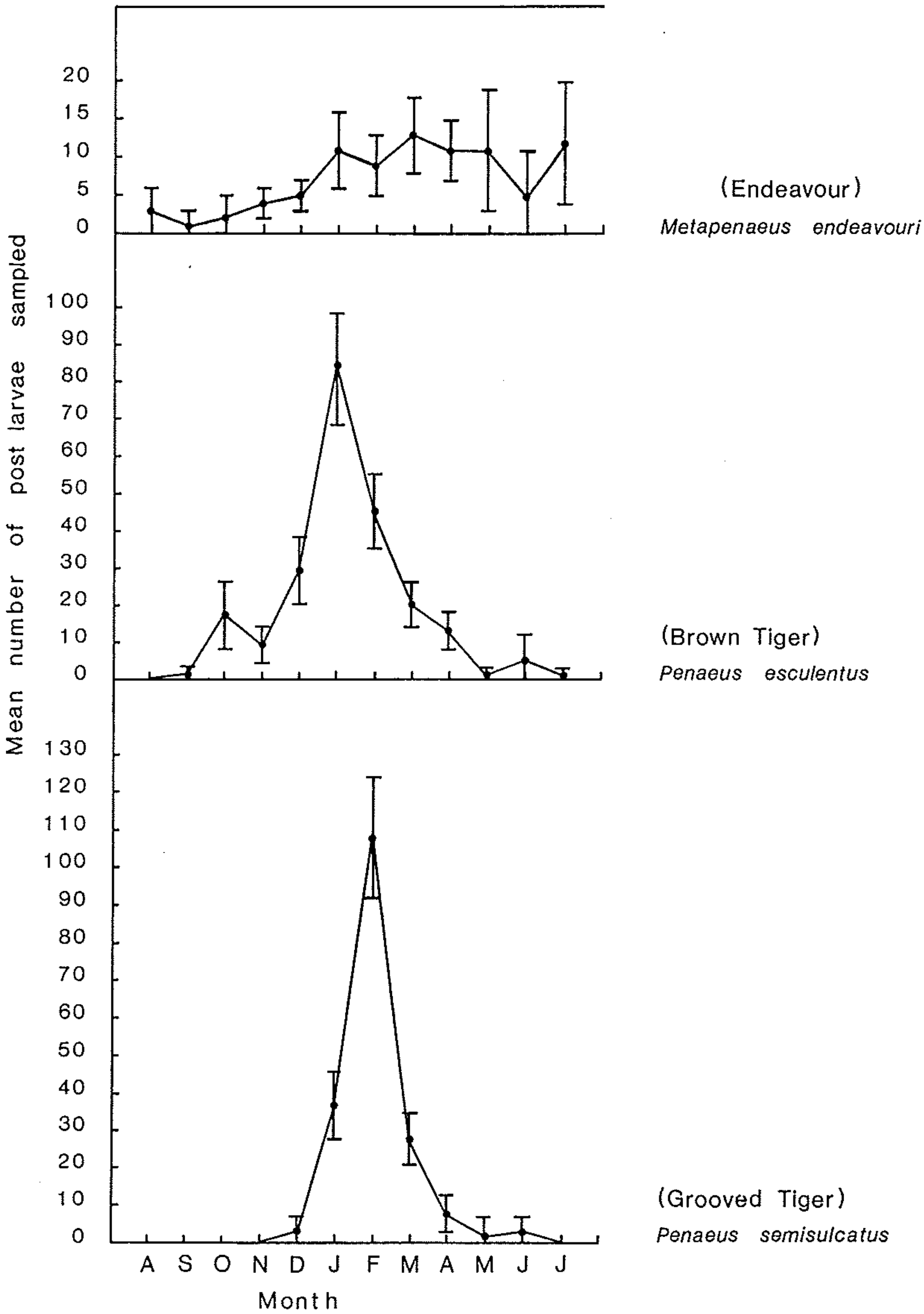


Figure 23a. The mean number and standard error of post larval prawns of the three major commercial species caught for each month in Cairns Harbour. Data are from years 1980 to 1986.

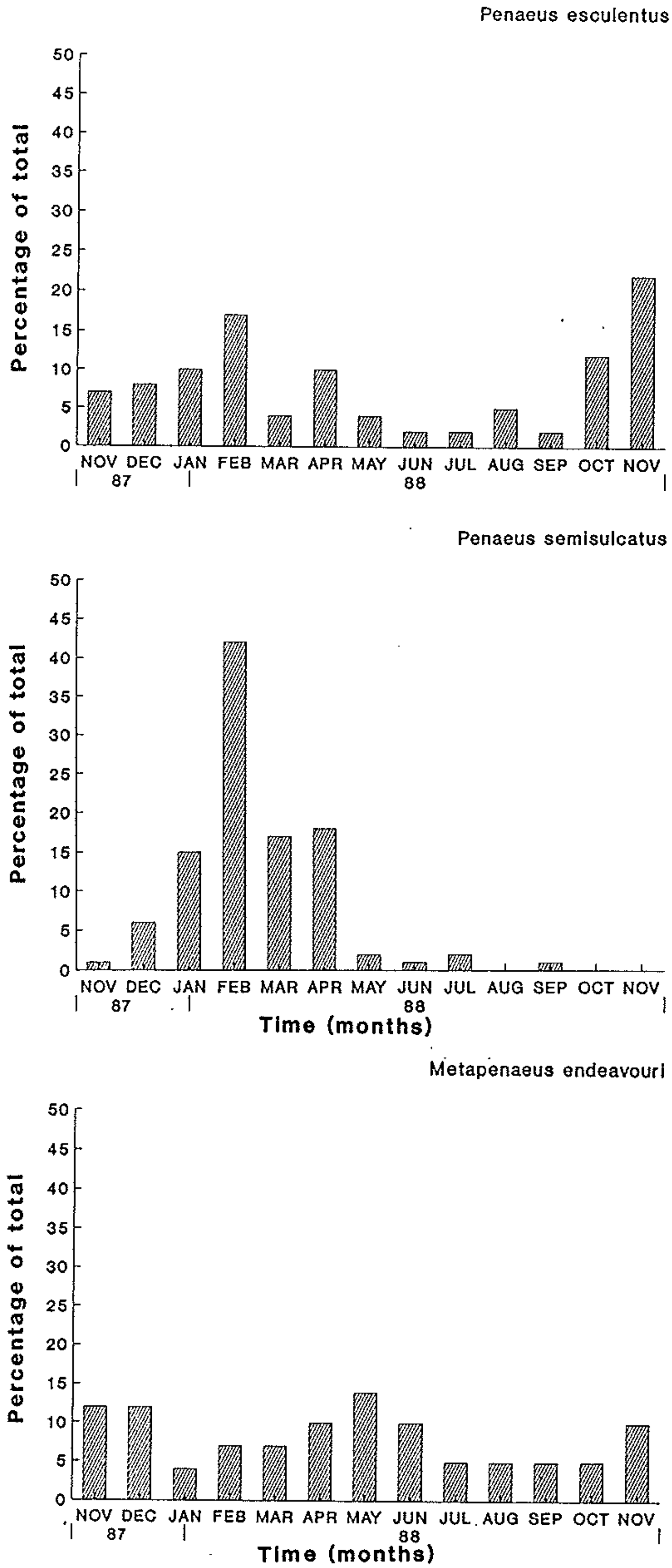


Figure 23b. Distribution of prawn catch over the period November 1987 to November 1988, for the three most common commercial species in Cairns Harbour monthly beam trawls. Each monthly catch is represented as a percentage of the total yearly catch for each species.

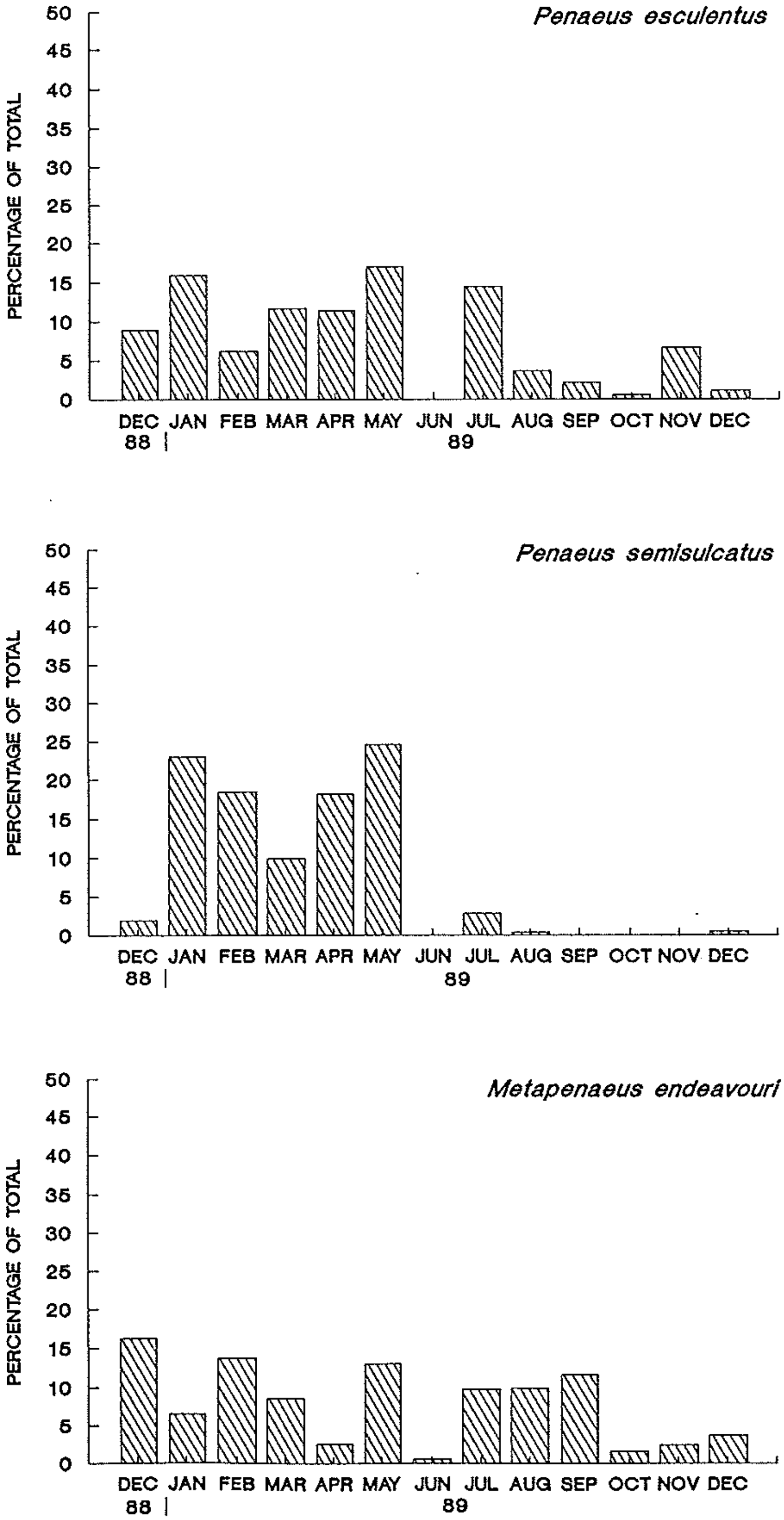


Figure 23c. Distribution of prawn catch over the period November 1987 to November 1988, for the three most common commercial species in Cairns Harbour monthly beam trawls. Each monthly catch is represented as a percentage of the total yearly catch for each species.

3.3.4 Fish

Samples of fish were obtained using beam trawls, gill nets and seine nets at a number of sites in the Cairns Harbour. In total, 136 species were collected. Sizes ranged from 7mm to 560mm in standard length. The average length of fish caught using the sampling gears described (Appendix 2) was 32mm and most of the fish collected were immature (Table 10a).

Of the 5 564 fish collected, the most numerous species were a goby Yongeichthys criniger and a pony fish, Leiognathus splendens (Table 10a). The largest individual fish species was a shark of genus Carcharhinus. The greatest biomass, other than sharks, was contributed by the king salmon, Polydactylus sheridani, the queenfish, Scomberoides commersonianus and the catfish, Arius proximus (Table 10a).

The species list for the Cairns Harbour and Trinity Inlet was expanded by including catch records of commercial fishermen and species reported in scientific publications for the area. By including this additional information, a total of 223 species of fish can be listed as using or frequenting the study area (Table 10b).

Species were classified according to their value to commercial and recreational fishermen. Thirty species are highly valued by recreational fishermen with a further 44 species valued lowly (used if caught). A total of 149 (67%) of the species present in the Cairns Harbour and Trinity Inlet were of no direct value to recreational fishermen. Detailed information on recreational fishing appears in a companion report by Environmental Science and Services (Environmental Assessment).

Using the same classification system, 23 species are highly valued by commercial fishermen with a further 18 species valued lowly (used if caught). A total of 182 (82%) of the species present were of no direct value to commercial fishermen (Table 10b). Of the 223 species, 18% were highly valued by both commercial and recreational fishermen.

The relative abundance of fish within the Cairns Harbour was established using beam trawls (Table 10c). Fish which could be caught using this method were most abundant over Caulerpa algae and seagrass covered substrates on the lease site. Fish on mud substrates and seagrass substrates off the lease site supported a lower density of fish than on the lease site. Fish abundances on mud and seagrass substrates off the lease site were very similar. Thirty beam trawl samples caught 1 982 fish for an average calculated density of 8 809 per hectare.

A comparison of Cairns Harbour trawls with trawl surveys at Mornington Island (1987) and in the area Bowen to Water Park Point (1987) demonstrate that the trawl-caught fish faunas, although composed of different species, are similar in terms of diversity and fish size (Appendix 11). Of the three locations, Mornington Island had the fewest species (19 families, 37 species) and Bowen to Water Park Point had the smallest fish (average standard length 16 mm).

Although larger juvenile and adult fishes are regularly taken within Cairns Harbour and Trinity Inlet by commercial and recreational fishermen, it is important to understand that the fish fauna is dominated by juveniles of most species. In this regard, it is a true nursery ground. With the exception of the dense Caulerpa algae and seagrass beds on the

Table 10a. Species, size and abundance data for fish collected in the Cairns Harbour.

Legend for net types:

B - Beam trawl

G - Gill nets

S - Seine net

SPECIES *	LENGTH RANGE (mm)	AVERAGE LENGTH (mm)	TOTAL WEIGHT (g)	% BIOMASS	TOTAL NUMBER	% ABUNDANCE	NET TYPE
Acanthopagrus berda	140-225	173	757.5	1.61	3	0.05	G
Ambassis nalua	19-90	40	632.2	1.34	217	3.92	B,S
Ambassis telkara	36-50	42	18.5	0.04	9	0.16	B
Amblygobius sp.1	35-74	53	12.5	0.03	4	0.07	B
Amblyrhychotes spinosissimus	9-11	10	1.2	<0.01	5	0.09	B
Anodontostoma chacunda	57-88	77	169.0	0.36	12	0.22	B
Apogon ellioti	35-45	40	5.5	0.01	2	0.04	B
Apogon quadrifasciatus	31	31	1.1	<0.01	1	0.02	B
Apogon sp.1	23-32	26	3.1	0.01	4	0.07	B
Arius c.f. argyropleuron	245-255	251	1335.0	2.83	4	0.07	G
Arius proximus	415	415	1928.0	4.09	1	0.02	G
Arius sp.1	235-260	247	1327.0	2.82	4	0.07	G
Arothron hispidus	12-25	18	2.1	<0.01	2	0.04	B
Arothron immaculatus	13-82	29	165.8	0.35	39	0.70	B,S
Arrhamphus sclerolepis	27-119	73	55.4	0.12	11	0.20	B
Atherinomorus c.f. endrachtensis	41-53	46	12.0	0.03	8	0.14	B
Bombonia spicifer	46-105	83	14.9	0.03	36	0.65	B
Callionymus sp.1	25	25	0.2	<0.01	1	0.02	B
Canthigaster margaritatus	31	31	1.5	<0.01	1	0.02	B
Caranx sp.1	49	49	3.0	0.01	1	0.02	S
Carcharhinus c.f. sorrah	510-625	573	13037.0	27.66	12	0.22	G
Carcharhinus sealei	420-440	430	904.0	1.92	2	0.04	G
Centriscus scutatus	63-74	67	0.8	<0.01	3	0.05	B
Centrogenys vaigiensis	15-41	26	7.1	0.02	7	0.13	B
Chaetodontidae sp.1	13	13	0.2	<0.01	1	0.02	B
Chelonodon patoca	28-35	32	6.6	0.01	3	0.05	B,S
Conger labiatus	235	235	14.1	0.03	1	0.02	B
Cymbacephalus nematophthalmus	19-131	82	187.8	0.40	12	0.22	B,S
Cynoglossus puncticeps	15-87	47	62.0	0.13	43	0.78	B,S
Cynoglossus sp.	37	37	0.6	<0.01	1	0.02	B
Dexilichthys muelleri	180-190	185	321.0	0.68	2	0.04	B,S
Drepane punctata	121-215	168	711.0	1.51	2	0.04	B
Eleutheronema tetradactylum	335-505	420	3006.0	6.38	2	0.04	G
Elops australis	435	435	850.0	1.80	1	0.02	G
Engraulidae spp.	14-33	9	22.1	0.05	142	2.57	B
Engyprosopon grandisquama	31-33	32	1.0	<0.01	2	0.04	B,S
Escualosa thoracata	21-46	15	21.1	0.04	36	0.65	B
Foa brachygramma	16-41	35	33.1	0.07	18	0.33	B
Gazza minuta	30-60	36	16.7	0.04	11	0.20	B
Gerres abbreviatus	154-166	160	391.0	0.83	2	0.04	B
Gerres argyreus	67	67	10.1	0.02	1	0.02	G
Gerres filamentosus	99-145	115	191.4	0.41	3	0.05	B

Table 10a continued.

SPECIES	LENGTH RANGE (mm)	AVERAGE LENGTH (mm)	TOTAL WEIGHT (g)	% BIOMASS	TOTAL NUMBER	% ABUNDANCE	NET TYPE
Gerres poieti	33-60	50	15.2	0.03	3	0.05	B,S
Glossogobius sp.1	40-51	45	6.0	0.01	4	0.07	B
Gobiidae spp.	10-29	7	7.9	0.02	113	2.04	B
Gobiidae sp.1	8-35	13	55.1	0.12	225	4.06	B
Gobiidae sp.2	10-28	19	3.1	0.01	20	0.36	B
Gobiidae sp.3	18-35	29	2.4	0.01	5	0.09	B
Gymnothorax sp.1	83-160	109	8.7	0.02	7	0.13	B
Haemulidae sp.	31-14	14	0.2	<0.01	2	0.04	B
Harengula macrolepis	92-106	98	139.2	0.30	6	0.11	G
Herklotsichthys koningsbergeri	69	69	7.5	0.02	1	0.02	B
Himantura granulata	-	-	813.0	1.72	1	0.02	S
Hyporhamphus australis	25-111	59	10.1	0.02	3	0.05	B
Hyporhamphus quoyi	34-135	80	126.1	0.27	20	0.36	B
Inegocia isacanthus	23-49	36	1.5	<0.01	2	0.04	B
Lactarius lactarius	238	238	342.0	0.73	1	0.02	G
Leiognathus bindus	38-45	42	7.2	0.02	3	0.05	B
Leiognathus decorus	8-76	34	203.6	0.43	117	2.11	B,G,S
Leiognathus equulus	13-150	57	572.5	1.21	21	0.38	B
Leiognathus sp.1	7-11	7	1.1	<0.01	31	0.56	B
Leiognathus splendens	10-65	15	722.2	1.53	659	11.90	B,G,S
Leiognathus spp.	7-12	9	4.4	0.01	129	2.33	B
Lethrinus lentjan	25-132	56	195.2	0.41	24	0.43	B,S
Lethrinus reticulatus	41-84	67	55.9	0.12	5	0.09	B,S
Lethrinus spp.	16-26	19	1.4	<0.01	6	0.11	B
Lethrinus sp.1	15-84	21	71.9	0.15	103	1.86	B,S
Liza vaigiensis	255	255	390.0	0.83	1	0.02	S
Lutjanus erythropterus	48	48	4.1	0.01	1	0.02	B
Lutjanus fulviflammus	17-117	49	466.1	0.99	55	0.99	B,S
Lutjanus russelli	27-97	49	46.2	0.10	6	0.11	B,S
Lutjanus sp.1	18	18	0.2	<0.01	1	0.02	B
Megalops cyprinoides	415	415	1372.0	2.91	1	0.02	G
Mugil cephalus	57-205	139	370.3	0.79	4	0.07	S
Mugil georgii	157-182	169	338.4	0.72	3	0.05	S
Nematalosa come	95-190	151	1305.9	2.77	11	0.20	G
Nibea soldado	40-250	117	1662.3	3.53	10	0.18	B,G
Otolithes ruber	300	300	389.0	0.83	1	0.02	G
Paracentropogon longispinis	26-42	35	4.5	0.01	3	0.05	B
Paramonacanthus sp.1	15-26	20	5.4	0.01	18	0.33	B
Paraplagusia guttata	42-130	74	17.3	0.04	3	0.05	S
Pelates quadrilineatus	10-75	22	360.1	0.76	571	10.31	B,S
Platycephalidae spp.	10-51	34	2.1	<0.01	3	0.05	B
Platycephalus fuscus	41-46	44	1.7	<0.01	2	0.04	B
Platycephalus indicus	175-395	285	745.4	1.58	2	0.04	B,G
Polydactylus heptadactylus	24-33	29	1.3	<0.01	2	0.04	B
Polydactylus multiradiatus	13-52	33	10.7	0.02	22	0.40	B
Polydactylus sheridani	225-375	287	4200.0	8.91	9	0.16	G
Polydacylus sp.1	16-24	19	0.6	<0.01	4	0.07	B
Pomadasys kaakan	13-290	96	920.1	1.95	7	0.13	B,S
Pomadasys maculatum	9-40	14	16.2	0.03	129	2.33	B,S
Pomadasys opercularis	35-205	109	781.3	1.66	9	0.16	B,G,S
Pomadasys sp.1	12-22	17	1.2	<0.01	6	0.11	B
Psammoperca vaigiensis	73-85	79	215.0	0.46	2	0.04	B
Pseudorhombus arsius	31-40	36	2.0	<0.01	2	0.04	S
Pseudorhombus elevatus	16-125	49	108.1	0.23	20	0.36	B,S
Repomuscenus belcheri	45	45	1.0	<0.01	1	0.02	B

Table 10a continued.

SPECIES	LENGTH RANGE (mm)	AVERAGE LENGTH (mm)	TOTAL WEIGHT (g)	% BIOMASS	TOTAL NUMBER	% ABUNDANCE	NET TYPE
Rhinogobius sp.1	24-40	31	5.0	0.01	8	0.14	B
Rhynchorhamphus georgi	25	25	0.1	<0.01	1	0.02	B
Sardinell sp.1	17-25	22	2.0	<0.01	16	0.29	B
Saurida nebulosa	103-122	113	31.2	0.07	2	0.04	S
Scomberoides commersonianus	235-342	305	2094.0	4.44	5	0.09	G
Scomberoides tol	268	268	239.0	0.51	1	0.02	G
Secutor ruconius	7-66	17	137.9	0.29	326	5.89	B
Siganus canaliculatus	19-72	39	90.3	0.19	35	0.63	B,S
Siganus fuscescens	18-39	25	5.3	0.01	15	0.27	B
Siganus guttatus	19-60	30	17.0	0.04	14	0.25	B,S
Siganus spinus	18-32	21	7.2	0.02	40	0.72	B
Siganus spp.	17-21	20	2.2	<0.01	16	0.29	B
Sillago maculata	32-84	50	8.6	0.02	3	0.05	B,S
Sillago sihama	22-200	60	142.7	0.30	17	0.31	B
Sillago spp.	8-37	21	16.5	0.04	103	1.86	B
Sphyraena jello	33	33	0.1	<0.01	1	0.02	B
Sphyrna lewini	560	560	812.0	1.72	1	0.02	G
Stolephorus devisi	27-42	29	0.9	<0.01	3	0.05	B
Stolephorus indicus	25-34	29	0.9	<0.01	3	0.05	B
Stolephorus c.f. tysoni	10-57	19	89.4	0.19	285	5.15	B
Stolephorus spp.	14-33	22	25.7	0.05	161	2.91	B
Strongylura strongylura	220	220	15.7	0.03	1	0.02	S
Suggrundus sp.1	33	33	0.4	<0.01	1	0.02	B
Terapon puta	9-65	35	289.5	0.61	201	3.63	B,S
Teraponidae spp.	10-14	12	0.6	<0.01	24	0.43	B
Tetrabrachium ocellatum	18-41	33	7.2	0.02	3	0.05	B
Tetraodontidae sp.1	15-16	16	0.5	<0.01	2	0.04	B
Tetraodontidae sp.2	11-17	14	0.8	<0.01	3	0.05	B
Thryssa hamiltonii	32-158	88	248.9	0.53	16	0.29	B
Thryssa sp.1	20-40	26	3.2	0.01	13	0.23	B
Thryssa spp.	27-20	23	0.7	<0.01	5	0.09	B
Torquigener sp.1	14-19	16	0.6	<0.01	3	0.05	B
Triacanthus biaculeatus	135	135	45.4	0.10	1	0.02	S
Trixiphichthys weberi	7-27	16	6.9	0.01	29	0.52	B,S
Unidentified larvae	11-25	18	0.8	<0.01	14	0.25	B
Upeneus sp.1	22-86	44	32.3	0.07	9	0.16	B,S
Valamugil seheli	152	152	81.8	0.17	1	0.02	S
Yongeichthys criniger	7-83	12	131.0	0.28	1087	19.64	B,S
Zabidius novemaculeatus	16-24	20	1.2	<0.01	4	0.07	B
TOTAL	7-560	32	47947.0	101.72	5564	100.00	

* Some identifications in this report are provisional

Table 10b. Fish species and value classification for fish recorded in Cairns Harbour and Trinity Inlet.

Legend for codes:	Number of species
A - targeted aquarium species	45
a - incidental aquarium species	54
B - targeted baitfish species	7
b - incidental baitfish species	29
C - targeted commercial species	23
c - incidental commercial species	18
R - targeted recreational species	30
r - incidental recreational species	44
T - targeted traditional (aboriginal/islander) species	3
t - incidental traditional (aboriginal/islander) species	0
- no fishery value	41

Legend for surveys:

X - QDPI survey 1988

Y - Professional fisherman/collector

Z - Blaber 1980

FAMILY	SPECIES	COMMON NAME	CODE	SURVEY
ACANTHURIDAE	Acanthurus xanthopterus	Ring-tailed surgeonfish	ar	XY
AMBASSIDAE	Ambassis nalua	Perchlet	a	XYZ
	Ambassis telkara	Perchlet	a	X
APOGONIDAE	Apogon ellioti	Cardinalfish	a	X
	Apogon quadrifasciatus	Cardinalfish	a	XY
	Apogon sp.1	Cardinalfish	a	X
	Foa brachygramma	Cardinalfish	a	XY
	Glossamia aprion aprion	Mouth almighty	a	Y
ARIIDAE	Arius c.f. argyropleuron	Fork-tailed catfish	Ar	X
	Arius proximus	Fork-tailed catfish	Ar	XZ
	Arius thalassinus	Fork-tailed catfish	Ar	Z
	Arius sp.1	Fork-tailed catfish	Ar	XY
ATHERINIDAE	Atherinomorus c.f. endrachtensis	Hardyhead	b	XY
BATRACHOIDIDAE	Halophryne diemensis	Banded frogfish	A	Y

Table 10b continued.

BELONIDAE	?Ablennes hians	Giant long-tom	br	Y
	Strongylura strongylura	Black-spot long-tom	br	XYZ
	Tylosurus crocodilus	Choram long-tom	br	Z
	Tylosurus leiura	Hornpike long-tom	br	Z
BOTHIDAE	Engyprosopon grandisquama	Flounder	a	X
CALLIONYMIDAE	Callionymus sp.1	Dragonet	A	X
	Repomuscenus belcheri	Dragonet	A	X
CARANGIDAE	Alectis indica	Diamond trevally	Arc	Y
	Caranx ignoblis	Lowly trevally	acr	YZ
	Caranx sexfasciatus	Trevally	cR	Z
	Caranx sp.1	Trevally	cr	X
	Gnathanodon speciosus	Golden trevally	acR	Y
	Scomberoides commersonianus	Queenfish	CR	XYZ
	Scomberoides tala	Deep queenfish	r	Z
	Scomberoides tol	Slender queenfish	-	XZ
	Trachinotus blochii	Snub-nosed dart	acr	Y
	Trachinotus russelli	Swallowtail	a	Y
CARCHARHINIDAE	Carcharhinus sealei	Shark	Cr	XY
	Carcharhinus c.f. sorrah	Black-tip shark	?	X
	Scoliodon palasorrah	Little blue shark	Cr	Z
CENTRISCIDAE	Centriscus scutatus	Razorfish	A	X
CENTROPOMIDAE	Lates calcarifer	Barramundi	ARC	YZ
	Psammoperca vaigiensis	Sand bass	Ar	XY
CHAETODONTIDAE	Chaetodontidae sp.1	Butterflyfish	A	X
	Heniochus acuminatus	Feather-fin bullfish	A	Y
CHANIDAE	Chanos chanos	Milkfish	br	YZ
CHIROCETRIDAE	Chirocentrus dorab	Wolf Herring	br	YZ
CLUPEIDAE	Anodontostoma chacunda	Mud herring	b	XY
	Escualosa thoracata	Herring	?	X
	Harengula macrolepis	Northern herring	b	XZ
	Herklotsichthys koningsbergeri	Spotted herring/sardine	B	XY
	Hyperlophus vittatus	Herring	b	Z
	Nematalosa come	Hair-back mud herring	b	XZ
	Pellona ditchela	Ditchelee herring	b	Z
	Sardinella sp.1	Sardine	b	X
CONGRIDAE	Conger labiatus	Conger eel	ar	X
CYNOGLOSSIDAE	Cynoglossus bilineatus	Tongue sole	a	Z
	Cynoglossus heterolepis	Tongue sole	a	Z
	Cynoglossus puncticeps	Tongue sole	a	XY
	Cynoglossus sp.1	Tongue sole	a	X
	Paraplagusia guttata	Tongue sole	a	X
DASYATIDIDAE	Dasyatis sephen	Cowtail ray	Ar	Y
	Himantura granulata	Mangrove ray	Ar	XY
	Himantura uarnak	Leopard ray	Ar	YZ

Table 10b continued.

ECHENEIDAE	Echeneis naucrates	Remora	-	Z
ELEOTRIDAE	Ophiocara aporos	Snake-headed gudgeon	a	Z
	Oxyeleotris lineolatus	Sleepy cod	ar	Y
ELOPIDAE	Elops australis	Giant herring	r	XYZ
	Megalops cyprinoides	Oxeye herring	r	X
ENGRAULIDAE	Engraulidae spp.	Anchovies	-	X
	Stolephorus carpentariae	Anchovy	-	Z
	Stolephorus devisi	Anchovy	-	XZ
	Stolophorus indicus	Anchovy		X
	Stolephorus c.f. tysoni	Anchovy	-	X
	Stolephorus spp.	Anchovy	-	X
	Thryssa hamiltonii	Anchovy	-	XZ
	Thryssa setirostris	Anchovy	-	Z
	Thryssa sp.1	Anchovy	-	X
	Thryssa spp.	Anchovy		X
EPHIPPIDAE	Drepane punctata	Sicklefish	AR	XYZ
	Platax tiera	Batfish	Ar	Y
	Zabidius novemaculeatus	Batfish	Ar	X
GERREIDAE	Gerres abbreviatus	Silver biddy	b	XZ
	Gerres argyreus	Darnley Island silverbelly	b	XY
	Gerres poieti	Silver biddy	b	XZ
	Gerres punctatus	Silver biddy	b	Z
	Gerres sp.1	Silver biddy	b	X
GOBIIDAE	Amblygobius sp.1	Goby	-	X
	Ctenogobius ?nebulosus	Goby	-	Z
	Glossogobius giuris	Flat-headed goby	-	Z
	Glossogobius sp.1	Goby	-	X
	Gobiidae sp.1	Goby	-	X
	Gobiidae sp.2	Goby	-	X
	Gobiidae sp.3	Goby	-	X
	Gobiidae spp.	Gobies	-	X
	Parvigobius sp.	Goby	-	Z
	Periophthalmus koelreuteri	Mud-skipper	A	Y
	Periophthalmus sp.	Mud-skipper	-	Z
	Periophthalmodon barbarus	Mud-skipper	-	Z
	Rhinogbius sp.1	Goby	-	X
	Stigmatogobius sp.	Goby	-	Z
	Yongeichthys criniger	Hair-finned goby	-	X
HAEMULIDAE	Haemulidae sp.1	Grunter	?	X
	Plectorhincus gibbosus	Brown sweetlip	aR	Y
	Pomadasys kaakan	Grunter	R	XYZ
	Pomadasys maculatus	Grunter	a	X
	Pomadasys opercularis	Spotted grunter	R	XYZ
	Pomadasys sp.1	Grunter	?	X

Table 10b continued.

HEMIRHAMPHIDAE	Arrhamphus sclerolepis	Snub-nosed garfish	bC	XZ
	Hemirhamphus far	Five-spot garfish	BC	Y
	Hyporhamphus australis	Sea garfish	BC	X
	Hyporhamphus dussumieri	Dussumier's garfish	bC	Z
	Hyporhamphus quoyi	Short-nosed garfish	bC	XY
	Rhynchorhampus georgi	Long-nosed garfish	bC	XY
	Zenarchopterus buffonis	Buffon's garfish	bC	Z
LEIOGNATHIDAE	Gazza minuta	Ponyfish	-	XZ
	Leiognathus bindus	Ponyfish	-	X
	Leiognathus decorus	Ponyfish	-	X
	Leiognathus equulus	Ponyfish	-	XZ
	Leiognathus fasciatus	Ponyfish	-	Z
	Leiognathus leuciscus	Ponyfish	-	Z
	Leiognathus moretoniensis	Ponyfish	-	Z
	Leiognathus splendens	Ponyfish	-	X
	Leiognathus sp.1	Ponyfish	-	X
	Leiognathus spp.	Ponyfishes	-	XY
	Secutor insidator	Ponyfish	-	Z
	Secutor ruconius	Ponyfish	-	XZ
LETHRINIDAE	Lethrinus lentjan	Purple-headed emperor	a	X
	Lethrinus nebulosus	Spangled emperor	CR	Z
	Lethrinus reticulatus	Reticulated emperor	r	X
	Lethrinus sp.1	Emperor	?	X
	Lethrinus spp.	Emperors	?	X X
LOBOTIDAE	Lobotes surinamensis	Triple-tail	cR	Y
LUTJANIDAE	Lutjanus argentimaculatus	Mangrove jack	ARC	YZ
	Lutjanus erythropterus	Small-mouthed nannygai	CR	X
	Lutjanus fulviflammus	Moses perch	ar	XYZ
	Lutjanus russelli	Fingermark	aCR	XY
	Lutjanus sp.1	Sea perch	?	X
MONACANTHIDAE	Monacanthus chinensis	Fan-bellied leatherjacket	A	Y
	Paramonacanthus sp.1	Leatherjacket	A	X
MONODACTYLIDAE	Monodactylus argenteus	Diamond butterfish	Ar	YZ
MUGILIDAE	Liza dussumieri	Flat-tailed mullet	b	Z
	Liza vaigiensis	Diamond-scaled mullet	b	XYZ
	Mugil cephalus	Sea mullet	BT	XYZ
	Mugil georgii	Creek mullet	B	XY
	Valamugil buchanani	Mullet	B	Z
	Valamugil cunnesius	Mullet	B	Z
	Valamugil seheli	Blue-tailed mullet	bC	XZ
MULLIDAE	Upeneus vittatus	Goatfish	a	Z
	Upeneus sp.1	Goatfish	a	XY
MURAENESOCIDAE	Muraenesox sp.	Pike eel	ar	Y
MURAENIDAE	Gymnothorax favagineus	Moray eel	A	YZ
	Gymnothorax sp.1	Moray eel	A	XY
MYLIOBATIDAE	Aetobatus narinari	Eagle ray	Ar	Y
	Aetomyleus sp.	Frog ray	Ar	Y

Table 10b continued.

ORECTOLOBIDAE	Stegastoma fasciatum	Zebra shark	A	Z
PARALICHTHYIDAE	Pseudorhombus arsius	Flounder	a	X
	Pseudorhombus elevatus	Flounder	a	XY
	Pseudorhombus jenynsii	Flounder	a	Z
PLATYCEPHALIDAE	Cymbacephalus nematophthalmus	Fringe-eyed flathead	cr	X
	Inegocia isacanthus	Flathead	-	X
	Platycephalus fuscus	Dusky flathead	cR	XYZ
	Platycephalus indicus	Bar-tailed flathead	cR	XZ
	Platycephalidae spp.	Flathead	?	X
	Suggrundus sp.1	Flathead	?	X
PLOTOSIDAE	Plotosus anguillaris	Striped catfish	A	Y
POLYNEMIDAE	Eleutheronema tetradactylum	Blue salmon	cR	XYZ
	Polydactylus heptadactylus	Tassel-fish	r	X
	Polydactylus multiradiatus	Threadfin	r	XZ
	Polydactylus sheridani	King salmon	CR	XYZ
	Polydactylus sp.1	Threadfin	?	X
POMACANTHIDAE	Pomacentrus sp.	Yellow-tailed damselfish	a	Y
PSETTODIDAE	Psettode erumei	Halibut	cr	Y
PSEUDOMUGILIDAE	Pseudomugil signifer	Blue-eye	a	Z
RHINOBATIDAE	Rhinobatus batillum	Shovelnose ray	Ar	Z
	Rhinobatus spp.	Shovelnose rays	Ar	Y
SCIAENIDAE	Nibea soldado	Silver jewfish	cR	XYZ
	Otolithes ruber	Three-toothed jewfish	r	XZ
	Protonibea diacanthus	Black jewfish	CR	Y
	Sciaenidae sp.1	Jewfish	?	X
SCOMBRIDAE	Scomberomorus commerson	Mackerel	CR	Y
	Scomberomorus queenslandicus	Mackerel	CR	Y
	Scomberomorus semifasciatus	Mackerel	CR	Y
SCORPAENIDAE	Paracentropogon longispinis	Waspfish	A	XY
	Pterois violitans	Butterfly cod	A	Y
	Synanceia horrida	Coastal stonefish	A	Y
	Synanceia verrucosa	Reef stonefish	A	Z
SCYLIORHINIDAE	Atelomycterus macleayi	Cat shark	A	Y
SERRANIDAE	Centrogenys vaigiensis	False scorpionfish	A	X
	Epinephalus merra	Wire netting cod	aR	Y
	Epinephalus tauvina	Estuarine cod	AcR	Y
	Epinephalus spp.	Groupers	Ac	Y
SIGANIDAE	Siganus canaliculatus	Spinefoot	a	X
	Siganus fuscescens	Spinefoot	a	X
	Siganus guttatus	Golden-lined spinefoot	AT	XYZ
	Siganus spinus	Black spinefoot	aT	XY
	Siganus spp.	Rabbitfishes	a	X

Table 10b continued.

SILLIGANIDAE	Sillago maculata	Winter whiting	bR	XYZ
	Sillago sihama	Northern whiting	bR	XYZ
	Sillago sp.1	Whiting	r	X
SOLEIDAE	Aesopia heterorhinus	Sole	a	Z
	Dexilichthys muelleri	Sole	a	X
	Synaptura setifer	Sole	a	Z
SPARIDAE	Acanthopagrus australis	Silver bream	CR	Y
	Acanthopagrus berda	Black bream	CR	XYZ
SPHYRAENIDAE	Agrioposphyraena barracuda	Giant barracuda	cR	Y
	Sphyraena jello	Pickhandle barracuda	cR	XYZ
SPHYRNIDAE	Sphyrna lewini	Hammerhead shark	cr	XY
SYNGNATHIDAE	Bombonia spicifer	Pipefish	A	XYZ
	Syngnathidae spp.	Seahorses	A	Y
SYNODONTIDAE	Saurida nebulosa	Grinner/Rock whiting	r	X
TERAPONIDAE	Pelates quadrilineatus	Trumpeter	-	X
	Terapon jarbua	Trumpeter	-	Z
	Terapon puta	Trumpeter	-	X
	Terapon spp.	Trumpeters	-	X
TETRABRACHIIDAE	Tetrabrachium ocellatum	Smooth anglerfish	A	X
TETRAODONTIDAE	Amblyrhynchotes spinosissimus	Toadfish	a	X
	Arothron hispidus	Stars and stripes toadfish	a	XZ
	Arothron immaculatus	Narrow-lined toadfish	a	X
	Canthigaster margaritatus	Ocellated toby	a	X
	Chelonodon patoca	Toadfish	a	XZ
	Sphaeroides laevigatus	Toadfish	a	Z
	Sphaeroides pleurostictus	Toadfish	a	Z
	Tetraodontidae sp.1	Toadfish	a	X
	Tetraodontidae sp.2	Toadfish	a	X
	Torqugener sp.1	Toadfish	a	X
TOXOTIDAE	Toxotes chatareus	Archerfish	Ar	YZ
TRIACANTHIDAE	Triacanthus biaculeatus	Tripodfish	a	XZ
	Trixiphichthys weberi	Tripodfish	a	X

Table 10c. Fish species and numbers caught on three substrate types,on and off the lease site.

SUBSTRATE	NUMBER OF TRAWLS	NUMBER OF SPECIES	NUMBER OF INDIVIDUALS	INDIVIDUALS PER HECTARE
ALGAE (LEASE SITE)	2	29	336	22400
MUD (OFF LEASE)	10	35	646	8667
SEAGRASS (OFF LEASE)	10	38	367	4933
SEAGRASS (LEASE SITE)	8	45	633	10533
TOTAL	30		1982	

lease site, the fish were relatively evenly distributed across the substrate of Cairns Harbour.

On the Caulerpa algae beds, which fall within the lease site, four species of small gobies (31%) and four species of pony fish (49%) were numerically dominant.

It is not possible to put a dollar value on the fish since most do not constitute part of an organised fishery with an appropriate marketing infrastructure. Many of these fish are of considerable value to recreational fishermen. While the wholesale value of the other species may be relatively unimportant, the abundance and the consequent catch per unit effort of fish are significant factors in establishing how the general public perceives and uses Cairns Harbour and Trinity Inlet. Many of the small fish not of direct value to fishermen may be a food source for larger more valuable species. Juveniles of species such as mackerels are only found on inshore mudflats and seagrass at certain times of the year. Loss of these inshore fish habitats may have an effect on these pelagic species far beyond the confines of Cairns Harbour.

3.3.5 Fluctuations in fish populations

Data on temporal changes in fish species and numbers are based on species records from one collection technique, beam trawling (Appendix 2). Samples were analysed for 11 months from January 1988 to November 1988.

Despite the limitations of sampling and time scale, distinct and statistically significant differences were found between months in both the number of individuals and number of species (Kruskal-Wallis, $P<0.05$) (Siegel, 1956).The largest number of species was recorded in January, February and March (Fig. 24). Individual numbers of fish were variable and depended on chance capture of species. The number of individuals exceeded 200 in February, June, August and November with no obvious seasonal trend identified (Fig. 25).

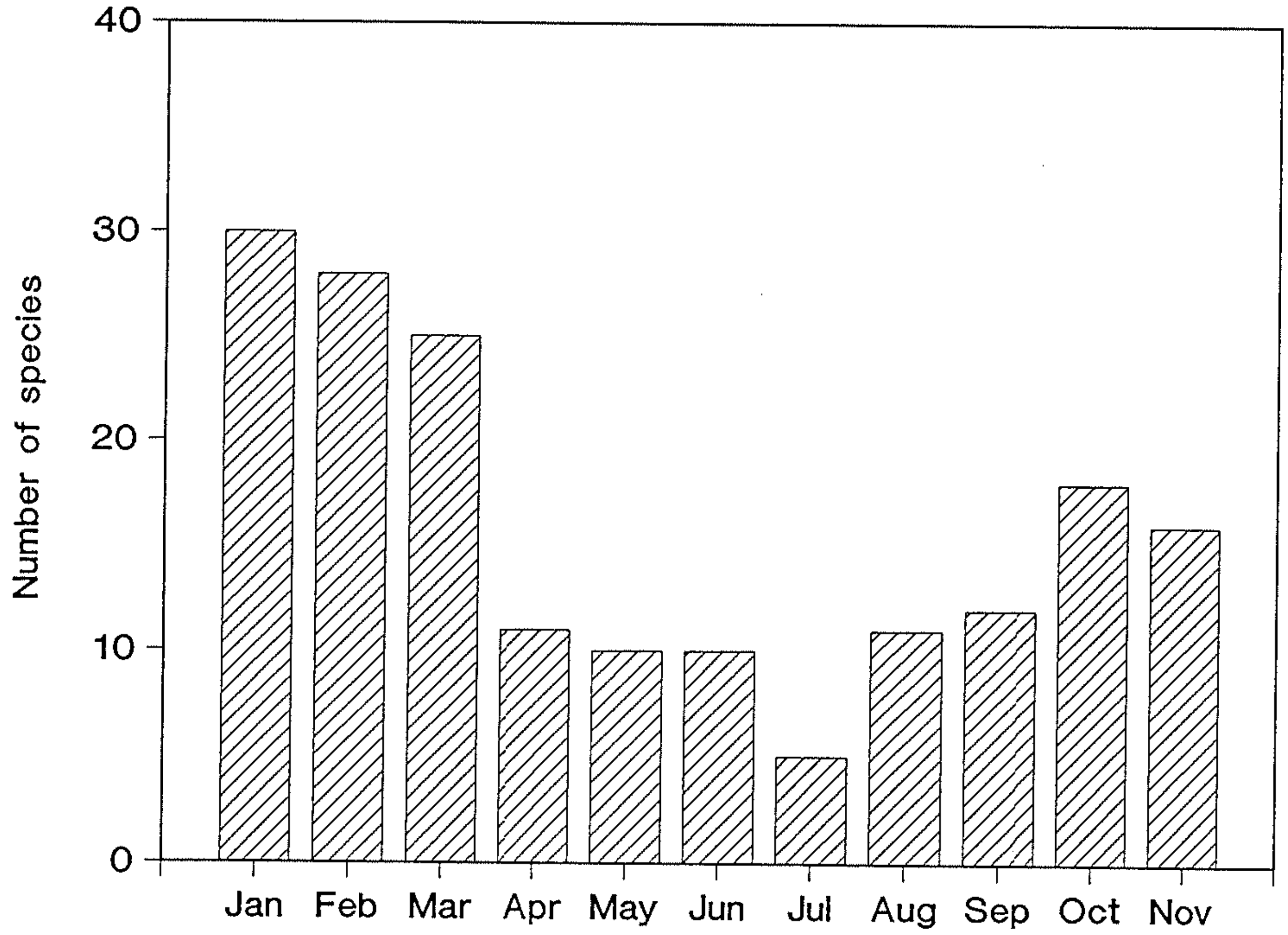


Figure 24. Seasonal changes in number of fish species caught in monthly beam trawls in Cairns Harbour.

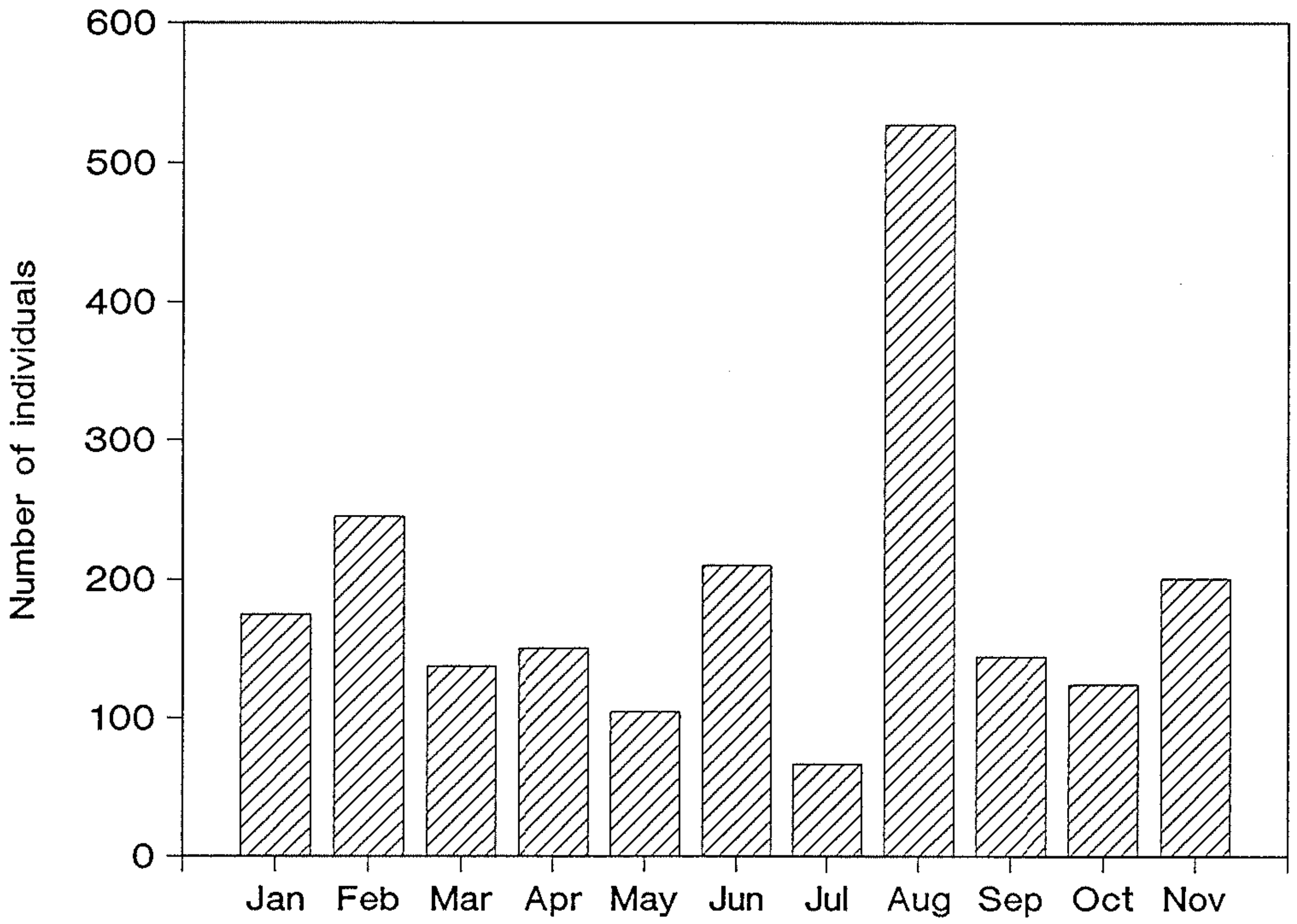


Figure 25. Seasonal changes in number of individual fish caught in monthly beam trawls in Cairns Harbour.

3.3.6 Crabs and non-prawn crustacea

Eighteen species of crabs were collected using three sampling methods (Table 11a and 11b). The sand crab, Portunus pelagicus, was the most numerous. Only two crab species have a value to the commercial and recreational fishery: Portunus pelagicus and the mud crab Scylla serrata (Table 11b).

A survey was conducted of crab holes on the intertidal mudflats within the Development lease site in December 1988. The number of crab holes in a square metre of mud surface ranged from 4 to 304 with a mean of 120. The maximum diameter of the holes was 50mm. The holes were most likely formed by crabs of the family Grapsidae (Table 11b). No mud crab holes were encountered, although mud crabs have been caught on the lease site (Table 11a). Mud crabs move onto the harbour foreshore when the tide is high and generally move back to the deeper inlet and creek waters at low tide. They can occasionally be found in shallow depressions or pools on the exposed mudflats according to local crab fishermen but this was not observed during our study. The crab holes found in our survey were mostly restricted to the band of unvegetated mud between the seagrass beds and the esplanade retaining wall.

Other crustacea captured by beam trawls on the lease site include amphipods, isopods, ostracods, carid prawns and sergestid prawns. None of these animals have direct commercial value and most were small (Table 12).

3.3.7 Infauna

Eighteen samples of the surface (0-50mm) sediment of the intertidal Cairns Harbour were collected and sieved to quantify the number of animals living in this habitat (Appendix 2). The most common animals found were polychaete worms (Table 13). Insect larvae and worms of the Phylum Sipuncula were also relatively common. Samples from the esplanade seagrass beds, mudflat areas with an algal mat cover and the saltcouch areas all contained the greatest numbers of animals. Most animals were very small, ranging in size from 0.5 to 8.0mm.

The number of animals and their size appears to be too small to support the observed bird population of the mudflats. Birds must therefore supplement their diet by feeding elsewhere, or by feeding on marine animals living in shallow ponds or in the shallow water edge.

The intertidal mud contains pesticides and heavy metals such as lead (section 3.1.1), and is oxygenated for only the surface 2-5mm. These factors, combined with lengthy exposure to high temperature and freshwater run-off from the shore would make this environment a harsh one for most animals.

Table 11a. Species, size and abundance data for crabs collected in the Cairns Harbour.

SPECIES *	LENGTH RANGE (mm)	AVERAGE LENGTH (mm)	TOTAL WEIGHT (g)	% BIOMASS	TOTAL NUMBER	% ABUNDANCE	NET TYPE
Dorippe c.f. australiensis	5-13	7	2.8	0.03	7	1.14	B
Dorippe sp.1	7-9	8	0.1	<0.01	3	0.49	B
Grapsidae sp.1	3-9	5	1.2	0.01	12	1.96	B
Matuta granulosa	6-8	7	0.4	<0.01	3	0.49	B
Matuta lunaris	20	20	3.2	0.03	1	0.16	B
Ocypodidae sp.1	3-6	4	1.0	0.01	15	2.45	B
Parthenope sp.1	8	8	0.6	<0.01	2	0.33	B
Portunidae spp.	4-6	5	0.2	<0.01	3	0.49	B
Portunus andersoni	8-14	11	14.2	0.15	18	2.94	B
Portunus orbitosinus	9	9	0.4	<0.01	2	0.33	B,S
Portunus pelagicus	4-73	19	6259.7	67.95	505	82.52	B,G,S
Scylla serrata	74-97	53	2891.0	31.38	7	1.14	B,S
Thalamita sp.1	15	15	1.9	0.02	1	0.16	B
Thalamita sp.2	5-26	10	30.9	0.34	21	3.43	B
Thalamita parvidens	11	11	1.8	0.02	2	0.33	B,S
Thalamita sima	6-11	8	1.9	0.02	5	0.82	B
Unidentified spp.	5-7	6	0.4	<0.01	4	0.65	B
Xanthidae sp.	6	6	0.2	<0.01	1	0.16	B
TOTAL	3-97	13	9211.9	100.00	612	100.00	

* Some identifications in this report are provisional.

Table 11b. Crab species and value classification for crabs recorded from Cairns Harbour and Trinity Inlet.

Legend for codes:	Number of species
C - Targeted commercial species	2
c - incidental commercial species	0
R - targeted recreational species	2
r - incidental recreational species	0
- no fishery value	16

Legend for surveys:

X - QDPI survey 1988

FAMILY	SPECIES	COMMON NAME	CODE	SURVEY
CALAPPIDAE	Matuta granulosa	Box crab	-	X
	Matuta lunaris	Box crab	-	X
DORIPPIDAE	Dorippe c.f. australiensis	Crab	-	X
	Dorippe sp.1	Crab	-	X
GRAPSIDAE	Grapsidae sp.1	Crab	-	X
OCYPODIDAE	Ocypodidae sp.1	Crab	-	X
PARTHENOPIDAE	Parthenope sp.1	Crab	-	X
PORTUNIDAE	Portunidae spp.	Swimming crabs	?	X
	Portunus andersoni	Swimming crab	-	X
	Portunus orbitosinus	Swimming crab	-	X
	Portunus pelagicus	Sand crab	CR	X
	Scylla serrata	Mud crab	CR	X
	Thalamita sp.1	Swimming crab	-	X
	Thalamita sp.2	Swimming crab	-	X
	Thalamita parvidens	Swimming crab	-	X
	Thalamita sima	Swimming crab	-	X
UNIDENTIFIED	unidentified spp.	Crabs	?	X
XANTHIDAE	Xanthidae sp.1	Crab	-	X

Table 12. Other Crustacea and molluscs from beam trawl samples on the Cairns Esplanade seagrass (four trawls, October 1988)

TAXONOMIC GROUP	COMMON NAME	NUMBER	WEIGHT(g)
CRUSTACEA			
Amphipoda	Amphipods	34	0.5
Caridea	Carid prawns	1473	90.6
Grapsidae	Grapsid crabs	2	0.1
Isopoda	Isopods	12	0.4
Ocypodida	Ghost crabs	4	0.2
Ostracoda	Ostracods	26	0.3
Palinurid	Rock lobsters	1	0.1
Portunida	Swimming/Sand crabs	26	74.4
Sergestid	Sergestid prawns	3	0.1
Xanthidae	Xanthid crabs	1	0.2
MOLLUSCA			
Cerithiid	Sand creepers	6	0.1
Trochidae	Top shells	2	0.1

Table 13. Total numbers of infauna in eighteen $0.002m^3$ surface samples of Cairns Harbour sediment.

Faunal Groups	Region						
	Seagrass Esplanade	Mangrove Forest	Bessie Point Mudflat	Algal Mat Esplanade	Salt Couch	Drainage Channel	Size Range (mm)
Polychaeta	45		8	133	1	12	0.5 - 2.0
Brachyura	5	2	5	9	2		0.5 - 2.0
Insect larvae		1	4		69	2	0.5 - 4.0
Bivalvia	3	2	2			3	0.5 - 8.0
Gastropoda	5	4	5				0.5 - 4.0
Sipuncula	1	22		8			1.0
Echuira				1	1		0.5 - 2.0
Holothuroidea		1					0.5
Platyhelminthes	7						0.5
Foraminiferida	2						1.0
Pycnognida	1						0.5
Copepoda				1			0.5
Total	69	32	24	152	73	17	

3.3.8 Dugong, turtles, crocodiles

Seagrasses form the major dietary component for dugong and thus seagrass beds are of considerable significance to the long-term viability of dugong populations.

Relevant information on the local incidence of dugongs was obtained from shark contractor records and by personal communication with the James Cook University dugong research specialist, Dr. Helene Marsh. A summary of dugong catch data in the Cairns to Port Douglas region is listed in Table 14. Catches suggest that dugong have been present in the past in large numbers in Mission Bay and possibly also in Cairns Harbour itself. Records are intermittent but demonstrate a decline in numbers since 1965. Recent surveys have not found dugong in the region (Marsh, 1984) but it is possible dugong herds occasionally move into the area.

Although dugong feeding trails were not observed in seagrass beds during sampling, they were noted during preliminary work by Greenway in 1987 in the vicinity of Ellie Point (see photographs, Appendix 7). Dugong feeding trails have also been recorded in Cairns Harbour during low level helicopter flights in 1989.

The decline in dugong numbers in the Cairns region may have resulted from both hunting pressure from the nearby Yarrabah aboriginal community and the dugongs' avoidance of areas of heavy motor boat activity.

There are no quantitative data on turtle or crocodile populations in the Cairns Harbour. Turtles are commonly sighted in the False Cape region and Mission Bay. A small population of crocodiles exists in Trinity Inlet. Neither crocodiles nor turtles were sighted during surveys of the Cairns Harbour.

3.3.9 Birds

This topic is addressed in a companion report by Environmental Science and Services (Environmental Assessment).

Table 14. Records of dugong captured at Cairns and from the Yarrabah to Port Douglas region (from Marsh, 1984).

Date	Details	Source
Traditional fishing		
1965	200 taken per year by 6 Yarrabah fishermen; one person took 64 in a single year	Bertram & Bertram (1973)
Incidental capture		
1965 - 66	7 caught in Cairns shark nets	Patterson (1979)
1966	1 caught in Trinity Bay fishing net taken to Cairns Oceanarium	Oke (1967)
1966 -67	7 caught in Cairns shark nets	Patterson (1979)
1967 - 68	3 "	"
1968 - 69	20 "	"
1969 - 70	7 "	"
1970 - 71	12 "	"
1971 - 72	6 "	"
1972 - 73	10 "	"
1973 - 74	6 "	"
1974 - 75	8 "	"
1975 - 76	8 "	"
1976 - 77	3 "	"
1977 - 78	4 "	"
1978	1 caught in fishing net in Trinity Bay taken to Cairns Oceanarium	Heinsohn & Marsh (1979)
1979 - 80	2 caught in Cairns shark nets	Patterson (pers. comm. 1984)
1980 - 81	1 "	"
1980's	Three commercial fishermen working between Innisfail and Port Douglas reportedly kill about 5 dugongs each per year. Most are taken during beachfront netting between Cairns and Port Douglas.	Marsh & Heinsohn (1982)
Sightings		
1965	A herd of 100 had recently been seen in Cairns-Yarrabah area	Bertram & Bertram (1973)
1975	3 dugongs seen in Trinity Bay during an aerial survey on November 3	Heinsohn (1975)
1978	No dugongs were seen between Cairns and Port Douglas during a survey in November	Heinsohn & Marsh (1979)

After Marsh (1984)

3.4 Historical changes in mudflats and seagrass distribution (Greenway/Hollingsworth)

3.4.1 Historical mapping

Seagrass beds, mudflats and mangroves in Cairns Harbour between Ellie Point and Bessie Point have been mapped from aerial photographs taken in 1952, 1971, 1974, 1979, 1983 and 1987 (Appendix 8). Caution must be exercised in comparing the extent of seagrass as shown in these figures since factors such as tide level, water clarity and sea conditions at the time of photography, as well as the quality (some are monochrome, some are colour) and scale variation between photographs make the task of interpretation difficult. Furthermore algal vegetation of all kinds can easily be mistaken for seagrass in high level, wide angle imagery.

The 1979, 1983 and 1987 photographs were all taken at approximately the same tide level (1.0m), thereby providing a better comparative picture of seagrass distribution and cover over the last decade (Appendix 8). However, despite similarities in tide levels, the extent of exposed mudflats and associated seagrass adjacent to Gatton Street and Saltwater Creek is quite variable. Such variable factors associated with mapping of seagrass from a series of aerial photographs taken at different tide times and sea conditions make the task of direct comparison difficult. However, the major changes in seagrass distribution in Cairns Harbour over the past 35 years have been mapped, subject to the constraints listed above.

Seagrass areas and changes

This mapping exercise has shown that intertidal mudflats and associated seagrass beds have been, over the past 35 years at least, a major component of the marine communities in Trinity Inlet.

The 1952, 1971 and 1974 photographs indicate a continuous band of dense seagrass existed between Ellie Point and Shields Street. Good mapping coverage of the seaward extent was facilitated by the clearer waters of neap tides in 1952 and 1974 and the lower tide level of 0.69m in 1971. The 1971 photographs also indicate dense seagrass could be found between Hills Creek and Bessie Point. The situation over time is described in more detail below.

1952 - 1971

In general, the observed pattern of seagrass distribution did not change greatly between 1952 and 1971. The 1971 photographs show an increased cover of seagrass in the Ellie Point region. Coverage may have been just as extensive in 1952, but the poor quality of the aerial photography for this area precluded mapping. Similarly, poor photograph quality precluded mapping of seagrass in the Bessie Point region in 1952. One significant change worthy of note appears to be the loss of about 26ha of seagrass from the upper intertidal area (landward margin) between Little Barron River and the start of the Esplanade, most probably due to the progradation of mangroves and associated sediment deposition. Ten hectares were lost probably as a direct result of mangrove colonization of the seagrass zone, the remaining 16ha becoming unvegetated mudflats probably as a result of elevation of the seagrass by sediment deposition in an accreting environment. Similarly progradation of mangroves and sediment deposition between Hills Creek and Bessie Point could have caused an apparent loss in upper intertidal seagrass beds and an increase in bare mudflats over this 20 year period.

1971 - 1974

The distribution pattern of seagrass in 1971 and in 1974 is very similar. The landward extent of seagrass between Ellie Point and the area in front of Shields Street is the same; however, there are some changes apparent in seagrass abundance, namely a reduction of dense seagrass cover and an increase in mid-dense seagrass cover. Between Little Barron River and Saltwater Creek, the area of dense seagrass appears to have decreased by 12ha, between Little Barron River and Grove Street by 23ha and between Grove Street and Shields Street by 9ha. Seagrass abundance seems reduced along the upper intertidal landward fringe between Saltwater Creek and Upward Street, with only isolated clumps of seagrass characterising the landward extent. Elevation of seagrass by sediment deposition probably accounts for these observed alterations in seagrass cover. Continuing mangrove progradation between Hills Creek and Bessie Point and associated sediment deposition would have caused further seagrass loss and a reduction in abundance along the upper intertidal fringe in this region. This is particularly evident from the 1979 distribution pattern.

1971 and 1974 - 1979

From the limited mapping information for 1979, it would appear that no significant changes in seagrass distribution or abundance occurred between 1974 and 1979. Comparison of the 1971 and 1979 maps however, showed a considerable change from dense to mid-dense seagrass cover between Hills Creek and Bessie Point. Sediment deposition is suggested as the reason for this loss.

1974 and 1979 - 1983

The distribution pattern and abundance of seagrass in 1983 seems very similar to that of both 1979 and 1974, with no significant decreases in seagrass cover detected.

1983 - 1987

The distribution patterns of seagrass in 1983 and in 1987 were similar overall; however, there was a considerable decrease in seagrass cover between Saltwater Creek and the area in front of Grove Street, with isolated clumps of seagrass replacing mid-dense (25ha) and dense (15ha) beds. Between Grove and Shields Street there was a change of 14ha of dense seagrass to mid-dense to sparse seagrass or isolated clumps. The decrease in seagrass from the upper intertidal areas resulted in an increase in the area of bare mudflats.

There was a marked increase observed in algal cover between Little Barron River and Saltwater Creek over the period. However, this increase may be temporary since algal cover is highly ephemeral.

Lease Site

The aerial photographs indicate that the intertidal mudflats in front of the esplanade between Minnie Street and Shields Street have consistently supported a dense seagrass cover over the past decade (Table 15).

Table 15. Cover of dense (50-100% substrate coverage) intertidal seagrass within the lease site between 1979 and 1987.

	1979	1983	1979 - 1983 Loss(-) or gain(+)	1987	1983 - 1987 Loss(-) or gain(+)
Total cover (ha)	25.2	28.8	+3.6	22.0	- 6.8

Conclusions

Historical mapping of the mudflat and seagrass communities in Cairns Harbour has provided an insight into the temporal changes that have taken place over the past 25 years. Although the mapping has been limited to intertidal seagrass beds exposed or visible at the time of aerial photography, some noteworthy changes have been observed. These changes relate primarily to losses in seagrass or a decrease in seagrass density from upper intertidal areas. The aerial photographs clearly demonstrate that mangroves between Little Barron River and Saltwater Creek and between Hills Creek and Bessie Point have replaced seagrass communities. Sediment deposition associated with shoreline progradation has probably caused elevation of seagrass beds resulting in either a complete loss of seagrass from upper intertidal areas or a reduction in seagrass abundance from dense to sparse or even isolated clumps.

The results of current and sediment analysis (see companion report, Trinity Point Coastal Processes Vol. 3) suggest a similar change would have occurred on the lease site area if mangrove seedlings were not removed by the Cairns Port Authority. It is highly likely that the coastline adjacent to the esplanade would be 300-700m seaward, and that most of the present seagrasses would be replaced by a mangrove forest, if seedlings had not been removed in the past.

3.4.2 Weather

Information on rainfall and cyclones in the Cairns area over the past 40 years was obtained from the Bureau of Meteorology. Total and monthly rainfall over a six month period prior to the date of the aerial photographs are given in Table 16a. Cyclones in the Cairns area are given in Table 16b.

Average annual rainfall over the four to five year period prior to the aerial photographs does not vary greatly (see Table 16a). Lower salinities (<20g/l) lasting for a period of two or more days can cause blade loss in seagrasses and complete recovery of the seagrass beds may take several months (Greenway, 1988 unpublished data). The seagrass beds most likely to be affected by lowered salinities are those in shallower water. Thus a decrease in seagrass abundance in the upper intertidal regions could result from prolonged freshwater flushes. There is no indication from the monthly rainfall data that lowered salinities prior to the taking of the aerial photographs would have been the responsible for a decrease in seagrass abundance in the upper intertidal regions.

Cyclones have the potential to cause severe destruction to seagrass beds, particularly to shallow water beds (Kenyon and Poiner, 1987; Rothlisberg et al., 1988). However, despite the frequent occurrence of cyclones and associated tropical storms in the Cairns region, there is no indication from the aerial photographs of large scale seagrass loss due to cyclonic conditions. Cyclone Winifred in January 1986 may have contributed to the decrease in seagrass abundance between Saltwater Creek and Shields Street and between Hills Creek and Bessie Point which was evident in the 1987 aerial photographs. In the absence of aerial photography both prior to and immediately after the cyclone no conclusions can be drawn. Sediment movement associated with wind and wave action and localised build-up of sediment may cause a decrease in seagrass abundance in the upper intertidal region.

3.4.3 Dredging

Dredging activities may cause increased turbidity and siltation. This has the potential to cause seagrass loss by smothering and bed elevation. Dredging of the Cairns Harbour shipping channel has been conducted on a full time basis between 1913 and 1975, and since 1975 an annual maintenance service has been carried out (Dennis Chant, Cairns Port Authority, pers. comm., 1988). Turbidity measurements taken while the Cairns Harbour and the Trinity Inlet shipping channel were being dredged in 1988 indicate that dredging does not measurably increase turbidity on the lease site (Fig. 7). A decrease in seagrass abundance between Hills Creek and Bessie Point and between Shields Street and Saltwater Creek due to dredging is likely to be small, difficult to quantify and difficult to detect.

3.4.4 Reclamation

Reclamation of the esplanade foreshore between 1974 and 1987 for parkland has resulted in the direct loss of about 10ha of mudflats and associated algal mat. Whilst the aerial photographs indicate that these upper littoral mudflats probably never supported any significant seagrass cover, saltcouch (Sporobolus virginius) would have occurred at the landward fringe especially in areas receiving freshwater run-off.

Table 16a. Annual and monthly rainfall data for period prior to aerial photographs.

Date of photo	Monthly rainfall (mm) in six months preceding date of photo										Total	Average annual rainfall (mm) for 4 years preceding date of photo
	J	F	M	A	M	J	J	A	S	O		
30 June 1952	634	180	199	167	134	21					1 355	1 966
16 August 1971		550	699	329	20	33	9				1 640	1 965
22 September 1974			764	74	173	9	3	9			1 032	2 510
21 November 1979					60	116	20	18	10	17	241	2 294
3 July 1983	100	58	804	172	299	15					1 448	1 884
13 July 1987	297	428	227	307	103	144					1 505	1 953

Table 16b. Cyclones prior to aerial photographs.

Date of photograph	Date of cyclone		Distance of Cyclone Centre from Cairns	
30.06.52	January & March 1950		55 and 60 km N	
16.08.71	March	1967	130 km	NE
22.09.74	February	1974	100 km	S
21.11.79	January	1979	130 km	NNW
03.07.83	January	1983	140 km	ENE
13.07.87	January	1986	80 km	S

Recent reclamation of the intertidal area for carpark and marina facilities between Spence Street and Shields Street has resulted in the direct loss of about 4ha of mudflats, associated algal mat, and possibly seagrass patches.

3.4.5 Rising Sea Level

A 'Greenhouse' scenario predicts higher temperatures, higher rainfall, higher sea levels and increased frequency of cyclone activity for the Cairns region (Pearman, 1988). The effects of higher rainfall, rising sea levels and increased cyclone activity on the intertidal mudflats and seagrass beds in Cairns Harbour will be briefly considered here. Rising sea levels are likely to result in retrogression of mudflat communities unless sediment is accreting at the same rate as the sea level rise.

There is a definite zonation of estuarine and marine communities related to the extent of seawater inundation and exposure . Salt pan and associated saltmarsh communities are found in areas only inundated by the highest spring tides. The plants can tolerate hypersaline sediments but not frequent inundation. Mangrove communities occur between mean high water spring (approximately 2.5m above Port Datum) and mean low water spring (approximately Port Datum), and within this tidal range several discrete communities are found (Dowling, 1983). The distribution and zonation of mangrove communities is related to the tolerance levels of the various species to tidal inundation.

Bare mudflats or mudflats with algal mat occur above 1.0m Datum whilst dense seagrass communities occur between 1.0m and -0.5m. The upper landward extent of seagrass is limited by exposure and dehydration. The depth of seagrass at the seaward margin is limited by low light levels (section 3.2.3). The seagrasses in Cairns Harbour have a very restricted depth distribution due to the highly turbid waters (section 3.2.3).

Historical mapping over the past 40 years (Appendix 8 and Figure 9) has shown a seaward progradation of mangroves and a loss of seagrass from the upper intertidal areas. Rising sea levels over the next 50 years may result in the landward retreat of mangroves and the landward extension of seagrass over what is now intertidal mudflats.

The sea level rise adopted for this project is 0.9m over the next 50 years, a "middle of the road" value for the various scenarios commonly quoted (further information is in the companion report; MacDonald Wagner 1988 - Coastal Processes , Vol. 3, Project Impact and Design Criteria).

Assuming this rise in sea level, the response of the seagrass beds to the rising sea level in Cairns Harbour will depend on the relationship between the rate of sedimentation and the rate of submergence. In the total absence of sediment deposition, the seagrass could be expected to move landward over the mudflats to the current level of the 1.9m contour (ie. 0.9m above present upper limit). At the same time the lower seaward limit of seagrass would be expected to recede since light levels above the existing seagrass beds would decrease with the increase in water depth. Under such low light intensities (below the light compensation point necessary for photosynthetic maintenance) the seagrass would gradually die off. Thus the lower limit in 50 years time would correspond to approximately the current 0.4m contour (ie. 0.9m above the present lower limit). Thus, based on the current contour plan for Cairns Harbour, the landward movement of seagrass would occur over distances ranging between

300m and 1 000m between the Little Barron River and Trinity Inlet. The existing seawall along the esplanade, however, would act as a barrier to the further landward migration of seagrass particularly where the contour level is below 2.0m. The seagrass would also extend into what is presently a mangrove zone.

The area that seagrass can occupy between Ellie Point and False Cape within the 1.9m and 0.4m contour would decrease from an estimated 927 hectares to 842 hectares, a loss of 9%. Seagrass, however, does not cover the entire mud surface between the 1.0m and -0.5m contours at present and it is not possible to estimate the actual extent of the cover of the 842 hectares that would exist after a 0.9m sea level rise occurred.

The success of seagrass colonising such large areas of intertidal mudflats over the 50 year period will depend on the ability of seagrasses to propagate. Currently only one species, Zostera capricorni, occurs commonly in the upper intertidal areas. Zostera does not appear to reproduce by seeds in Cairns Harbour; colonisation is due to vegetative growth of the horizontal rhizome system and the number of proliferating shoots. Transplant experiments with Zostera capricorni in Cairns Harbour (see Section 4.2) and in Botany Bay, NSW, (West et al., 1988) and with other species of Zostera (Zostera noltii in England and Zostera marina in USA) have demonstrated that this genus may colonise suitable mudflats quite successfully.

These predicted contour levels for the upper (1.9m) and the lower limit (0.4m) of seagrass growth assume the tidal range in 50 years will be similar to that at present (ie. MHSW 2.41m and MLWS 0.58m). Smaller or larger tidal ranges will alter the duration of intertidal exposure and the depth of water covering the seagrass, which in turn will affect seagrass distribution.

Rising sea levels in the absence of sediment deposition is most unlikely in Cairns Harbour. Historical evidence and the results of numerical modelling and sediment analysis (Trinity Point Coastal Processes, Vol. 3, MacDonald Wagner, 1988) demonstrate that the sediments of the Cairns Harbour are naturally accreting and consequently landward edges are moving slowly seaward. This analysis indicates that during periods of minimal inlet run-off flow, another long-term effect operates; ingestion of sediment into Cairns Harbour. Fine silts and clays, brought into suspension by wind within Trinity Bay as well as being carried northwards from the Mulgrave River by longshore currents, are carried into the quieter water and associated mangrove areas of the Inlet, where they deposit. During run-off floods, material deposited in the Trinity Inlet would be flushed out into Cairns Harbour with consequent accretion on the mudflats adjacent to the Trinity Inlet entrance. In the long-term, tidal ingestion would be a more dominant process than run-off flood flushing, except in the areas immediately adjacent to the Inlet entrance. Thus sediments should continue to accrete over the next 50 years between Shields Street and the Little Barron River and between Hills Creek and Bessie Point. Since the Greenhouse scenario also predicts higher rainfall, the frequency and magnitude of run-off floods in Cairns Harbour will also be greater, and result in increased sediment deposition in the Harbour.

If sediment accretion is less than 0.9m in 50 years then landward migration of seagrass will occur but the extent will depend on the amount of sediment deposited relative to the upper tidal limit of seagrass distribution. It is unlikely that the rate of sedimentation will be uniform in the Cairns Harbour (see companion report, Coastal Processes, Vol. 3).

Increased rainfall and flooding associated with the Greenhouse effect could also affect the seagrass adversely through prolonged increased turbidity and lowered salinities (Section 3.2.3). The shallow seagrass beds in Cairns Harbour would be particularly susceptible to freshwater flushing, resulting in a decrease in biomass, and may be completely lost from the upper intertidal areas.

Rising sea levels may affect the distribution and abundance of the various species of seagrass in Cairns Harbour due to changes in substrate and micro-relief. Thalassia hemprichii and Cymodocea serrulata have a very restricted distribution in Cairns Harbour, and these species may not be able to colonise the silty mud substrate more typical of the upper intertidal areas. Thalassia hemprichii and Cymodocea serrulata are found commonly in tidal pools, and should such depressions be rapidly infilled with sediments, then loss of these species may occur. Zostera capricorni is currently the most abundant species and grows in a wide variety of substrate types. It is also more tolerant of exposure than Thalassia hemprichii and Cymodocea serrulata.

The Greenhouse scenario predicted increased cyclone activity which could cause severe destruction of seagrass beds, particularly to shallow water inshore beds (Kenyon and Poiner, 1987; Rothlisberg et al., 1988). Increased turbidity and lowered salinity associated with rainfall and sediment movement, and physical turbulence associated with wave and wind action, are all factors that could contribute towards a decrease in seagrass abundance. Furthermore, increased cyclone frequency would mean that between cyclones the recovery time for seagrass beds would be shorter. Rothlisberg et al. (1988) suggest that the potential loss of seagrass beds in the Gulf of Carpentaria due to the Greenhouse effect could result in a decrease in tiger prawn catches since the seagrass beds are nursery habitats for the tiger prawn. Similar effects in Cairns Harbour could present similar problems for its tiger prawn fishery.

4.0 FISHERY HABITAT MODIFICATION AND RESTORATION

4.1 Introduction

The proposed Trinity Point Development would replace approximately 81ha of seagrass, mudflat and algal mat with a marina basin and channel system. It may be possible to reduce the impact that the loss of such habitat may have on the Cairns Harbour marine fauna through restoring lost habitat by transplantation or replanting and restoring marine vegetation.

The feasibility of two different methods was investigated: transplanting and restoring of seagrass, and the development of artificial reefs which can provide additional habitat for fish.

4.2 Seagrass transplantation and restoration feasibility studies

Literature review (Greenway/Hollingsworth)

4.2.1 General

Seagrasses are of importance to the coastal marine environment as a shelter and nursery for commercial species of fish and prawns and as a sediment stabilizer. There has been an increasing awareness of the need to restore seagrass beds denuded by both natural and man made causes.

A variety of seagrass transplantation techniques have been applied over the past 20 years. Vegetative techniques essentially involve either the transplantation of individual seagrass plants (turions) including rhizomes and shoots, or the transplantation of seagrass turfs (plugs, sods) which are removed with accompanying sediment and relocated to excavated holes at the new site. Restoration has also been carried out by planting seedlings.

Success rates of seagrass restoration are highly variable. The biology of the individual species and the environment of the transplant site are important parameters in determining survival.

The substrate-energy regime and the light-depth regime within which the plants grow are likely to affect the success and growth of transplants, as do the season of year and the interaction with other seagrass species. Kenworthy and Fonseca (1977) examined the seagrass-substrate relationship with respect to transplantation of Zostera marina whilst Dennison and Alberte (1986) examined the photosynthetic adaptation of Zostera marina transplants along a depth gradient. Although the experiments were carried out in the USA on a temperate species of seagrass, the results have significant implications for all seagrass transplantation work and hence will be outlined here.

4.2.2 Substrate

Kenworthy and Fonseca (1977) found that Zostera marina transplant plants originating from a natural silty substrate "displayed the best overall growth" when compared with plants from sandy substrates. Plants originating from a sand substrate "showed a significantly better growth" when placed in silt, possibly due to their better developed subsurface root system. Furthermore regardless of origin the transplants "continually afforded better growth" when grown in a silty loam substrate as opposed to coarse sand or sandy loam.

Although Zostera marina grows in a wide variety of sediment types ranging from coarse sand to fine silt, these results suggest that the seagrass plants which grow in a certain sediment type are not necessarily physiologically adapted only to that particular substrate. Morphological features such as a well developed sub-surface root system are also important, and could be advantageous in transplants.

Kenworthy and Fonseca (1977) also conducted an experiment which showed that transplants grown in undisturbed natural sediment were more successful than transplants grown in sun-dried sediment in which the biological activity had been highly altered. Sun-dried sediment simulated exposed dredged spoil.

Zostera capricorni like Zostera marina grows in a variety of sediment types, although in Cairns Harbour it predominantly grows in a silty substrate. A small, pilot scale study will be necessary to determine the nature of the new substrate and to evaluate its suitability for the transplant species to be used for seagrass restoration.

4.2.3 Zostera capricorni transplants

West et al. (1988) carried out Zostera capricorni transplant trials in Botany Bay to assess the feasibility and cost effectiveness of a proposed large scale transplant programme. Plugs of about 20-30 shoots were used as the transplant "units". The experiment was monitored for only a four month period as an unusual storm resulting in increased wave action and sand movement destroyed the transplants.

Zostera capricorni displays seasonal growth patterns in more southerly locations (Moreton Bay, Botany Bay), however it will be necessary to determine whether or not there are any seasonal trends for Zostera capricorni in a more tropical location such as the Cairns Harbour.

4.2.4 Light

The field transplant experiments of Dennison and Alberte (1986) showed that reciprocal transplants from shallow to deep water sites within the natural distribution of a Zostera marina seagrass bed adapted to the respective site light regime (total daily irradiance and daily period above light saturation point for Zostera marina photosynthesis).

At both deep water and shallow sites the photosynthesis-irradiance relationships of the transplants were similar to controls in terms of photosynthetic maximum, initial slope, light saturation and compensation points and dark respiration points. In spite of this photo-adaptation, reductions in growth and biomass occurred at both shallow and deep stations over a four month experimental period. This indicated that the transplanted plants were not able to acclimatise effectively to the different environmental conditions. Transplants from low light or deep water to high light or shallow water had higher growth rates and biomass than reverse transplants (from high light/shallow water to low light/deep water), indicating that the "shift up" from low light to high light had less effect on Zostera marina growth and biomass than a "shift down" from high light to low light.

Zostera marina plants transplanted in deeper water beyond the natural extent of the seagrass bed were light limited; the combination of low photosynthetic maximum values and elevated dark respiration rates resulted in negative net daily photosynthesis and, ultimately, mortality. Zostera marina plants transplanted in the intertidal region landward of the existing edge of the seagrass bed had the highest photosynthetic maximum values and lowest dark respiration rates, resulting in the highest net daily photosynthetic values. At this inshore site plant growth and biomass were highest, although the transplants did not survive for longer than two years and a mechanism for limiting long-term survival (and preventing establishment by natural means) must have existed. Physical disturbance due to increased exposure to wave action has been suggested as a possible cause (Dennison and Alberte, 1986).

Zostera capricorni, like Zostera marina, shows photo-adaptation. However, due to the very low light intensities in Cairns Harbour careful consideration needs to be given to the origin of the transplants and the area for seagrass restoration if these were to be attempted.

4.2.5 Season

Seagrass growth and biomass usually show definite seasonal trends which appear to follow seasonal patterns of water temperature and light. Transplanting of seagrass at times most favourable for growth for the particular species would be expected to give the greatest success.

4.2.6 Field studies (QDPI)

Attempts to mitigate against the likely impact of coastal developments have encouraged the development of techniques for the transplantation and subsequent restoration of seagrass beds. Much of this work has been carried out in the United States. Unfortunately, little if any of this information is directly applicable to the Australian situation. For this reason a feasibility study was undertaken to establish some of the difficulties in attempting to transplant/restore seagrasses in Cairns Harbour.

Three seagrass transplant experiments were conducted (see Appendix 2). Initially 1.0m^2 areas of seagrass adjacent to the lease site were cleared and replanted with three species of seagrass, Zostera capricorni, Thalassia hemprichii and Cymodocea rotundata. This was repeated in 4.0m^2 plots. In both cases the density of the transplanted seagrass was similar to that of control plots when re-examined after several months.

In a second experiment seagrasses that were not normally found in the intertidal region of Cairns Harbour, Halophila decipiens and Halophila tricostata, were planted in cleared areas adjacent to the lease site. These transplants did not survive and had completely disappeared after four weeks. A third experiment was conducted at Green Island, 25km offshore from Cairns where clear water allowed for regular photographic recording of seagrass regrowth. Cleared 0.25m^2 plots were photographed each month and the rate of regrowth recorded. A mixture of three species (Halodule uninervis, Halophila ovata and Cymodocea serrulata) recolonised greater than 80% of the cleared areas in four months with an average lateral rhizome growth of about 100mm per month. Having established with these experiments that seagrasses could be replanted successfully, a larger scale experiment was designed to monitor growth of esplanade seagrass replanted on a site where seagrass did not occur. An area near Saltwater Creek was chosen at approximately the 0.5m contour line. In this region seagrasses survived where water pools occur at low tide. Raised areas of mud between pools dry out at low tide and do not support seagrass growth (Appendix 7 and Fig. 31, Appendix 12). Six plots were marked out, two experimental and four controls (see Appendix 2). In four of these a $9m^2$ pond was created either by bunding or by digging. On the 24 October 1988 one of each treatment was transplanted with Zostera capricorni at an estimated density of 400-500 shoots/m^2. Seagrass has survived in transplanted plots with shoot density averages after one month of 357 shoots/m^2 for bunded plots and 345 shoots/m^2 for dug plots. This was despite heavy rainfall soon after planting which would have stressed seagrasses exposed at low tide.

These feasibility studies demonstrated that it is possible to replant and transplant seagrasses in the Cairns Harbour. It is possible that if seagrass beds adjacent to the Trinity Point Development were damaged during construction, they may naturally recolonize. Seagrass transplanting from nearby beds could speed up this natural process.

4.2.7 Laboratory studies (QDPI)

Seagrasses were maintained in experimental recirculating seawater aquaria in 1988 at the Northern Fisheries Research Centre to gain some experience with germinating, transplanting and holding seagrasses for future laboratory studies.

In one experiment, solitary plants of Zostera capricorni, Thalassia hemprichii, Cymodocea rotundata and Halophila ovalis were collected from Cairns Harbour and transplanted to the recirculating seawater aquaria. The best survival was obtained with Halophila ovalis and Thalassia hemprichii. Future trials are required to test a range of light intensities.

In another experiment, seeds of Halophila decipiens and Halophila tricostata were collected at 15m depth near Fitzroy Island on 14 December 1987. They were transported in seawater to the laboratory and placed on a sandy substrate in recirculating seawater aquaria. A large number of these seeds germinated in late March 1988. Subsequent growth appeared to be very slow and individual plant survival was poor.

While further trials are required to determine conditions in the laboratory for optimum growth and survival, the results to date demonstrate that it is feasible to maintain seagrass in aquaria and to germinate and grow some species from seeds collected in the field.

4.3 Artificial reefs (QDPI)

The development of artificial reefs was considered as a method of increasing habitat and shelter for fish. The idea is not new and various forms of artificial reefs have been constructed throughout the world (Bohnsack and Sutherland 1985; Young, 1988).

Pilot studies in the Cairns Harbour (QDPI, unpublished data, 1987) have demonstrated that even the simplest bottom structure was colonized by large numbers of fish of many species. A feasibility study, using a South Australian artificial reef design (Appendix 12) is recommended for the sheltered waters of either Cairns Harbour or Trinity Inlet. Deployment of the reef module which is presently at the Northern Fisheries Centre has been cancelled due to cessation of research funding. The opinion of fishing clubs and local authorites has been sought on site location. As part of the brief to investigate feasabilities for fisheries enhancement programmes, a review of the scientific literature on artificial reefs, with recommendations for future research, will be provided as an addendum to this report.

4.4 Conclusions

The focus of this research has been to investigate techniques that might offset possible negative impacts on the Cairns Harbour environment that could occur as a result of the proposed Development of the lease site.

It is evident that any seagrass losses could be minimised by transplanting and restoring damaged areas, thus speeding up the natural regrowth processes. Losses of seagrass productivity in the Harbour could also be partially offset by allowing regrowth of the mangrove forest on the esplanade foreshore region. The upper intertidal zone could be landscaped in much the same fashion as occurs on land. Opportunities exist on the esplanade foreshore, either in conjunction with, or in the absence of, the proposed development for ecological enhancement. This could boost productivity and provide additional environment for associated mangrove fauna by selective cultivation of mangrove zones and fringing bands. Provision of artificial reef structures would provide additional fish habitat in the Cairns Harbour albeit of a somewhat different nature to the present habitats.

5.0 PROJECT IMPACT

5.1 General

The proposed Development would replace approximately 81ha of subtidal and intertidal mud flats and seagrass with a reclaimed area and a marina basin and channels. This is likely to directly affect the marine environment of the Cairns Harbour by replacing one environment with another at least within the boundaries of the proposed Development lease site. Indirect effects may be felt over a wider area of the Harbour because of its shape and design, and during the construction phase by, for example, temporarily increasing turbidity. Likely changes associated with the completed development may not all be negative as the new habitats provided would be expected to support marine life, albeit of a different nature to the present.

This section addresses the likely impact on the marine communities of the proposed Trinity Point Development Project including possible effects of the construction phase.

5.2 Direct impact

The anticipated direct effect of the proposed Development if it goes ahead will involve the loss or removal of approximately 25ha of seagrass and 56ha of mud bottom, which includes some isolated seagrass plants, a zone of algal mat and a zone of saltcouch. This would remove a habitat now used by a variety of fish, crustacea and other animals.

It is likely that animal and plant communities would become established in the marina basin, in the access channels and on revetment walls. These communities would in all probability differ from the existing mudflat communities, but can be expected to contribute to the Cairns Harbour marine life.

5.3 Physical parameters

Computer modelling of the proposed marina basin and entrance channels show that the waterways would flush completely under all conditions (water velocities up to 0.4m/sec.; see companion report, Coastal Processes, Vol. 3). The uses of the land are proposed to be basically urban or semi-urban. Storm water run-off from this land mass would be diluted by virtue of the large sea-water mass incorporated in the project design. The existing central business district adjacent to the esplanade mud flats appears to have had little effect on nearby seagrasses, suggesting that the proposed Development would also have little effect. Debris screens and water traps could be used to limit the impact of pollution carried in storm water run-off and pollution levels should be monitored.

Present levels of coliform bacteria in the water and the pesticide and heavy metal contamination of the mud need to be taken into account. Subsequent use of pesticides, herbicides etc. in landscaping the proposed Development (and adjacent existing esplanade parkland) requires strict control.

Domestic pollution in low concentrations may enhance production of marine life (Kutkuhn, 1966). However, the bacterial contamination and heavy metal contamination levels found in analyses of Cairns esplanade mud samples is not desirable. The levels of coliform bacteria possibly result from uncontrolled human waste released from the nearby marina and anchorages. This could be readily controlled and the waste pump-out facilities proposed for the Trinity Point Development should be mandatory to ensure that pollution from this source should not increase. The origin of heavy metals in mud samples is uncertain and warrants further study.

5.4 Marine vegetation

The dredged channel and marina basin design (depth of 3.5m) would probably prevent seagrass and algae recolonizing the lease site waterways although it is possible that a fringe of seagrass may establish. However, wave action from passing vessels and the topography of engineered channels make this unlikely.

There are currently no mangroves growing on the Development lease site because of harvesting of young plants by the Cairns Port Authority. Loss of seagrass productivity could be offset to some extent by encouraging mangrove growth where practical within the developed area.

The anticipated major direct impact on marine vegetation will be the loss of 25ha of productive seagrasses and Caulerpa algae. This represents 2.9% of the Cairns Harbour and Mission Bay seagrasses and 0.04% of the coastal seagrasses between Cape York and Townsville. It is likely that algae mats and saltcouch fringes will re-establish in the vicinity of the proposed development and their immediate loss is not likely to significantly affect Cairns Harbour and Trinity Inlet marine life.

5.5 Commercial prawn populations

Seagrass research in Queensland (Coles and Lee Long, 1985) has shown that this habitat is vital to the survival of prawns that are the basis of the night-time trawl fishery. The immediate direct effect of the Development would be the loss of some 25ha of seagrass prawn nursery grounds and 56ha of mudflat and algae mat. This habitat loss represents an estimated loss of $131 263 per year to the east coast prawn fishery (Section 3.3.2). This is approximately 0.13% of the greater than $100 million per year east coast prawn fishery but the regional significance is likely to be much greater. A measure of this impact on regional or local fisheries is difficult to establish because there are large natural fluctuations in local prawn populations. Prawn nursery habitat losses could be offset by re-establishing similar areas of seagrasses for prawn nursery grounds, but much more research needs to be done. Detecting impacts to the local prawn populations requires intensive and long-term research and monitoring due to large natural fluctuations in prawn numbers.

5.6 Fish

Studies of the fish communities present in southern Queensland canal estates (Morton, 1988), may have some relevance to this study. The southern Queensland studies suggest that the new environment which would be created by the proposed Development would support similar numbers of fish species to those in the present environment. Compared with unmodified environments, the overall fish abundance in canal estate channels was reduced and the fish species composition was markedly different. Modified channels had less macrobenthic carnivores and more micro-carnivores and planktivores than nearby mangrove fringed channels (Morton, 1988). Changes would also be likely in the fish fauna in the Trinity Point Development and this could reduce the number and types of fish valuable to commercial and recreational fishermen. In Cairns Harbour this could mean, for example, a reduction in the numbers of macro-benthic carnivores such as grunter and threadfin salmon.

The impact on fish life in the channels could be minimized. Moreton (1988) suggested from his studies of fish populations in artificially modified estuarine habitats in southern Queensland, that rock-lined beaches or multi-faceted revetment walls in the waterways may encourage a greater density of invertebrates and algae than uniformally contoured beaches or smooth concrete walls. If so, this would provide both food and shelter for fish. Rock walls are proposed for the Trinity Point Development internal channels and basin and so their potential for lessening the impact should be investigated beforehand. The loss of productivity of the habitat might be further reduced by allowing, where practical, growth of a mangrove fringe along the waters edge and the provision of additional shelter and food for fish. Provision of mangrove fringes could be considered as a condition of development.

The direct loss of the lease site represents 2.9% of Cairns Harbour and Mission Bay seagrass and algae fish habitat, 0.0% of the mangrove communities and 6.2% of the mud flat and algae mat habitat. A new and different fish community would partially replace the present fish community, at least in this area. Given the large natural variability of fish numbers and large numbers of species in the Cairns Harbour it is unlikely that the direct impact of the development on the entire Harbour and Inlet would be easily detectable even with long-term and intensive sampling. However, it is important that appropriate monitoring methodology be developed and implemented if the Development proceeds.

5.7 Infauna

Animals living within the lease site sediments would be destroyed. It is highly likely animals would recolonize the intertidal fringes and subtidal channels from nearby but the species and their abundances are impossible to predict. It is possible that if mangrove fringes are allowed to establish, both non-commercial and commercial crab populations could establish within the proposed Trinity Point Development channels.

5.8 Dugong, turtles and crocodiles

As these animals were not sighted during our survey and appear to be uncommon in the area, the likely impact of the proposed Development is considered negligible.

6.0 INDIRECT IMPACT

6.1 Sediment deposition and water movement

Fine scale modelling (see companion report, Coastal Processes, Vol. 3) has been used to predict the likely effects of the proposed Development on water movements and sediment deposition. The model indicates that sediment accretion adjacent to the esplanade will be accelerated, particularly in the lee (west) of the site for 200m and to a smaller extent up to 1 200m.

It is possible that the accelerated accretion rate would result in the short-term loss of seagrasses in the lee of the site. The seagrass species in this area have been shown to recolonize relatively quickly. Although impossible to accurately predict, it is likely that seagrasses would naturally recolonize in the depth range 0.1-0.5m (Port Datum). This natural recolonization by seagrasses could be enhanced by replanting seagrasses from adjacent beds. The impact on the marine habitat and fisheries could also be partially compensated for by allowing a mangrove community to establish. This would occur now, if removal of these seedlings was stopped. Allowing natural progression to mangrove communities would be important if the resultant accretion produces large areas of mud above the 1.0m contour line, which are too often exposed at low tide to support seagrasses.

6.2 Marina activities

6.2.1 Sewage

Pollution levels (eg. coliform bacteria) from human and domestic sewage can at times be very high in Cairns Harbour (Section 3.1.6). As mentioned (Section 5.3) domestic waste products in low concentrations may enhance productivity. Excessive pollution of this type would increase the biological oxygen demand and could lead to super-enrichment and a loss of productivity. This type of impact would be lessened by the proposed pump-out facilities. Nevertheless, pollution levels from domestic sewage, whether it be from the proposed Development or Cairns city in general, should also be regularly monitored.

6.2.2 Fuel spillage

Fuel spillage could be expected to have a localized effect on marine life. Fuel spill control systems should be incorporated into proposed development plans.

6.2.3 Antifouling paint

Marine facilities of the proposed Development would house vessels, all of which would be a source of antifouling-derived pollutants. In assessing the possible impacts of these on the present environment of the Cairns Harbour, past and present levels and impacts of these pollutants must be considered. There is very little information to date on the impacts of antifouling pollutants on the Cairns Harbour marine life. Heavy metals contamination in QDPI sediment samples (Section 3.1.1) and tributyl tin in QDPI fish samples (Appendix 5) suggest that leachates from industrial wastes and/or antifouling paints are already at high levels in the Harbour and Inlet. Sources of pollutants from antifouling paints include the shipping, fishing and yatching vessels at the anchorages, marinas and refitting yards presently in Trinity Inlet. The present alarmingly high levels of these pollutants in Cairns Harbour are cause for concern and deserve greater attention. Some governments in Australia are already attempting to address these problems through avenues such as legislative bans on use of tributyl tin on vessels under 12m.

6.2.4 Greenhouse effect - sea level rise scenario

A Greenhouse related sea level rise of 0.9m is expected for Cairns Harbour (see companion report, Coastal Processes, Vol. 3). Hydraulic modelling studies suggest that the proposed Development would not increase any Greenhouse effect on the Cairns Harbour water currents and sediment movement. Therefore, changes in marine life due to the Greenhouse effect should be unaffected by the Development.

6.2.5 Construction phase

General

Separate from the likely impacts on the marine life caused by the proposed Development in its final form are short-term matters relating only to the construction process.

These would include:

- Turbidity due to dredging and reclamation.
- Accidental spillage of oil and fuel from construction equipment.
- Chemical residues in the fill material itself.

Turbidity

Increased turbidity has the potential to cause loss of adjacent seagrass and benthic communities. However, the seagrasses in Cairns Harbour are already able to tolerate low light levels and a degree of siltation and would therefore be able to withstand temporarily increased turbidity. Furthermore, the rhizome system of seagrasses enables shoot regrowth following dieback and siltation.

Increased siltation can cause smothering of benthic marine organisms and this may result in the death of adjacent sessile, or less mobile, filter feeding organisms. Resettlement and colonization of organisms such as these should occur once sediments have stabilized.

The coastal hydraulics study (see companion report) concludes that circulation patterns in Cairns Harbour are such that there is a nett ingress of sediment into Trinity Inlet. Therefore, any turbidity increases would be limited to Cairns Harbour and Trinity Inlet and would not have any detrimental effect on the coral reefs of Fitzroy and Green Island.

Increased turbidity associated with the construction phase would be temporary. Detailed construction planning should incorporate such initiatives as bunding of the area to be reclaimed/dredged to keep increases in turbidity to acceptable levels.

Seawater turbidity could be minimized by implementing on-site settlement of turbid water during reclamation. Any release of turbid water should be timed to coincide with periods of naturally high turbidity and on a falling tide to minimize the effects on marine life.

Oil spills from construction equipment

Petroleum products, heavy metals, and other toxic substances are detrimental to marine organisms. Therefore precautions should be taken, if the Development proceeds, to ensure that surface water run-off from the site which may contain these substances is not discharged directly into the adjacent waters.

Design of the proposed reclamation should prevent stormwater from any on-site workshops or equipment compounds from draining directly into the adjacent waterways.

Chemical residues from fill materials

The sand fill to be used for the construction would be obtained from farm land in the Barron Delta. Chemtest Laboratories have performed a field and laboratory testing program to investigate residual chemicals in the sand. This testing program analysed 34 samples from the site for 19 compounds, covering organochloride and organophosphate pesticides and heavy metals in particular. The report concluded that the sand fill should result in "no additional pesticide or heavy metals contamination" of the mudflats.

7.0 RECOMMENDED RESEARCH AND MONITORING

Three major areas of research are recommended to interface with any future reclamation work in the Cairns Harbour. These we set out briefly below.

7.1 Cairns Harbour seagrass ecology

An ecologically-oriented research programme is proposed in which the following projects should be carried out:

1. Monitor seasonal and long-term variations in representative seagrass communities. Fixed transects would be employed utilizing non-destructive photographic assessment. Movement of the edges of the seagrass beds as well as changes in shoot density would be assessed through time and correlated with reclamation activities in order to minimise harmful effects. This would enhance our ability to identify, detect and mitigate harmful effects as they may arise.

2. Seagrass transplantation technology. The refinement of handling and transplantation technology is necessary if seagrass beds are to be restored following damage caused by reclamation work or by natural causes. Experience overseas and success with preliminary experiments in the Cairns Harbour suggest that transplantation of adult plants may assist the regeneration process. Advice is being sought from overseas researchers, and Dr. R. Coles (QDPI) will be visiting American seagrass researchers in February and March 1989.

3. Seagrass seed collection and germination technology. An alternative to the transplantation of adult plants is the collection and germination of large numbers of seagrass seeds. Successful preliminary experimental work in the laboratory indicates that seed germination has promise as an effective method of restoring a seagrass bed.

4. Identification of alternative seagrass nursery sites. Little is known about the recruitment process of prawns and fishes to seagrass beds or the environmental conditions necessary for seagrass growth. Both sets of conditions must coexist if a successful nursery ground is to eventuate. A research project aimed at identifying these conditions and then selecting suitable sites in the Cairns Harbour-Mission Bay area is necessary if supplemental seagrass beds were required to maintain or enhance levels of fisheries production.

7.2 Cairns Harbour recreational fisheries enhancement

An ecologically-oriented research programme is proposed in which three projects should be carried out:

1. Monitor seasonal and long-term variations in the fish community. An understanding of the natural variability of fish populations will assist in assessing the level of impact of future reclamation work or Harbour development. The use of beam trawls and gill nets at fixed sampling sites will add valuable information to our understanding of long-term changes in fish populations in Cairns Harbour.

2. Fisheries enhancement techniques. A programme of artificial reef studies should be initiated in the Cairns region. Coordinated with a fisheries management strategy, these studies should investigate the feasibility of using artificial reefs for fisheries enhancement to offset possible losses of fish productivity associated with the proposed development. General agreement exists within the literature that artificial reefs are an important fishery management tool (Bohnsack and Sutherland, 1985). An addendum to this report discusses the use of artificial reef technologies for fisheries enhancement, with recommendations for future studies.

   The feasibility of establishing mangrove fringes or mangrove islands on the esplanade intertidal mudflats (or elsewhere in the harbour) should be studied to quantify their potential to enhance fish populations of the Cairns Harbour and Trinity Inlet. The Trinity Point Development plan proposes to replace the area where the reclamation fill is to be removed with a mangrove forest (approximately 30ha). This site should be monitored to measure mangrove growth rates and colonization by fauna and other experimental sites should also be assessed.

3. Monitoring catch and effort in the local fish and prawn fisheries. QDPI will investigate the introduction of fine scale catch and effort logbooks for the fisheries of the Cairns Region. Data would provide a measure of change, if any, in the size of fish and prawn stocks, over time.

7.3 Cairns Harbour and Trinity Inlet water quality monitoring

It is likely that any reclamation or harbour works would affect water quality within the Cairns Harbour. Changes in turbidity and light penetration are perceived problem areas. It would be necessary to assess these impacts against a background of natural levels to provide the information needed for construction site management and scheduling, and to establish when water quality parameters have returned to their acceptable levels.

8.0 PRINCIPAL FINDINGS AND CONCLUSIONS

This study was initiated to gather information about aspects of the marine life of the Cairns Harbour, and to assess the likely effect on this marine life of the proposed Trinity Point Development. The principal findings and conclusions are:

8.1 Physical parameters

(1) Salinity during the sampling period ranged from 18 g/l to 36 g/l. Salinities were lowest in March, April and May.

(2) Turbidity at the esplanade site was highly variable, ranging from 10 NTU to 70 NTU. The dredging of the shipping channel in July 1988 had no measurable effect on turbidity at the proposed Development site.

(3) Water temperature in the Cairns Harbour ranged from 25.5°C to 35.2°C during the study period. Temperatures as low as 21.5°C have been recorded during beam trawl sampling for prawns in the Cairns Harbour between 1980 and 1987.

(4) Salinity, temperature and turbidity were each highly variable during the summer months when seasonal rainfall changed the water quality of the estuary. Organisms that live in this environment are able to cope with these-short term fluctuations.

(5) Lead, cadmium, aldrin and dieldrin contamination levels (Appendix 4) are high in the mud and seagrass of the proposed lease site. Bacterial contamination, possibly from nearby marina facilities, was sufficiently high to warrant further investigation. Hatchery broodstock fish mortalities at the Northern Fisheries Research Centre have implicated tributyl tin contamination of Trinity Inlet water. These findings were based on a limited sampling programme and further sampling and monitoring are recommended. The levels of pollutants identified in the study are cause for concern and may have the potential for greater impact than the proposed Development on marine life.

8.2 Seagrasses

(1) Eight species of seagrass are found in Cairns Harbour in a depth range of 1.0m above Port Datum to 3.7m below Port Datum. This depth distribution is more restricted than found for seagrasses elsewhere along the Queensland coast. This may result from high turbidity in the Cairns Harbour and it is possible that sustained periods of high turbidity could endanger the deeper seagrasses. Dredging and reclamation work associated with the proposed Development could do this and therefore should be co-ordinated with naturally high periods of turbidity (summer) or periods of high tidal range to reduce the likely impact on bottom vegetation.

(2) Zostera capricorni was the most common seagrass species and had the greatest above ground biomass (78.8 g/m^2 and 54.5 g/m^2 for Cairns Harbour and lease site respectively). The maximum shoot density found was 4 798 shoots of Halodule pinifolia in a square metre of bottom.

(3) The area of seagrass in the proposed Development lease site with a cover greater than 10% is 25ha, representing 0.04% of the estimated 69 398ha of seagrass area along the coast between Townsville and Cape York.

(4) Cairns Harbour with 500ha and Mission Bay with 376ha together represent 1.3% of the estimated total area covered by seagrass (>10% bottom cover) between Townsville and Cape York.

(5) Historical records show that intertidal mudflats and seagrass beds have long been a major component of the marine communities of Cairns Harbour. In several areas there has been an apparent loss of seagrass through a progradation of mangroves and mudflats. It is likely that if the Cairns Port Authority did not remove mangrove seedlings, the proposed Development lease site would now support a mangrove forest extending out into the Inlet in much the same way as do the mangroves and mudflats on the eastern side of the shipping channel. If mangrove growth was permitted, this would replace a proportion of the present seagrass, algae and mudflat communities on the lease site.

(6) Preliminary experimental work has shown that seagrasses can be transplanted as whole plants in the field and in the laboratory, and be germinated in the laboratory from seed. Seagrasses were shown to spread by rhizome growth at a rate of 100mm per month under certain conditions. These results provide impetus to further studies aimed at developing the technology and assessing the potential for economical seagrass bed restoration.

8.3 Commercial prawns

(1) Twenty-three species of penaeid prawns have been collected in the Cairns Harbour. Nine of these species are marketed by the commercial prawn fishery. The brown and grooved tigers and the true endeavour were the three most numerous prawns in the Cairns Harbour.

(2) The estimated value of the tiger and endeavour prawns from the seagrass bed and mudflats occupying the Development site was $131 263/year, for the Cairns Harbour as a whole was $2 214 500 and from the greater Cairns Harbour-Mission Bay area $3 756 257.

(3) Fleet analysis showed that although Cairns is Australia's largest fishing port, only about 16 of the 419 trawlers based in Cairns actually rely on the local prawn stocks. The vast majority of the Cairns prawn trawl fishing fleet fish to the north of Cooktown and into the Torres Strait.

(4) The abundance of prawns in the seagrass beds of Cairns Harbour varied seasonally. Peak months for the commercially valuable prawns were in the summer, particularly January and February. There is also a high level of natural variability in prawn numbers on a year-to-year basis.

(5) Significantly more prawns were caught on seagrass and Caulerpa algae beds than on unvegetated mudflats.

8.4 Fish and Crabs

(1) A total of 223 species of fish were recorded in Cairns Harbour. The average length was 32mm (7mm-506mm range).

(2) Twenty-three fish species were valued highly by commercial fishermen and thirty fish species were highly valued by recreational fishermen.

(3) Density of fish in the Cairns Harbour was 8 809 fish/ha based on beam trawl sample estimates.

(4) Numbers of fish species peaked in spring and/or summer.

(5) Significantly more fish were caught on seagrass and Caulerpa algal beds than on bare mud substrate.

(6) Two species of crabs found on the lease site were commercially important: the mud crab Scylla serrata and the sand crab Portunus pelagicus. Neither species are residents of the mudflats and move into deeper water when the mudflats and seagrass are exposed at low tide. A total of 18 species of crabs were identified from Cairns Harbour samples.

8.5 Other marine animals

(1) Crocodiles, turtles and dugong possibly occasionally visit the development lease site although no sightings were made during our study.

(2) Dugong feeding trails were photographed in the Ellie Point seagrass beds and turtles have been recorded outside the study period at False Cape and in Mission Bay.

(3) A variety of infauna was recorded from sediment samples. These small animals provide part of the food source for the bird populations.

8.6 Project impact

8.6.1 Direct impact

(1) The direct impact of the project is anticipated to be the replacement of approximately 25 ha of seagrass and algae and 56ha of mudflat with a reclamation, marina basin and channel system. This would remove habitat currently used by fish, crustacea and other animals. New animal and plant communities are likely to become established in the marina basin and channels and on revetment walls and beaches. These communities can be expected to be different from the existing communities but would nevertheless contribute to the Cairns Harbour marine life.

(2) Both commercial fish and prawn populations and are likely to be reduced or be replaced in the area of the lease site if the Development proceeds. The natural variability of the Cairns Harbour fish and prawn populations and the anticipated relatively small area involved in the proposed lease site,

suggest that the likely impact of its development on these populations would be difficult to detect.

(3) There is a possibility that the loss of overall productivity resulting from the proposed Development could be reduced by modifying the Cairns Harbour environment with artificial reefs, with areas of transplanted seagrass and/or allowing regrowth of mangrove vegetation within the proposed Development site and along the esplanade.

8.6.2 Indirect impact

(1) The proposed development is likely to result in a marked increase in accretion rates of sediment in the lee (western) side of the lease site, extending 200 metres with a smaller effect to 1200 metres. This may result in short-term losses of seagrass, but it is expected that these marine plants would recolonise intertidal areas within the depth range where they are presently found. This process could be hastened by replanting seagrass.

(2) With appropriate controls, storm water run-off and water movements are not expected to greatly affect the Cairns Harbour marine life. Intertidal plant and animal communities do not appear to be greatly affected by the adjacent Cairns Central Business District at present. The usage of the proposed Development is consistent with that of the Cairns Central Business District.

(3) Marina activities may adversely affect water quality and marine life. Waste disposal and fuel spillage should be strictly controlled and monitored.

8.6.3 Construction Phase

(1) In the event of development construction proceeding, three short-term factors may affect marine life. These are turbidity, associated with earth works, spillage of oil and fuel and chemical residues from the fill material.

Increased turbidity and siltation can cause the loss of seagrass and benthic communities. This impact could be reduced by bunding reclaimed areas and timing the release of turbid water to coincide with periods of relatively high turbidity and falling tides.

(2) Adverse effects likely to arise from fuel spillages and chemical residues should be mitigated by careful site management.

8.6.4 Research and Monitoring

(1) Continuing detailed monitoring of water quality, fish and prawn populations, and of the distribution and abundance of seagrass communities is recommended.

(2) The methods and costs of seagrass transplanting and restoration should be further investigated as a potential tool for reducing the likely impact of the proposed Development.

(3) The relevance of additional mangrove habitat on the esplanade foreshore and of artificial reef habitat should be assessed as a means of maintaining and enhancing the productivity of the Cairns Harbour.

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APPENDIX 1

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RESEARCH ACTIVITIES

* A comparison of the fishing characteristics and efficiencies of different otter board designs under field conditions (FIRTA funded).

* A study of the avoidance behaviour of both prawns and unwanted by-catch in relation to commonly used prawn trawling nets (RBA funded).

* Determination of the age and growth of selected demersal reef fish species (QDPI & GBRMPA funded).

* Community structure of the by-catch of trawlers fishing for red-spot king prawns (Penaeus longistylus) in waters of the Great Barrier Reef Marine Park Region (QDPI & GBRMPA funded).

NAME Robert Graham Coles

ACADEMIC QUALIFICATIONS B.Sc. 1974 - University of Queensland

Hons (1st class) 1976 - University of Queensland

Ph.D. 1986 - University of Queensland

CURRENT APPOINTMENT

Senior Biologist, Acting Officer in Charge, Northern Fisheries Research Centre, Fisheries Research Branch, Queensland Department of Primary Industries.

PUBLICATIONS AND REPORTS

Beurteaux Y. and Coles R.G. (1987). Efforts and catch trends in north-eastern Qld prawn trawl fishery. Australian Fisheries 46(9): 36-38.

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NAME Margaret Greenway

ACADEMIC QUALIFICATIONS PhD. - University of the West Indies, Jamaica, 1977.

B.Sc.(Hons) - Reading University, UK, 1971.

Dip. Ed. - University of New England, 1984.

PROFESSIONAL REGISTRATION

Australian Marine Sciences Association. Environment Institute of Australia.

HOLLINGSWORTH CONSULTANTS SINCE 1986

Senior Biologist engaged in biological assessment of numerous environmental studies undertaken by the firm including:

* Great Barrier Reef Zoning Plan. Queensland Premier's Department Biological analysis of the Queensland waters of the Far Northern Section of the Great Barrier Reef Marine Park and development of a proposed zoning plan.

* Peel Island Project in conjunction with Department of Mapping and Surveying. Mapping of coastal resources of Peel Island using SPOT, Landsat TM and airborne scanner imagery.

* Redden Island Resort: Private Developers. Biological assessment of the effects of a proposed tourist resort on Redden Island at the mouth of the Barron River, Cairns.

* Trinity Point Reclamation Project: McKellar Development Corporation. Assessment of the effect on the marine biology and fishery of the Cairns foreshore from the proposed reclamation of 40ha of land for urban development purposes. Including the mapping from remote imagery of seagrass, mudflats and mangroves for all of Trinity Bay.

* Tweed River Canal Project: Private Developer. Evaluation of effects on water quality and marine biology from the construction of a residential canal estate on the Tweed River.

* The Beak Tourist Resort: East West Airlines. Assessment of the effects of a large tourist resort including land reclamation and marina construction on the terrestrial and marine environment near Airlie Beach in the Whitsunday area of Central Queensland.

* Springwood Environmental Area Management Plan: Logan City Council. Preparation of a management strategy and development plan for a large open space area of natural bushland within an extensive urban area of Logan City.

* Ensham Coal Project: AQC Pacific. Assessment of flora and fauna effects of the construction of the proposed Ensham open cut coal mine near Emerald.

* Cooroo Oilfield Environmental Advice Note: Delhi Petroleum. Preparation of an environmental assessment of the development of an oilfield and 20km pipeline in south-western Queensland.

* Cape York International Spaceport: Queensland Premier's Department Biological inventory and assessment of environmental and conservation constraints to the siting of a proposed spaceport within a 6 000 sq. km area of Cape York Peninsula.

* Gulf Region Tourism Study: Parrell Kerr Foster for Northern Territory Department. Natural resources inventory and ecological constraints identification of a large area of land along the coast of the Gulf of Carpentaria proposed for tourist development.

* Noosa Northshore Resort: Henderson Trout. Biological assessment of the effect of a large tourism development on the coastal ecosystem at the mouth of the Noosa River.

* Port Douglas: Associated Technology International. Biological assessment of the effect of a large tourism development on the coastal ecosystem at Port Douglas in far north Queensland.

NORTHERN RIVERS COLLEGE OF ADVANCED EDUCATION 1979-1985

Lecturer in Natural Resource Management and formerly a teaching fellow at Griffith University. Her skills are in the following areas:

Assessment of Terrestrial Ecosystems. Vegetation surveys and habitat assessment of heathlands, wetlands, rainforests and sclerophyll forests.

Assessment of Aquatic Ecosystems. Ecological studies of local marine and freshwater ecosystems.

Visiting Consultant Biologist at the Centre for Aquatic Resources Management. Florida State University. Participant in the Seagrass monitoring programme in Appalachicola Bay.

Participant in two coral reef ecology expeditions to the Great Barrier Reef.

Coastal Zone Management. Whilst Acting Dean of Science in 1984 Margaret Greenway was responsible for the preparation and implementation of a new multi-disciplinary Applied Science course in Coastal Zone Management. She spent four months in Florida studying coastal management practices.

PUBLICATIONS AND REPORTS

Greenway M. (1974). The effects of cropping on the growth of <u>Thalassia testudinum</u> Konig, in Jamaica. Aquaculture 4: 199-206.

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Greenway M. (1987). Broad Environmental Considerations Relating to Marinas. Paper presented to the International Marina Conference, Brisbane, February 1987.

APPENDIX 2

Field survey and laboratory methods used in the study.

a. **Methods used in measuring salinity, temperature, and turbidity**

To quantify levels of salinity, temperature, and turbidity in Cairns Harbour, water samples were collected each working day (from 21 January 1988 to 4 December 1988) from the surface and from one metre above the bottom of Smiths Creek. Water samples were also collected adjacent to the lease site once each week at the time of high tide (Fig. 26 and Fig. 27).

Measurements recorded included surface temperature, salinity using a Reichert refractometer, and turbidity using a Hach turbidimeter.

Physical measurements were also taken spanning a 24 hour period near subtidal seagrass beds just outside the lease site by instruments installed in the QDPI "Sea Lab".

Data presented from the period 1980 to 1987 are based on measurements taken on the lease site and at Hills Creek, each new moon period, near the time of high tide at night. Similar recording methods were used in these measurements to those dated after 21 January 1988.

b. **Sediment particle size analysis**

Analysis of the proposed development site sediment was conducted by Hollingsworth Consultants (Appendix 3, Fig. 28).

c. **Pesticides and heavy metal identification**

As a routine analysis, samples of the lease site surface sediments were tested for the presence of heavy metals and pesticides. Identical analyses of sediment in coastal waters of the Great Barrier Reef lagoon (near Fitzroy Island, Cairns) and lease site vegetation were conducted as a comparison.

Samples were tested using standard laboratory techniques by Chemtest Laboratories.

d. **Bacterial Analysis on water and seagrass samples from the lease site and Saltwater Creek**

Bacterial analyses were conducted by the Cairns Base Hospital Pathology Laboratory using standard bacterial count methods.

e. **Seagrasses**

Field surveys

Seagrasses were collected from sites along transect lines drawn across the study area. The extremities of the transect lines were set by the outer edges of the study site and by the requirement to sample from the proposed lease site itself.

Allowing for these constraints, seven transect lines were used and the bottom checked at sites with approximately 200m intervals between them. At each of these sites, a randomly selected area of the bottom was examined

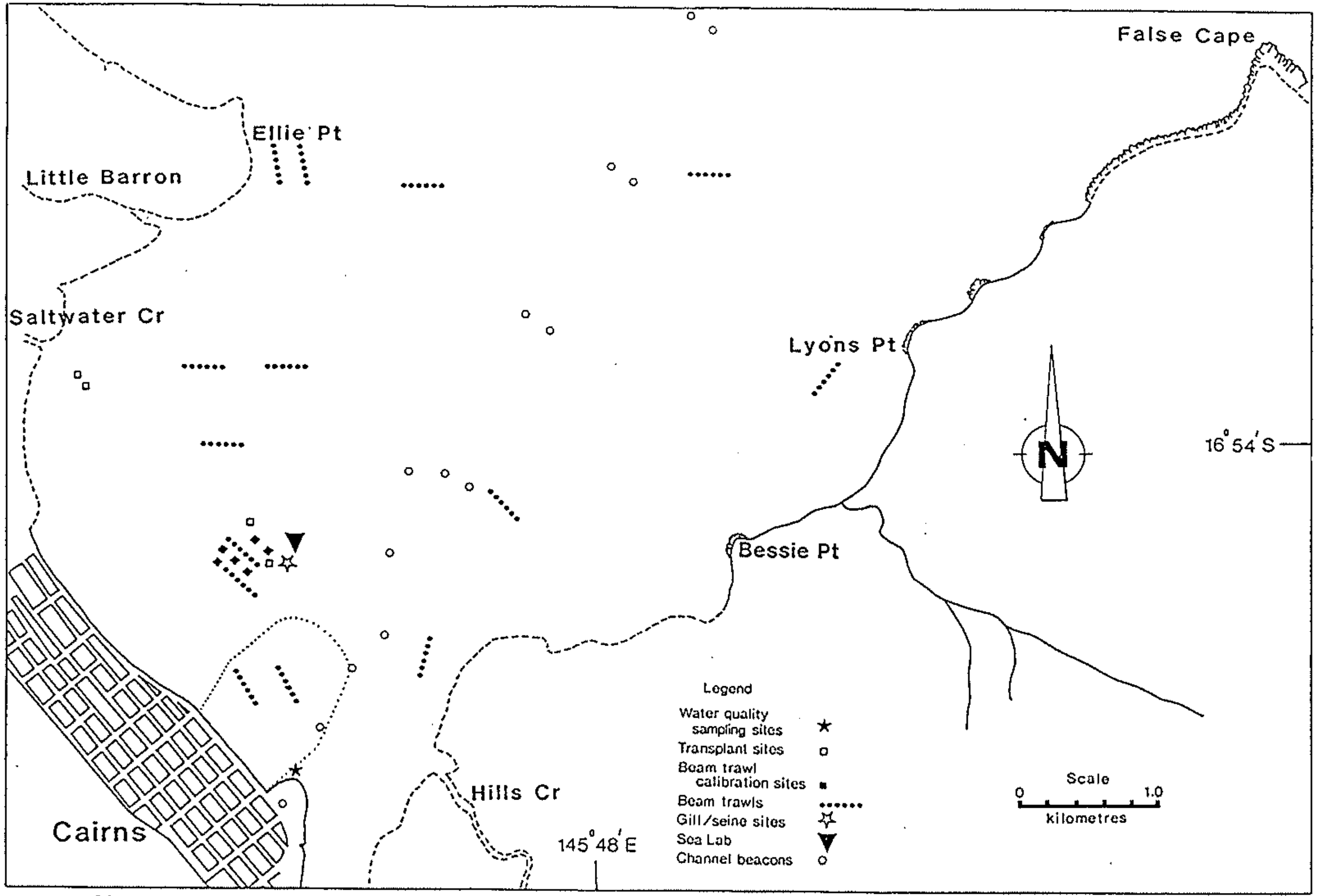


Figure 26a. Sampling sites in Cairns Harbour.

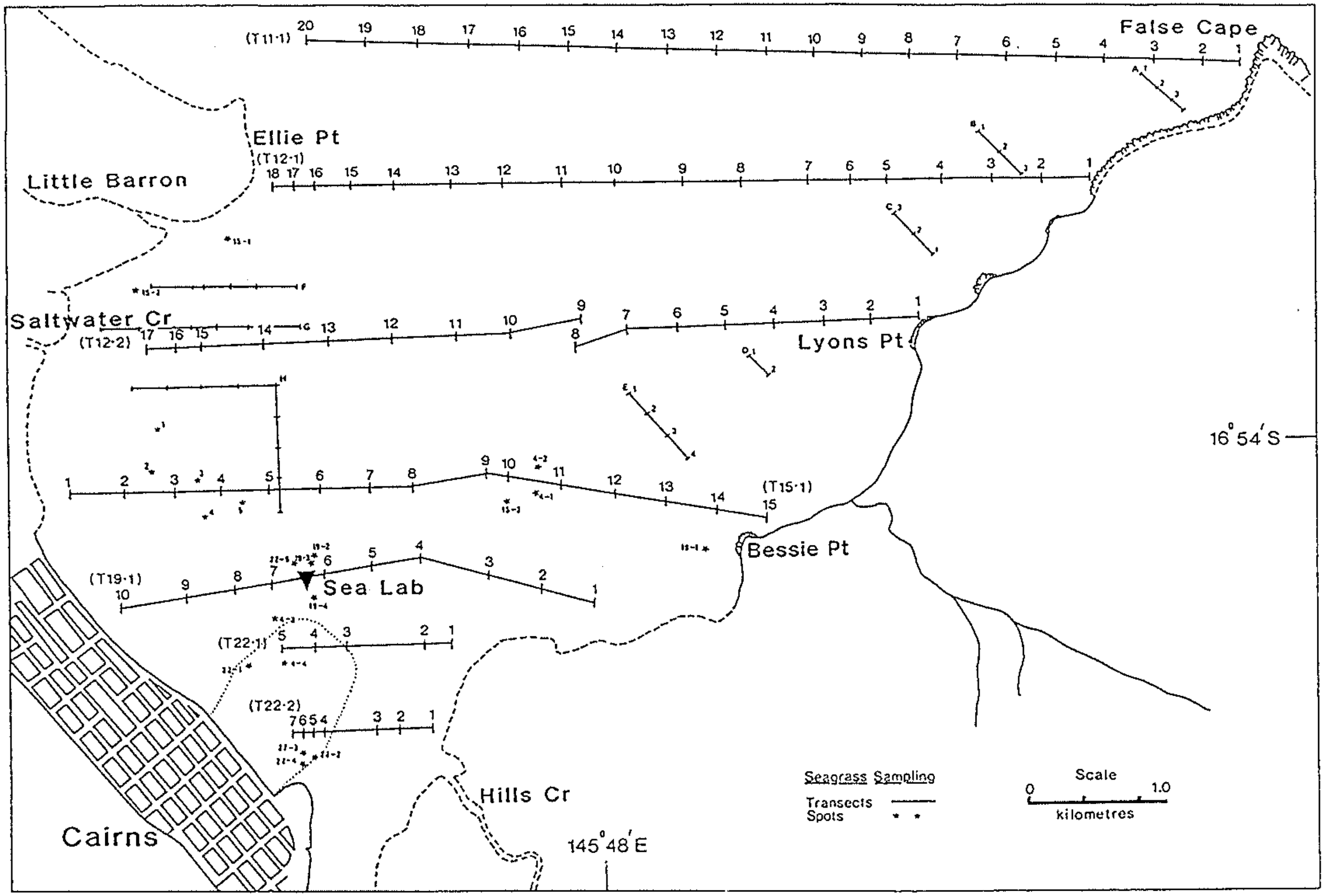


Figure 26b. Seagrass sampling sites in Cairns Harbour.

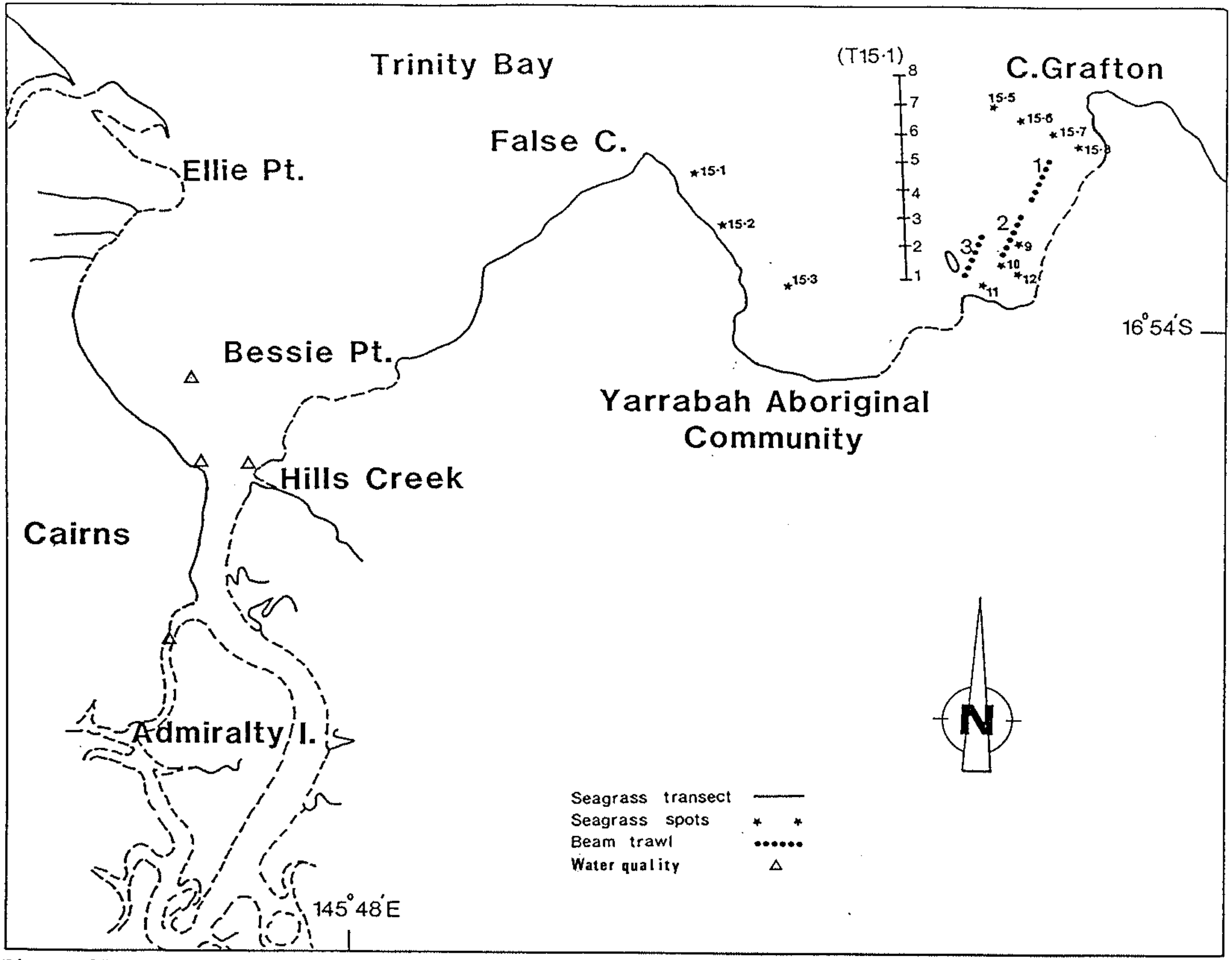


Figure 27. Sampling sites in Mission Bay and Trinity Inlet.

for the presence of seagrass. If seagrasses were found, two square quadrats each enclosing 0.25m^2 were placed randomly on the bottom, one by each of two divers. The seagrasses within these quadrats were then removed for biomass studies. Where a seagrass bed was continuous, additional samples were collected for taxonomic purposes only. The number of samples, sites and taxonomic collections is tabulated (Table 17).

Transect and sampling site positions are shown in Figure 26b and Figure 27. The position of sample sites was determined by using RADAR and a variable range marker to fix distance from the shore of Cairns Harbour. The water depth of each sample of seagrass collected was recorded using a recording depth sounder. These depths were converted to mean sea level and Cairns Port Datum using time of day and tidal plane information provided by the Queensland Department of Harbours and Marine. Areas of seagrass were determined from diver records of the presence of seagrass. Areas were marked on coastal maps and measured using a PATON electronic planimeter. All sampling methods used in the field work are standard methods published and accepted in the scientific literature.

Table 17. A summary of Cairns Harbour and Mission Bay seagrass samples.

Date	Sites	No. of sites sampled	Taxonomic samples	Biomass samples
15.10.87	Mission Bay	18	10	13
11.02.88	Cairns Harbour	20	3	2
12.02.88	Cairns Harbour	35	14	15
15.02.88	Cairns Harbour	18	6	6
19.02.88	Cairns Harbour	14	9	14
22.02.88	Cairns Harbour	17	9	6
04.03.88	Cairns Harbour	4	4	8

Field measurement

Temporal changes in biomass

A permanently marked 50m transect was set out on seagrass beds adjacent to the Queensland Department of Primary Industries "Sea Lab". Photographs were first taken on the 4 March 1988 of 0.25 m^2 quadrats placed on the seagrass bed at points each 5.0m apart along the transect. These quadrats were re-photographed on four separate occasions. The number of shoots in each quadrat was used as a measure of biomass.

Seagrass productivity measurements

Leaf stapling and marking methods used to determine the weight of new seagrass growth are standard methods described by Zieman (1974).

Productivity measurements using lacunal gas discharge follow methods described in detail in Roberts and Moriarty (1987).

Seagrass transplant experiment pilot study

A qualitative pilot study to assess the feasibility of transplanting seagrass was conducted by clearing quadrat squares of seagrass on the Esplanade seagrass beds. Sites were chosen at the lower edge of the dense _Zostera capricorni_ bed (approximately 0.5m above Port Datum) and in the centre of the seagrass bank (Figure 26a).

Cleared sites were replanted with _Zostera capricorni_, _Thalassia hemprichii_, _Halophila decipiens_, and _Halophila tricostata_.

Initially, two squares each of 0.25m^2 were cleared on 14 December 1987. The experiment was repeated using a larger square(4m^2) site on the 19 April 1988. Seagrass shoots were planted individually and as transported turfs, approximately 120mm square.

A larger scale transplanting experiment was conducted with _Zostera capricorni_ turfs in a site near Saltwater Creek on October 19, 1988.

Seven plots, 3m x 2m square, were marked out at the 0.5 m contour level.

These were:

1. A plot with a bund wall to retain water at low tide and planted with _Zostera capricorni_ turfs (25cm^2) at an average shoot density of 365 shoots/m^2.

2. A plot with a bund wall to retain water at low tide and not planted with seagrass, as a control.

3. A plot dug to a depth of 10 cm to retain water at low tide and planted with _Zostera capricorni_ at an average density of 365 shoots/m^2.

4. A plot dug to a depth of 10 cm and not planted with seagrass, as a control.

5. A plot of seagrass in an adjacent seagrass bed untouched as a control.

6. A plot of bare mud adjacent to the experimental area untouched as a control.

7. A plot of Zostera capricorni in an adjacent seagrass bed turfed and replanted in the same plot as a control.

Changes on these experimental plots were quantified by counting shoots from photographic records. Data are not available for this report.

Laboratory studies and methods

Biomass measurements

Each quadrat sample of seagrass was washed and sorted into component species (Coles et al., 1987b). Samples were not acid-treated as there was little contamination with epiphytes and sediment. Total wet weight and total number of shoots were recorded for each species. A subsample of 50 shoots of each species was then taken from the quadrats at each site. These shoots were divided into above ground (stems and leaves) and below ground (roots and rhizomes) portions.

The area of each shoot was established by passing it through a PATON electronic planimeter. The measurement was doubled to give a surface area for both sides of the plant. Wet weights were recorded before material was dried at 80°C for 48 hours and reweighed to obtain dry weights. Approximately ten shoots of each species were selected at random from each quadrat sample and an average shoot height recorded. Two morphological types of Halodule uninervis were recognized and treated separately in laboratory analyses: wide (leaf blade width > 1.5mm) and thin (blade width < 1.5mm).

Laboratory seagrass transplant experiment pilot study

A series of closed-circuit, saltwater tanks were set up at the Northern Fisheries Research Centre. Zostera capricorni, Thalassia hemprichii and Halophila ovalis were transplanted into one of these tanks and maintained at room temperature and with a 0600 - 1800 hour light and 1800 - 0600 hour dark regime. These seagrasses were established in the tanks on 4 March 1988.

Seeds were collected from Halophila decipiens and Halophila tricostata plants at Fitzroy Island. These were placed in tanks on 16 December 1987.

Seeds were kept at room temperature at two light levels 500 lux and 1 000 lux with the same light-dark cycle as the transplanted seagrass.

f. Penaeid prawns

Field sampling

During the study, samples of prawns were collected on 21 occasions (Table 18). Samples were taken from four sites each month at the time of new moon. They were also collected on two occasions from a randomly selected series of sites, 17 trawls on open mud bottoms, 125 trawls from seagrass vegetated areas and two from an algae (Caulerpa sp.) bed (Table 18, Fig. 26a). Samples were also collected in Mission Bay (Fig. 27).

Samples were collected at night using a mini-trawler towing two identical beam trawls. Each beam trawl was 1.5m wide, 0.5m high and fitted with a 2mm mesh net. The beam trawls were towed at a speed of 0.5m/sec usually for 2.5 minutes as described by Coles and Lee Long (1985). Methods employed have been widely accepted as suitable for sampling night-time active penaeid prawn species. Sample efficiency was calibrated by taking an absolute sample using a drop net/cutter device. This method described by Coles (1986) provides a method of estimating an actual number of prawns present in a square metre of bottom and in the water above it.

Information on temporal changes also includes samples collected near the time of high tide, at each new moon period, between 1980 and 1987. These data were collected at two sites on the lease site and at one site at Hills Creek (Fig. 26a) using methods similar to those described above. Only information on the three most economically important prawn species was analysed from these data.

Laboratory methods

Carapace length measurements were taken of all prawns caught using a dial micrometer. Only those prawns with a carapace length greater than 3mm were identified to species using keys of Dall (1957) and Grey et al. (1983) (see taxonomic reference list).

g. Fish

Field sampling

Fish were collected from sampling sites in Cairns Harbour in three ways (Fig. 26a, Table 10a and Table 18):

1. As a by-catch in beam trawls during sampling for prawns.

2. Gill netting using fine monofilament nets of 30.0m in length and 1.5m deep and three stretched mesh sizes; 3.0, 7.5 and 12.5cm to catch swimming fish. Three gill net samples were taken: March, September and December 1988.

3. Seine netting using a 2.0cm mesh net 30.0m long, during both night-time and daytime to trap all but the very fast swimming fish. Four seine net samples were taken: February, March, April and September 1988.

Table 18. A summary of Cairns Harbour and Mission Bay beam trawls for prawns and fish.

Date	Location	No. of Sites	Substrate	No. of Trawls	Duration (mins)
19.10.87	Mission Bay	2	Seagrass	4	10
17.11.87	Cairns Harbour	3	Seagrass	7	2.5
21.12.87	Cairns Harbour	3	Seagrass	8	2.5
19.01.88	Cairns Harbour	3	Seagrass	7	2.5
15.02.88	Cairns Harbour	3	Seagrass	8	2.5
22.02.88	Cairns Harbour	2	Seagrass	4	2.5
22.02.88	Cairns Harbour	5	Mud	10	2.5
28.02.88	Cairns Harbour	1	Algae	2	2.5
28.02.88	Cairns Harbour	4	Seagrass	8	2.5
21.03.88	Cairns Harbour	3	Seagrass	8	2.5
18.04.88	Cairns Harbour	3	Seagrass	8	2.5
19.05.88	Cairns Harbour	3	Seagrass	8	2.5
16.06.88	Cairns Harbour	3	Seagrass	8	2.5
14.07.88	Cairns Harbour	3	Seagrass	7	2.5
10.08.88	Cairns Harbour	3	Seagrass	8	2.5
14.09.88	Cairns Harbour	3	Seagrass	8	2.5
10.10.88	Cairns Harbour	3	Seagrass	8	2.5
10.10.88	Cairns Harbour	1	Mud	2	2.5
08.11.88	Cairns Harbour	3	Seagrass	8	2.5
06.12.88	Cairns Harbour	3	Seagrass	8	2.5
06.12.88	Cairns Harbour	1	Mud	5	2.5

The total fish species list was supplemented by previously published records (Blaber, 1980) and by records provided by a commercial bait collector.

Information on temporal changes in fish species and numbers, and comparative data from other seagrass sites on the eastern Queensland coast, are based on data collected using only the beam trawl.

Laboratory methods

Identification of juvenile fish in northern Queensland waters is extremely difficult. Taxonomic references used for identification are listed. The assistance of the Queensland Museum fish taxonomy specialists was also sought.

Measurements of fish presented are standard length measurements. Comparative fish data used in this report are from data included in reports to the Great Barrier Reef Marine Park Authority and to the Commonwealth Fishing Industry Research Committee and those published in scientific literature (eg. Blaber, 1980).

Dugong records

Data and information on dugongs were obtained from shark contractor records and by personal communication with the James Cook University dugong research specialist, Dr Helene Marsh.

Cairns Harbour foreshore benthic survey

Eighteen samples of surface mud were collected from Cairns Harbour foreshore. Each sample contained $0.002m^3$ of mud. Samples were replicated three times at each site. At the time of collection, a red biological stain, Bengal Rose, was added to the sample to aid in identifying interstitial fauna. Samples were washed through a series of Endecott sieves of 4mm, 2mm, 1mm and 500um aperture. Interstitial mud fauna was collected from each sieve, identified to order and class, counted, and weighed.

General

Statistical analyses used throughout the programme are standard methods commonly used in biological research. Statistical tests used were non-parametric tests as published in Siegel (1956). All methodologies used in collection and analysis are methodologies previously accepted by and widely published within the scientific literature.

APPENDIX 3

Hollingsworth Consultants particle size analysis

Sites where sediment analyses were undertaken on the Development lease site area are shown in Figure 28. An example of sediment analysis from site BH 605 is given. Full details of sediment, etc., are published in a companion report (Geotechnical Engineering, Vols 1-3).

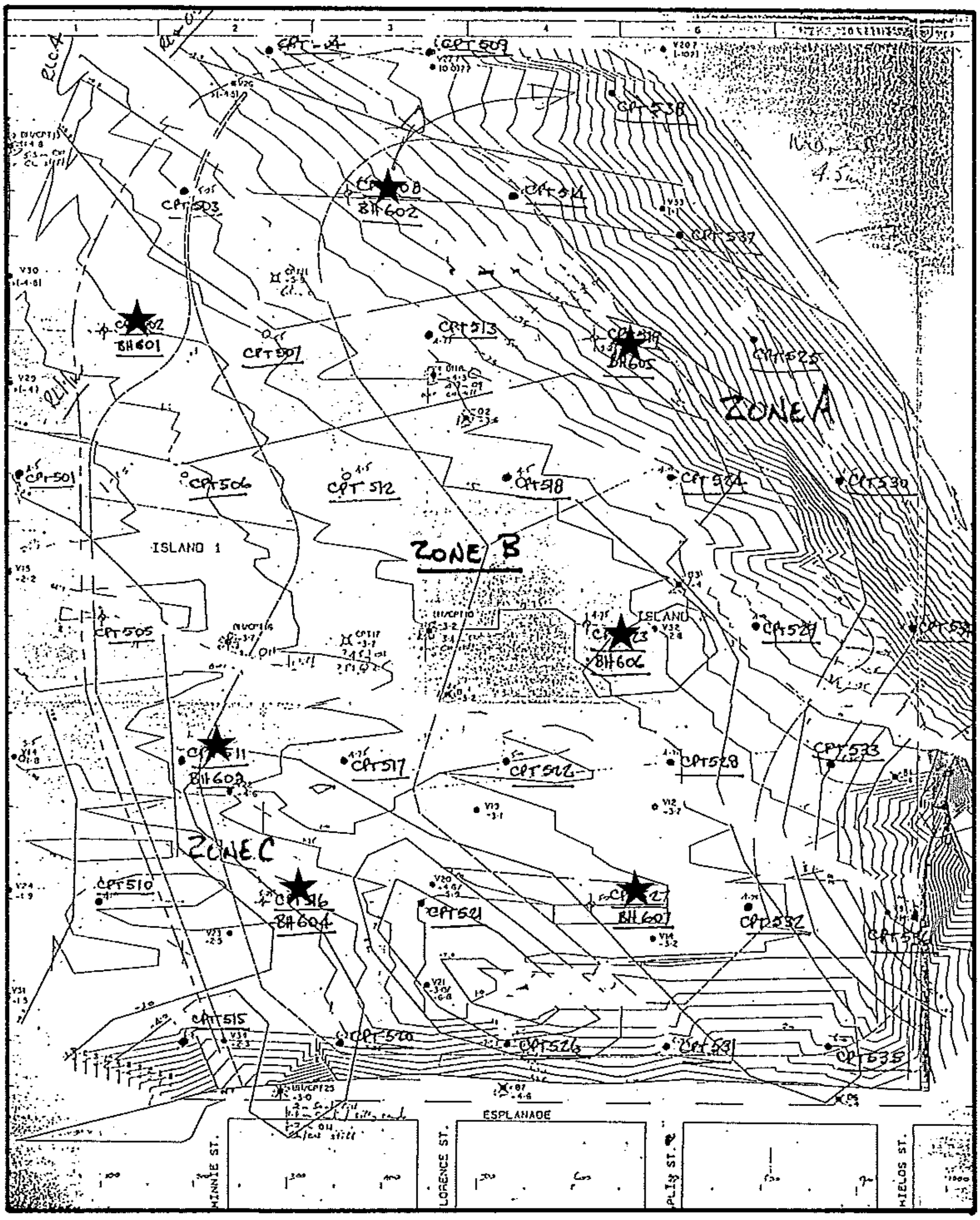
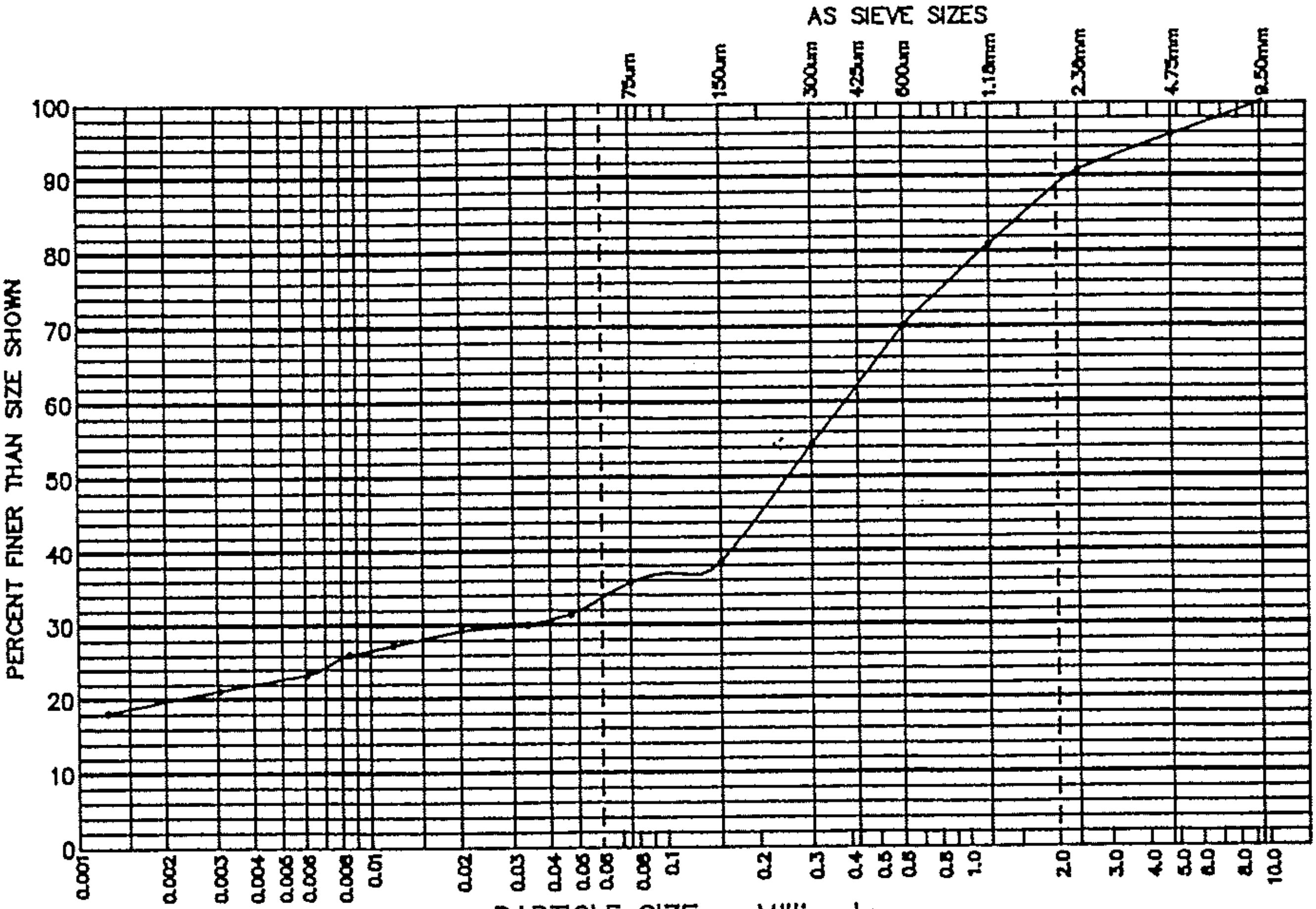


Figure 28. Locations of sediment core samples for particle size analyses on the Trinity Point Development lease site.

EARTHTECH LABORATORIES
Soils and Engineering Materials Testing
6/58 Wecker Road, Mt.Gravatt, 4122 Tel.(07)343 3166. Fax.(07)849 4705

CLASSIFICATION OF SOIL or SOIL/AGGREGATE

CLIENT	Hollingsworth Consultants	CERTIFICATE NO.	
PROJECT	TRINITY POINT	SAMPLE NO.	1169/88
FEATURE	BH. 605 0.85 – 1.10 m.	REGISTRATION NO.	B1641/88
LOCATION	Cairns Foreshore	JOB NO.	88044/N4205G

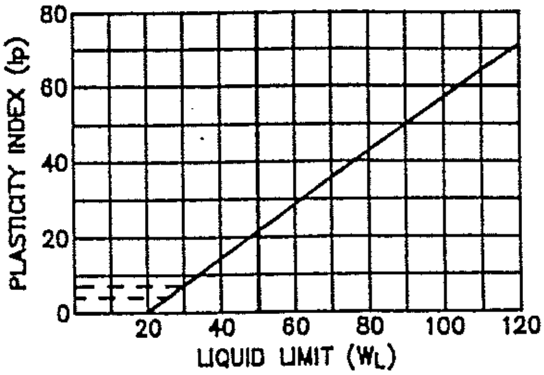


AS-1289

CLAY	SILT			SAND			GRAVEL	
	fine	medium	coarse	fine	medium	coarse	fine	medium

UNIFIED SOILS CLASSIFICATION (U.S.B.R.)

CLAY AND SILT	SAND			GRAVEL
	fine	medium	coarse	fine



PLASTICITY		
Liquid Limit (Wl)	*	
Plastic Limit (Wp)	*	
Plasticity Index (Ip)	*	
GRADATION		
Effect Size D10	*	mm
D30	*	mm
D60	*	mm
Uniformity Coefficient	*	
Coefficient of Curvature	*	
LINEAR SHRINKAGE	*	%

SOIL PARTICLE DENSITY		t/m³
Passing 2.36mm	*	
Retained 2.36mm	*	
Retained ** mm	*	
INSITU MOISTURE	37.6	%
INSITU DRY DENSITY	*	t/m³
DISPERSION		
River Water	*	
Distilled Water	*	
PRETREATMENT	*	
COLOUR	*	

REMARKS . SC clayey SAND predominantly medium to coarse some silt and shell fragments

TESTING PERFORMED TO STANDARDS AS BELOW
Q.M.R.D. . *
AS1289 . C 6.3.

PREPARED BY . . . ./. ./. . CHECKED BY . . . . / . ./. .

NATA

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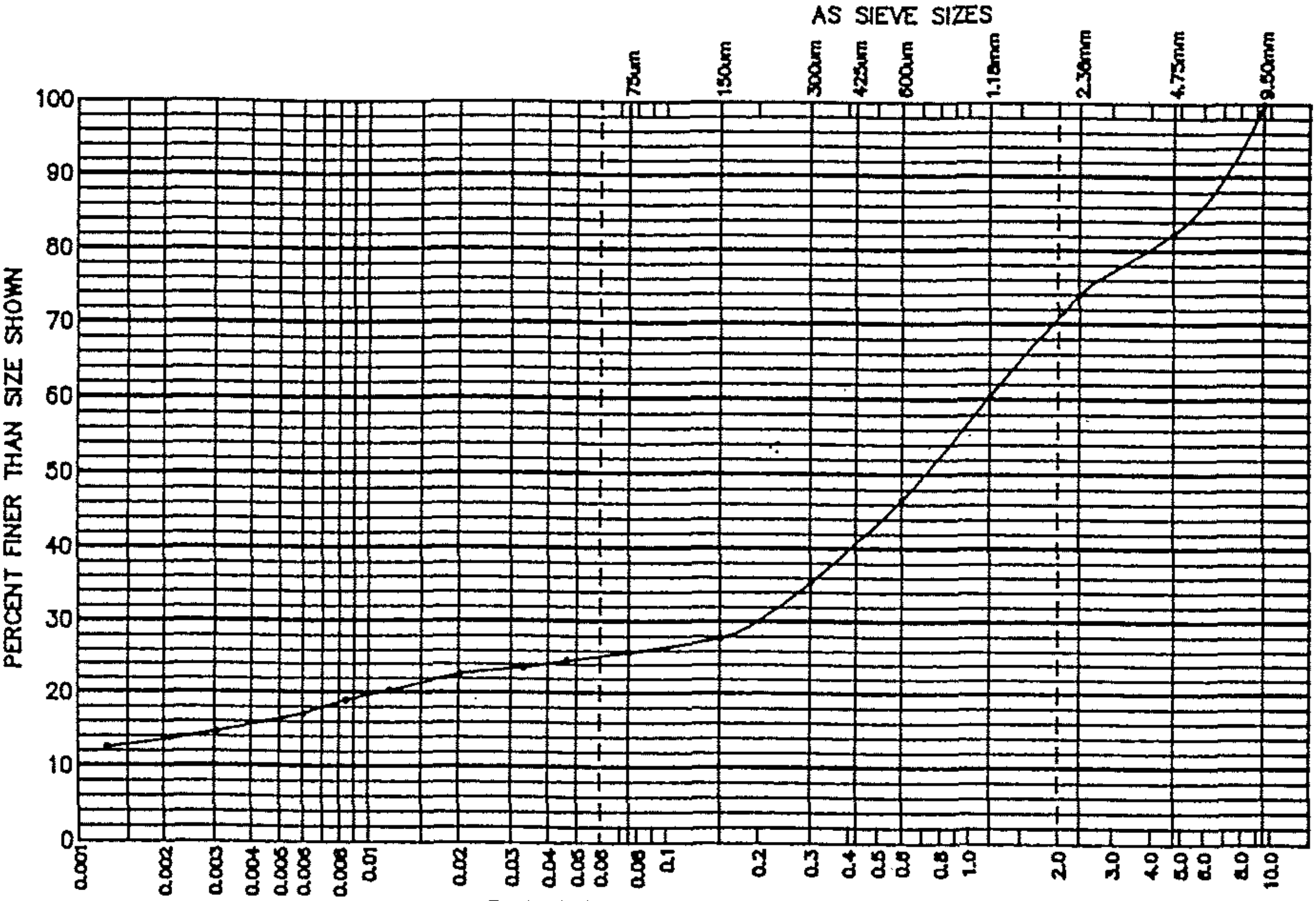
. . . . . Authorised Signatory . . . .

EARTHTECH LABORATORIES
Soils and Engineering Materials Testing
6/58 Wecker Road, Mt.Gravatt, 4122 Tel.(07)343 3166. Fax.(07)849 4705

CLASSIFICATION OF SOIL or SOIL/AGGREGATE

CLIENT . . .Hollingsworth. Consultants . . . . .
PROJECT . .TRINITY. POINT . . . .
FEATURE . BH. 605 . 0.04 .- .0.38 m . . . .
LOCATION . Cairns .Foreshore. . . . .

CERTIFICATE NO. . . . .
SAMPLE NO. . 1165/88 . . . .
REGISTRATION NO. B1640/88
JOB NO. . . . 88044/N4205G

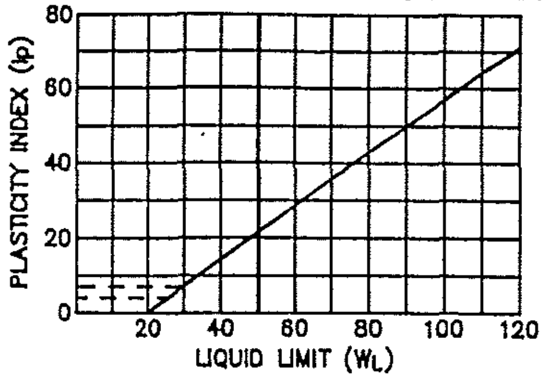


AS-1289

CLAY	SILT			SAND			GRAVEL	
	fine	medium	coarse	fine	medium	coarse	fine	medium

UNIFIED SOILS CLASSIFICATION (U.S.B.R.)

CLAY AND SILT	SAND			GRAVEL
	fine	medium	coarse	fine



PLASTICITY		
Liquid Limit (W_L)	*	
Plastic Limit (Wp)	*	
Plasticity Index (Ip)	*	
GRADATION		
Effect Size D10	*	mm
D30	*	mm
D60	*	mm
Uniformity Coefficient	*	
Coefficient of Curvature	*	
LINEAR SHRINKAGE	*	%

SOIL PARTICLE DENSITY		t/m^3
Passing 2.36mm	*	
Retained 2.36mm	*	
Retained * mm	*	
INSITU MOISTURE	27.9	%
INSITU DRY DENSITY	*	t/m^3
DISPERSION		
River Water	*	
Distilled Water	*	
PRETREATMENT	*	
COLOUR	*	

REMARKS . ML sandy,shelly SILT,some clay . . . .

TESTING PERFORMED TO STANDARDS AS BELOW
Q.M.R.D. . * . . . .
AS1289 . .C 6.3. . . . .

PREPARED BY . . . ./. ./. . CHECKED BY . . . . /. ./. .

NATA

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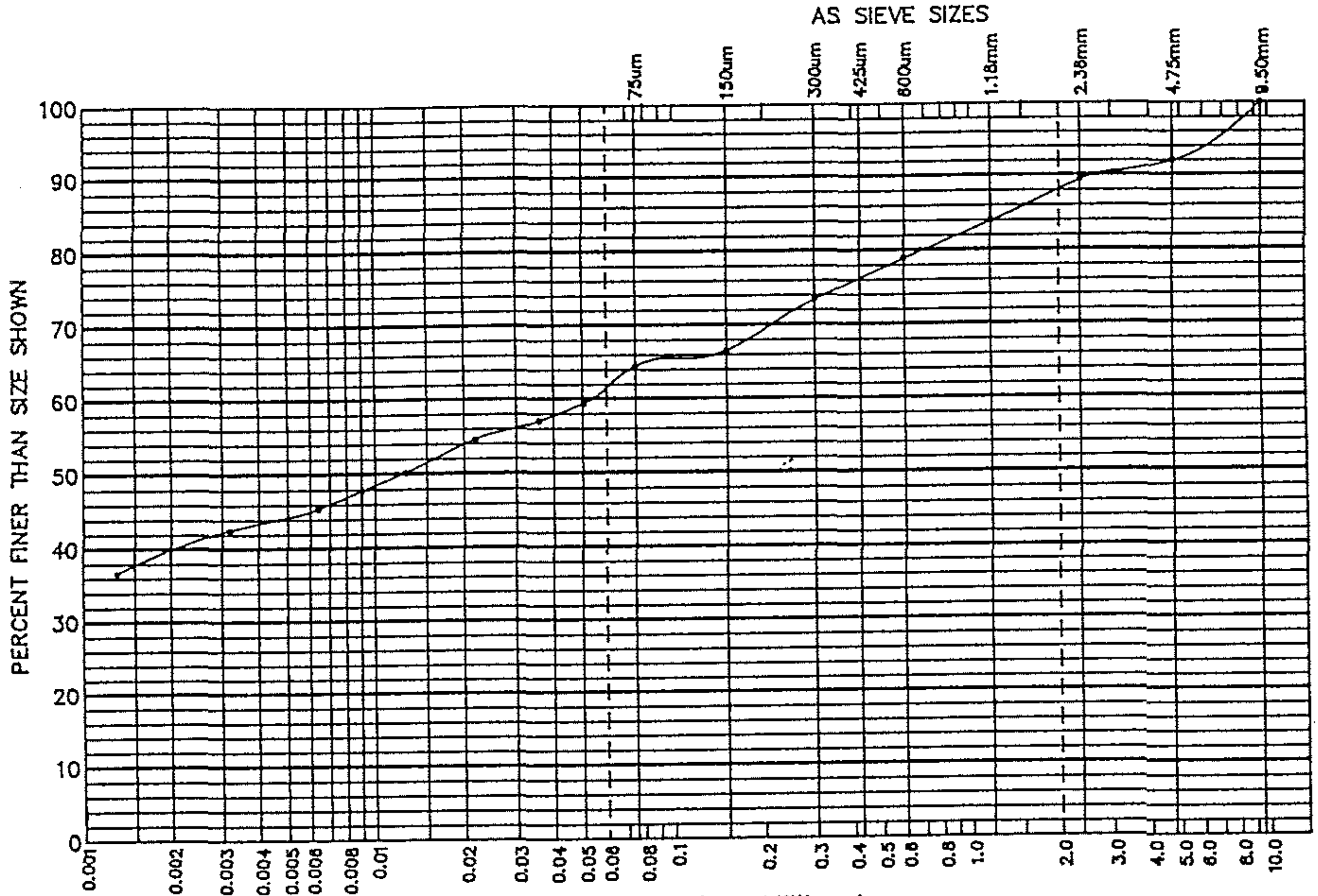
EARTHTECH LABORATORIES
Soils and Engineering Materials Testing
6/58 Wecker Road, Mt.Gravatt, 4122 Tel.(07)343 3166. Fax.(07)849 4705

CLASSIFICATION OF SOIL or SOIL/AGGREGATE

CLIENT . . .Hollingsworth. Consultants . . . .
PROJECT . .TRINITY. POINT . . . .
FEATURE . BH. 605 . 0.49 .-. .0.65 m . . . .
LOCATION . Cairns . Foreshore. . . . .

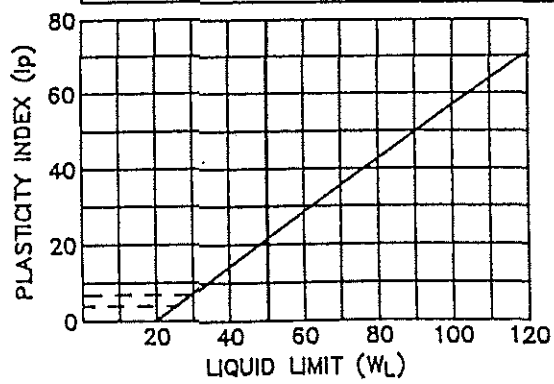
CERTIFICATE NO. . . . .
SAMPLE NO. . 1167/88 . . . .
REGISTRATION NO. B1642/88
JOB NO. . . . 88044/N4205G



CLAY	SILT			SAND			GRAVEL	
	fine	medium	coarse	fine	medium	coarse	fine	medium

UNIFIED SOILS CLASSIFICATION (U.S.B.R.)

CLAY AND SILT	SAND			GRAVEL
	fine	medium	coarse	fine



PLASTICITY		
Liquid Limit (W_L)	*	
Plastic Limit (Wp)	*	
Plasticity Index (Ip)	*	
GRADATION		
Effect Size D10	*	mm
D30	*	mm
D60	*	mm
Uniformity Coefficient	*	
Coefficient of Curvature	*	
LINEAR SHRINKAGE	*	%

SOIL PARTICLE DENSITY		t/m^3
Passing 2.36mm	*	
Retained 2.36mm	*	
Retained * mm	*	
INSITU MOISTURE	51.9	%
INSITU DRY DENSITY	*	t/m^3
DISPERSION		
River Water	*	
Distilled Water	*	
PRETREATMENT	*	
COLOUR	*	

REMARKS . CL slightly silty sandy CLAY,sand fine to coarse,some shell fragments. . . . .

TESTING PERFORMED TO STANDARDS AS BELOW
Q.M.R.O. . * . . . .
AS1289 . .C 6.3. . . . .

PREPARED BY . . . ./. ./. . CHECKED BY . . . ./. ./. .

NATA

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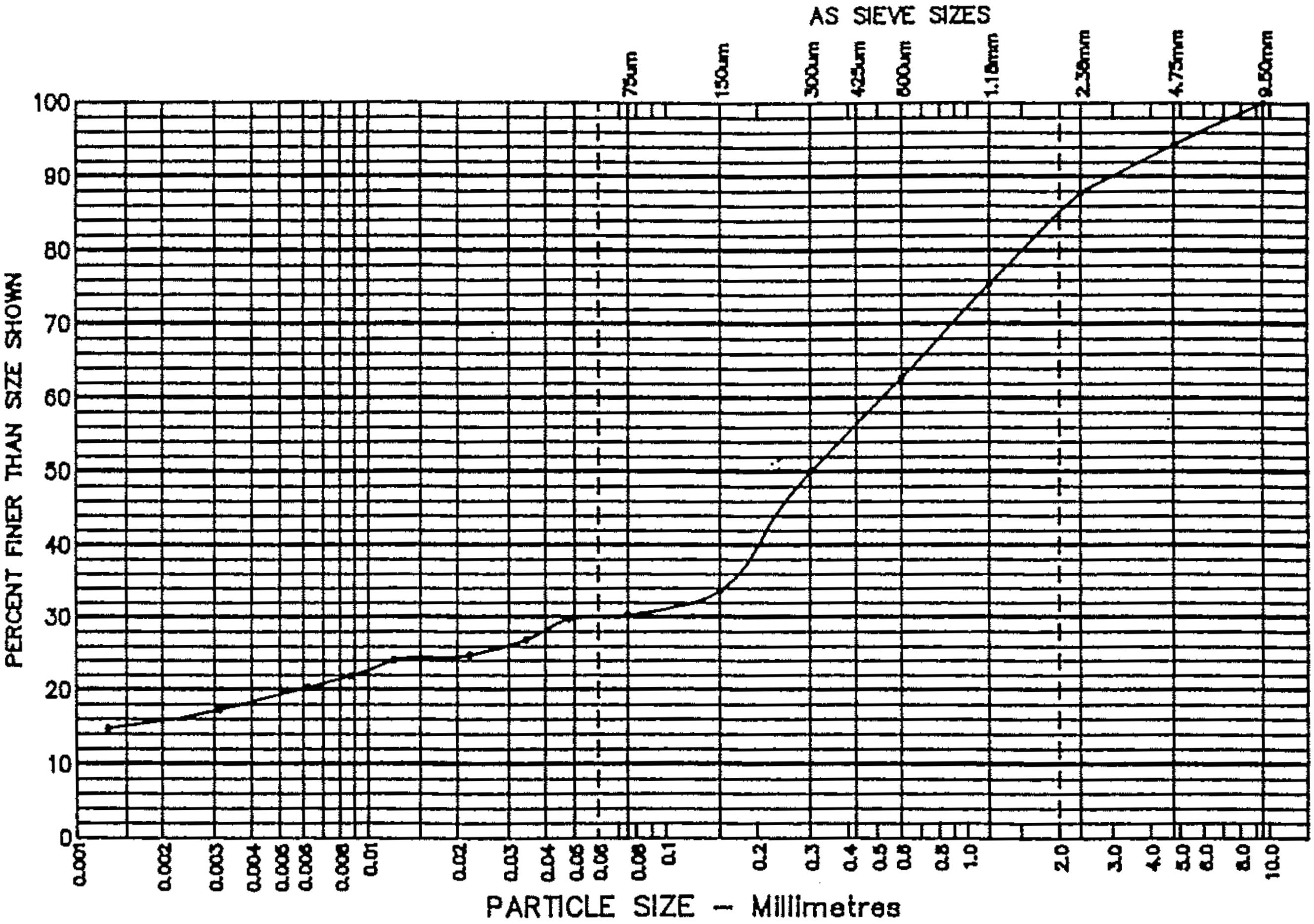
EARTHTECH LABORATORIES
Soils and Engineering Materials Testing
6/58 Wecker Road, Mt.Gravatt, 4122 Tel.(07)343 3166. Fax.(07)849 4705

CLASSIFICATION OF SOIL or SOIL/AGGREGATE

CLIENT	Hollingsworth. Consultants	CERTIFICATE NO.	
PROJECT	TRINITY. POINT	SAMPLE NO.	1171/88
FEATURE	BH. 605 . 1.33 – 1.70 m.	REGISTRATION NO.	B1643/88
LOCATION	Cairns. Foreshore	JOB NO.	88044/N4205G

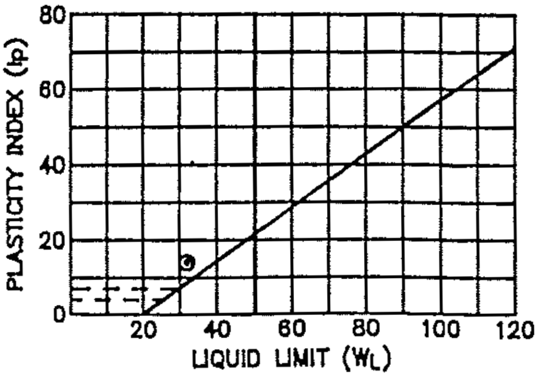


AS–1289

CLAY	SILT			SAND			GRAVEL	
	fine	medium	coarse	fine	medium	coarse	fine	medium

UNIFIED SOILS CLASSIFICATION (U.S.B.R.)

CLAY AND SILT	SAND			GRAVEL
	fine	medium	coarse	fine



PLASTICITY		
Liquid Limit (W_L)	32	
Plastic Limit (Wp)	18	
Plasticity Index (Ip)	14	
GRADATION		
Effect Size D10	*	mm
D30	*	mm
D60	*	mm
Uniformity Coefficient	*	
Coefficient of Curvature	*	
LINEAR SHRINKAGE	6.5	%

SOIL PARTICLE DENSITY		t/m³
Passing 2.36mm	*	
Retained 2.36mm	*	
Retained * mm	*	
INSITU MOISTURE	31.5	%
INSITU DRY DENSITY	*	t/m³
DISPERSION		
River Water	*	
Distilled Water	*	
PRETREATMENT	*	
COLOUR	*	

REMARKS . SM slightly clayey silty SAND predominantly medium to coarse with shell fragments . . . .

TESTING PERFORMED TO STANDARDS AS BELOW
Q.M.R.D. . * . . . .
AS1289 . C 1.2 . C 2.1 . C 3.1 . C 4.1 . C 6.3 . . . .

PREPARED BY . . . . / . / . . CHECKED BY . . . . / . / . .

NATA

. . . . . Authorised Signatory . . . .

APPENDIX 4

Test laboratory report for heavy metals and pesticides.

CHEMTEST
LABORATORIES

A Division of Inchcape Inspection and
Testing Services, Australia, Pty. Ltd.

63 Koppen Terrace, Cairns, Queensland
P.O. Box 11 Manunda, N.Qld., Australia 4870
Tele: (070) 546 020 Fax: (070) 547 217 Telex: AA 92560

CERTIFICATE OF ANALYSIS

DATE : 22/12/88 JOB NO: 880644

CLIENT: QUEENSLAND FISHERIES SERVICES

NO.OF SAMPLES: THREE

SAMPLE TYPE: SEAWEED

SAMPLE IDENTIFICATION: A: ZC 2 SEALAB
B: ZC SALTWATER CREEK
C: ZC 1 SEALAB

METHOD USED: GAS CHROMATOGRAPH, ELECTRON CAPTURE

RESULTS :
The sample(s) of soil / plants have been tested for the chemical compounds listed below with the following results (in parts per million).

	Sample 1	Sample 2	Sample 3
Endrin	<0.002ppm	<0.002ppm	<0.002ppm
DDT	<0.002ppm	<0.002ppm	<0.002ppm
DDE	<0.002ppm	<0.002ppm	<0.002ppm
DDD	<0.002ppm	<0.002ppm	<0.002ppm
TOTAL DDT	<0.002ppm	<0.002ppm	<0.002ppm
Lindane	<0.002ppm	<0.002ppm	<0.002ppm
Methoxychlor	<0.002ppm	<0.002ppm	<0.002ppm
Dieldrin	<0.002ppm	<0.002ppm	<0.002ppm
Aldrin	<0.002ppm	<0.002ppm	<0.002ppm
Benezene Hexachloride (BHC)	<0.002ppm	<0.002ppm	<0.002ppm
Oxychlordane	<0.002ppm	<0.002ppm	<0.002ppm
Heptachlor	<0.002ppm	<0.002ppm	<0.002ppm
Heptachlor Epoxide	<0.002ppm	<0.002ppm	<0.002ppm
Hexachlorobenezene (HCB)	<0.002ppm	<0.002ppm	<0.002ppm
Bromophos Ethyl	<0.01 ppm	<0.01 ppm	<0.01 ppm
Chlorpyrifos	<0.01 ppm	<0.01 ppm	<0.01 ppm
Ethion	<0.01 ppm	<0.01 ppm	<0.01 ppm
2,4 D	<0.01 ppm	<0.01 ppm	<0.01 ppm
2,4,5 T	<0.01 ppm	<0.01 ppm	<0.01 ppm

CHEMIST: pp L Dawrine
S. WEBB

CHEMTEST
LABORATORIES
A Division of Inchcape Inspection and
Testing Services, Australia, Pty. Ltd.

63 Koppen Terrace, Cairns, Queensland
P.O. Box 11 Manunda, N.Qld., Australia 4870
Tele: (070) 546 020 Fax: (070) 547 217 Telex: AA 92560

CERTIFICATE OF ANALYSIS

DATE: 01/12/88 JOB NO: 880635

CLIENT: QUEENSLAND FISHERIES SERVICE

NO.OF SAMPLES: TWO

SAMPLE TYPE: MUD

SAMPLE IDENTIFICATION: A: ESPLANADE, MUD FLATS
B: MOUTH, SALTWATER CREEK

METHOD USED: GAS CHROMATOGRAPH, ELECTRON CAPTURE

RESULTS:
The sample(s) of soil / plants have been tested for the chemical compounds listed below with the following results (in parts per million).

	Sample 1	Sample 2
Endrin	<0.002ppm	<0.002ppm
DDT	<0.002ppm	<0.002ppm
DDE	<0.002ppm	<0.002ppm
DDD	<0.002ppm	<0.002ppm
TOTAL DDT	<0.002ppm	<0.002ppm
Lindane	<0.002ppm	<0.002ppm
Methoxychlor	<0.002ppm	<0.002ppm
Dieldrin	**0.006ppm**	<0.002ppm
Aldrin	**0.271ppm**	**0.103ppm**
Benezene Hexachloride (BHC)	<0.002ppm	<0.002ppm
Oxychlordane	<0.002ppm	<0.002ppm
Heptachlor	<0.002ppm	<0.002ppm
Heptachlor Epoxide	<0.002ppm	<0.002ppm
Hexachlorobenezene (HCB)	<0.002ppm	<0.002ppm
Bromophos Ethyl	<0.01 ppm	<0.01 ppm
Chlorpyrifos	<0.01 ppm	<0.01 ppm
Ethion	<0.01 ppm	<0.01 ppm
2,4 D	<0.01 ppm	<0.01 ppm
2,4,5 T	<0.01 ppm	<0.01 ppm

CHEMIST:
S. WEBB pp L. Laurine

CHEMTEST
LABORATORIES

A Division of Inchcape Inspection and
Testing Services, Australia, Pty. Ltd.

63 Koppen Terrace, Cairns, Queensland
P.O. Box 11 Manunda, N.Qld., Australia 4870
Tele: (070) 546 020 Fax: (070) 547 217 Telex: AA 92560

CERTIFICATE OF ANALYSIS

DATE :	05/12/88	JOB NO: 880634
CLIENT:	NORTHERN FISHERIES RESEARCH CENTRE	
NO.OF SAMPLES:	ONE	
SAMPLE TYPE:	MUD	
SAMPLE IDENTIFICATION:	FITZROY ISLAND	
METHOD USED:	GAS CHROMATOGRAPH, ELECTRON CAPTURE	

RESULTS :
The sample(s) of soil / plants have been tested for the chemical compounds listed below with the following results (in parts per million).

	Sample 1
Endrin	<0.002ppm
DDT	<0.002ppm
DDE	<0.002ppm
DDD	<0.002ppm
TOTAL DDT	<0.002ppm
Lindane	<0.002ppm
Methoxychlor	<0.002ppm
Dieldrin	<0.002ppm
Aldrin	**0.033ppm**
Benezene Hexachloride (BHC)	<0.002ppm
Oxychlordane	<0.002ppm
Heptachlor	<0.002ppm
Heptachlor Epoxide	<0.002ppm
Hexachlorobenezene (HCB)	<0.002ppm
Bromophos Ethyl	<0.01 ppm
Chlorpyrifos	<0.01 ppm
Ethion	<0.01 ppm
2,4 D	<0.01 ppm
2,4,5 T	<0.01 ppm

CHEMIST: pp C. Sawrine
S. WEBB

CHEMTEST
LABORATORIES

A Division of Inchcape Inspection and
Testing Services, Australia, Pty. Ltd.

63 Koppen Terrace, Cairns, Queensland
P.O. Box 11 Manunda, N.Qld., Australia 4870
Tele: (070) 546 020 Fax: (070) 547 217 Telex: AA 92560

BIOCHEMICAL ANALYSIS REPORT

NAME:	**QUEENSLAND FISHERIES SERVICES**
ADDRESS:	**AUMULLER STREET, CAIRNS.**
DATE RECEIVED:	**14/12/88**
REPORT NUMBER:	**880644**
NUMBER OF SAMPLES:	**THREE**
TYPE OF SAMPLES:	**SEAWEED**
SAMPLE IDENTIFICATION	**A: ZC 2 SEALAB; B: ZC SALTWATER CREEK; C: ZC 1 SEALAB**

RESULTS:

	SAMPLE A	SAMPLE B	SAMPLE C
MERCURY	0.07ppm	0.04ppm	0.04ppm
CADMIUM	<0.01ppm	0.20ppm	<0.01ppm
LEAD	4.70ppm	5.20ppm	7.50ppm

Yours faithfully,

C. Saurine

C. SAURINE
TECHNICIAN

CHEMTEST
LABORATORIES

A Division of Inchcape Inspection and
Testing Services, Australia, Pty. Ltd.

63 Koppen Terrace, Cairns, Queensland
P.O. Box 11 Manunda, N.Qld., Australia 4870
Tele: (070) 546 020 Fax: (070) 547 217 Telex: AA 92560

BIOCHEMICAL ANALYSIS REPORT

NAME:	**QUEENSLAND FISHERIES SERVICES**
ADDRESS:	**AUMULLER STREET. PORTSMITH. CAIRNS.**
DATE RECEIVED:	**24/11/88**
REPORT NUMBER:	**880635**
NUMBER OF SAMPLES:	**TWO A: ESPLANADE, MUD FLATS; B: MOUTH, SALTWATER CREEK**
TYPE OF SAMPLES:	**MUD**

RESULTS:

	SAMPLE A	SAMPLE B
Oxygen	8.60ppm @ 29°C	8.00ppm @ 32°C
Mercury	0.29ppm	0.18ppm
Cadmium	<0.10ppm	0.10ppm
Lead	26ppm	18ppm

Yours faithfully.

C. Saurine

C.SAURINE
TECHNICIAN

CHEMTEST
LABORATORIES
A Division of Inchcape Inspection and
Testing Services, Australia, Pty. Ltd.

63 Koppen Terrace, Cairns, Queensland
P.O. Box 11 Manunda, N.Qld., Australia 4870
Tele: (070) 546 020 Fax: (070) 547 217 Telex: AA 92560

BIOCHEMICAL ANALYSIS REPORT

NAME:	**QUEENSLAND FISHERIES SERVICES**
ADDRESS:	**AUMULLER STREET, PORTSMITH. CAIRNS**
DATE RECEIVED:	29/11/88
REPORT NUMBER:	**880634**
NUMBER OF SAMPLES:	ONE
TYPE OF SAMPLES:	MUD

RESULTS:

Mercury	=	0.04ppm
Cadmium	=	<0.50ppm
Lead	=	4.40ppm

Yours faithfully,

C. Saurine

C. SAURINE
TECHNICIAN

CHEMTEST
LABORATORIES

A Division of Inchcape Inspection and
Testing Services, Australia, Pty. Ltd.

63 Koppen Terrace, Cairns, Queensland
P.O. Box 11 Manunda, N.Qld., Australia 4870
Tele: (070) 546 020 Fax: (070) 547 217 Telex: AA 92560

QUEENSLAND FISHERIES SERVICES
AUMULLER STREET,
PORTSMITH.
CAIRNS. QLD. 4870

INTERPRETATION ON REPORTS 880634, 880635 AND 880644

These results indicate, in our opinion, an unacceptable level of contamination to marine life with particular reference to crustaceans.

There are variety of sources of heavy metal contamination, some of which are:
mining, farming and leachate from the dump.

The unusually high levels of both pesticide and heavy metals found at Fitzroy Island, indicate, in our opinion, a major source of concern.

RECOMMENDATION

Further work on a greater number of samples for both statistical and locational reasons is recommended.

Yours faithfully,

pp C. Sawrine

STEVE WEBB.
CHEMIST

APPENDIX 5.

Results of water quality tests and fish tissue analyses in Smiths Creek near the Northern Fisheries Research Centre.

CSIRO
AUSTRALIA
Division of Fuel Technology
Lucas Heights Research Laboratories, New Illawarra Road, Lucas Heights, NSW.
Postal Address: Private Mail Bag 7, Menai, NSW 2234
Telephone: (02) 543 3111. Telex: AA 73341. Fax: (02) 543 6774

GB:JM 2 April 1988

Mr M. Rimmer
Northern Fisheries Research Centre
Box 5396
Cairns Mail Centre
QLD. 4871.

Dear Mike

Enclose is a copy of our results for the analysis of barramundi and water samples. The water concentrations are rather low, maybe not typical of the boat yard area. To what extent are barramundi bottom feeders? The sediment may give a better measure if you feel that is important.

If you want to extend the study further do not hesitate to contact me. Perhaps we can work out a low-cost collaborative research exercise.

Regards

GRAEME BATLEY

Encl.

Tributyltin in Barramundi

The following are results for analysis for tributyltin (TBT) in samples of muscle and liver from captive broadstock barramundi which are suspected of having died at your centre from acute TBT toxicity. Water samples were also analyzed.

Sample	ng Sn g^{-1} as TBT
Barramundi 7804 liver A	148
Barramundi 7804 liver B	210
Barramundi 7804 muscle	145
Barramundi 7838 liver	200
Barramundi 7838 muscle	108
Seawater - incoming tide	6.5 (ng Sn L^{-1})
Seawater - outgoing tide	12.5 (ng Sn L^{-1})

Analytical Methods

Tissue samples were homogenized, then 0.2 g was ultrasonicated in a mixture of concentrated hydrochloric acid (5 mL) asnd methanol (5 mL). The mixture was extracted with 0.05% tropolone in methylene chloride (15 mL) and back-extracted into 0.05 M nitric acid (20 mL). Aliquots of this sample were then added to a 50 mL reaction bottle into which was added sodium borohydride solution. The tributyltin hydride formed was flushed from the bottle with helium gas and collected on a trap, containing 3% OV101 on Chromosorb G, held at liquid temperature. The trapped hydrides were volatilized by a heating ramp and after mixture with hydrogen and oxygen were combusted in a heated quartz furnace at 800°C, with the tin being detected by atomic absorption spectrometry.

Water samples (500 mL) were similarly extracted with 0.05% tropolone in hexahe (25 mL) with the extracts evaporated to low volume in the presence of 0.05 M nitric acid. The acid extract was then analyzed for TBT by atomic absorption spectrometry after hydridization as before.

Discussion of Results

Very little data is available on TBT accumulation by fish. Acute toxicity has been reported for TBT concentrations in the range 0.6 - 10 ng Sn L^{-1} for a range of fish species (Rexrode, 1987). In studies of sheepshead minnows, muscle and whole body concentrations of 0.8 and 1.7 µg Sn g^{-1} were found, while liver and muscle concentrations in chinook salmon were 2.8 and 0.2 µg Sn g^{-1}) respectively. Both bioaccumulation data sets were from tank testing at µg L^{-1} concentrations of TBT. Bioaccumulation in salmon liver and muscle of 4300 and 280-fold respectively have been reported (Short and Thomer, 1986). The measured concentrations in the barramundi samples represent a much greater bioaccumulation of the measured water concentrations of TBT. These later values are not considered high compared to marine concentrations above 100 ng Sn L^{-1} (Batley et al., 1987) It is however difficult to comment, in the absence of addition experimentation, on the impact of such TBT levels on barramundi mortality.

APPENDIX 6

Seagrass and water bacteria analysis.

Table 19. Bacteria found in water samples and seagrass samples on Cairns mudflats.

Species Name	Salt Water	Seagrass
Escherichia coli	+	+
Citrobacter freundii	+	+
Klebsiella oxytoca		+
Enterobacter cloacae		+
Enterobacter agglomerans		+
Serratia marcescens		+
Proteus vulgaris	+	
Providencia rettgeri		+
Aeromonas hydrophila	+	+
Pseudomonas cepacia		+
Pseudomonas putrefaciens	+	
Pseudomonas spp.	+	+

+ Present in samples

<u>Sea water bacteria analysis</u>

Standard plate count/100ml = 6.0×10^6
Coliform count/100ml = 1.8×10^4
Escherichia coli/100ml = 100

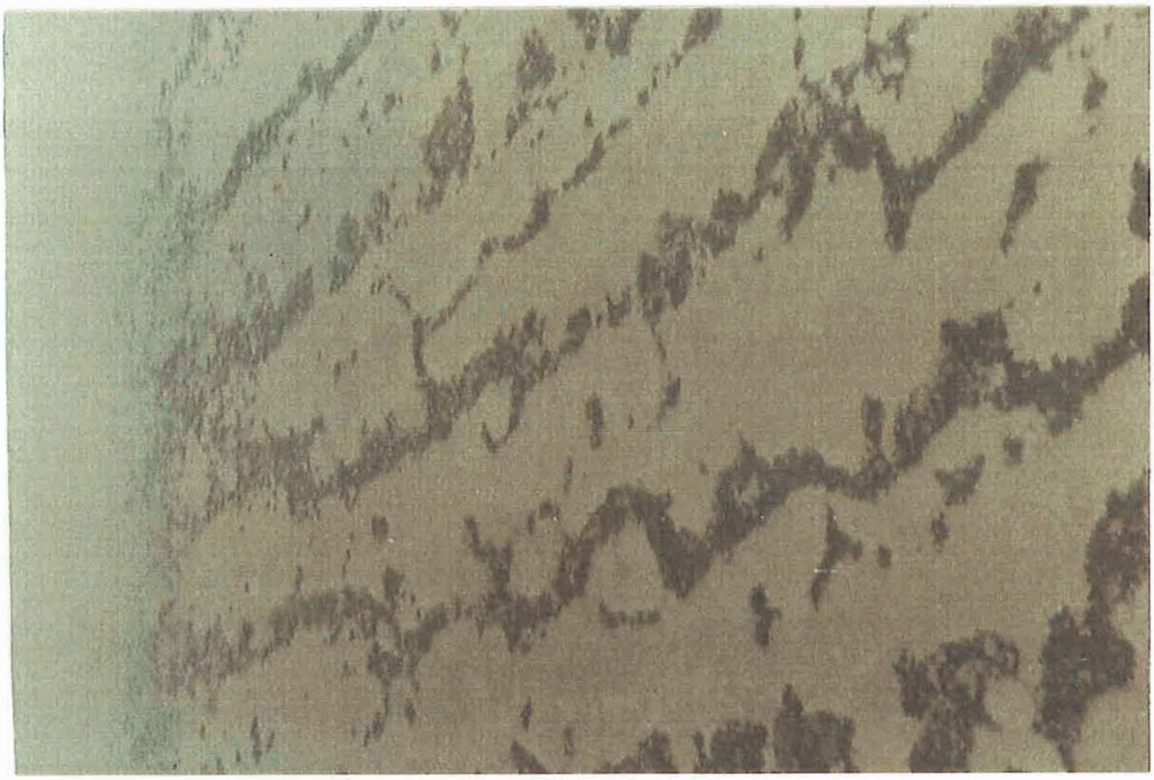
APPENDIX 7

Photographs of seagrass and mudflat of the Cairns Harbour study area.

Seagrass bed near SEALAB, February 1988.

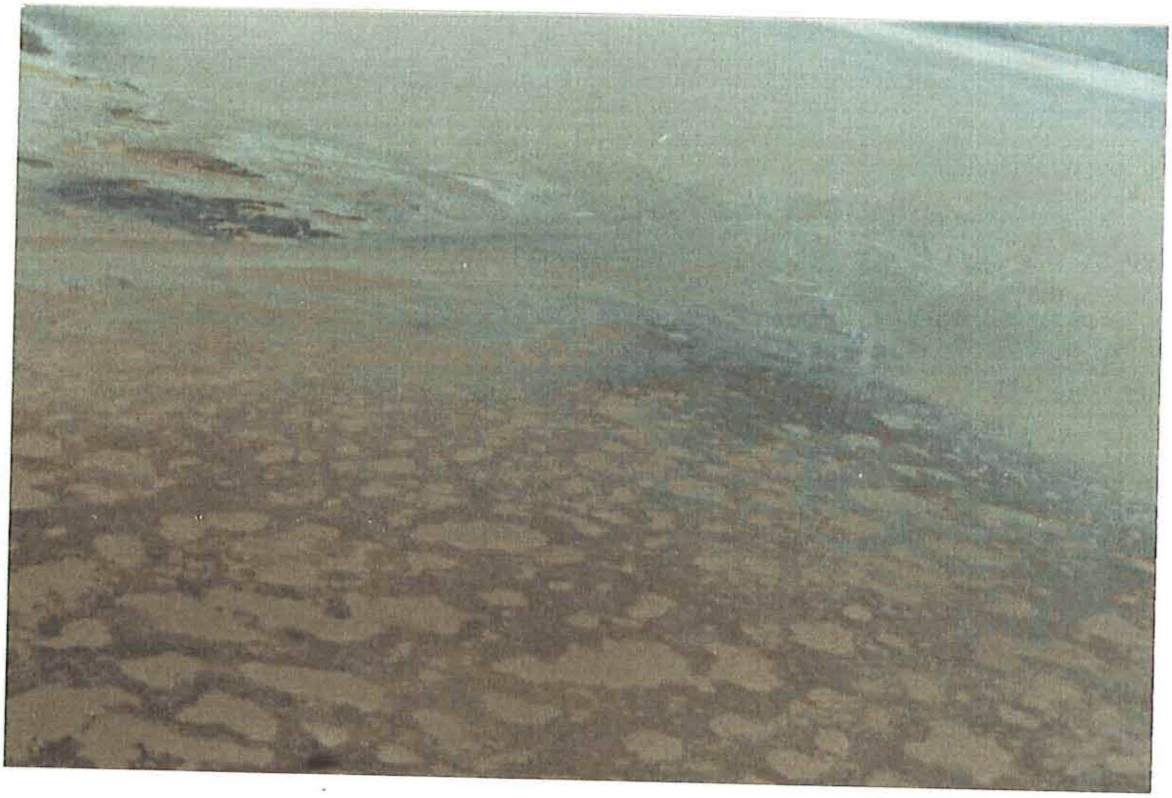
Seagrass bed in Mission Bay, February 1988..

Examples of patchy and dense seagrass on the Cairns mudflats.



An example of seagrass growth in natural drainage channels and depressions on Cairns mudflats.

Dense seagrass bed at Ellie Point.



Surface micro-algal cover on exposed mudflats near Ellie Point.

Possible dugong feeding trails on seagrass beds near Ellie Point.

Zone of beach sand and marine couch at landward edge of Cairns esplanade mudflats.

Algal Mat, Pseudodichotomosiphin sp. (F. Xanthophyceqe), present in upper tidal reaches of Trinity Bay mudflats.

Algal Mat, Pseudodichotomosiphin sp. present in the upper tidal reaches of Trinity Bay mudflats.

APPENDIX 8

Hollingsworth Consultants seagrass mapping from aerial photographs.

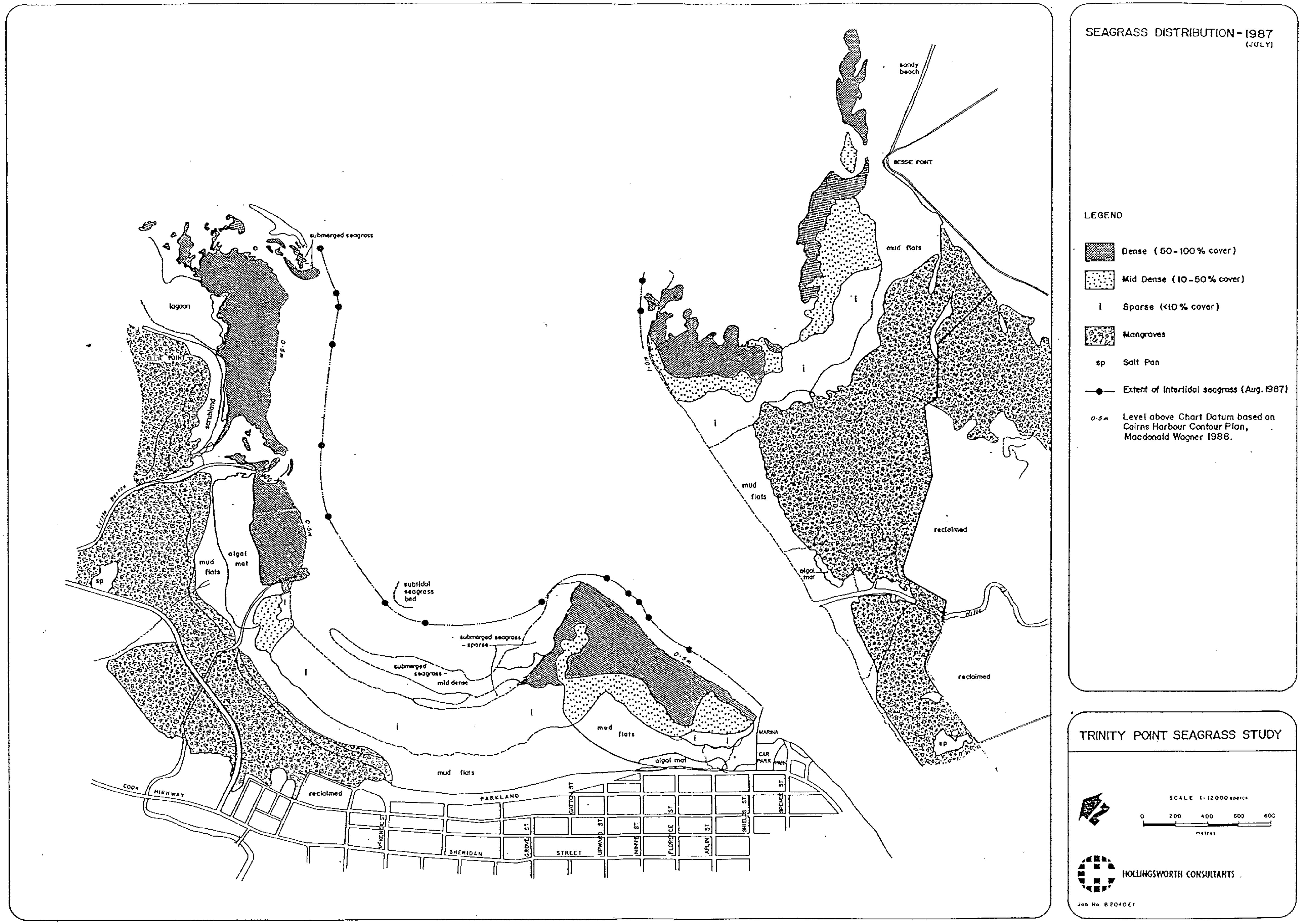


Figure 9. Seagrass distribution mapped from 1987 aerial photographs.

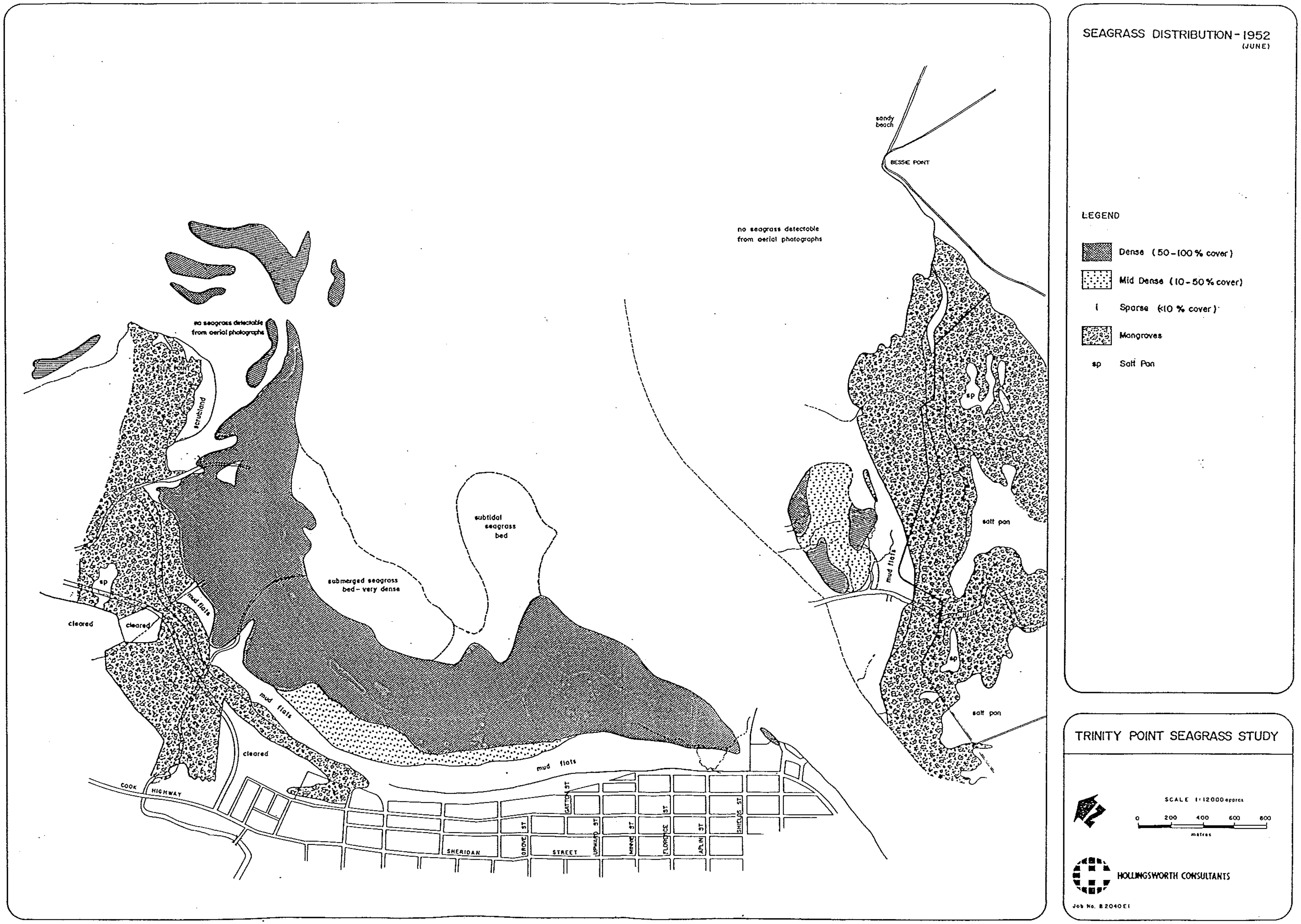


Figure 10. Seagrass distribution mapped from 1952 aerial photographs.

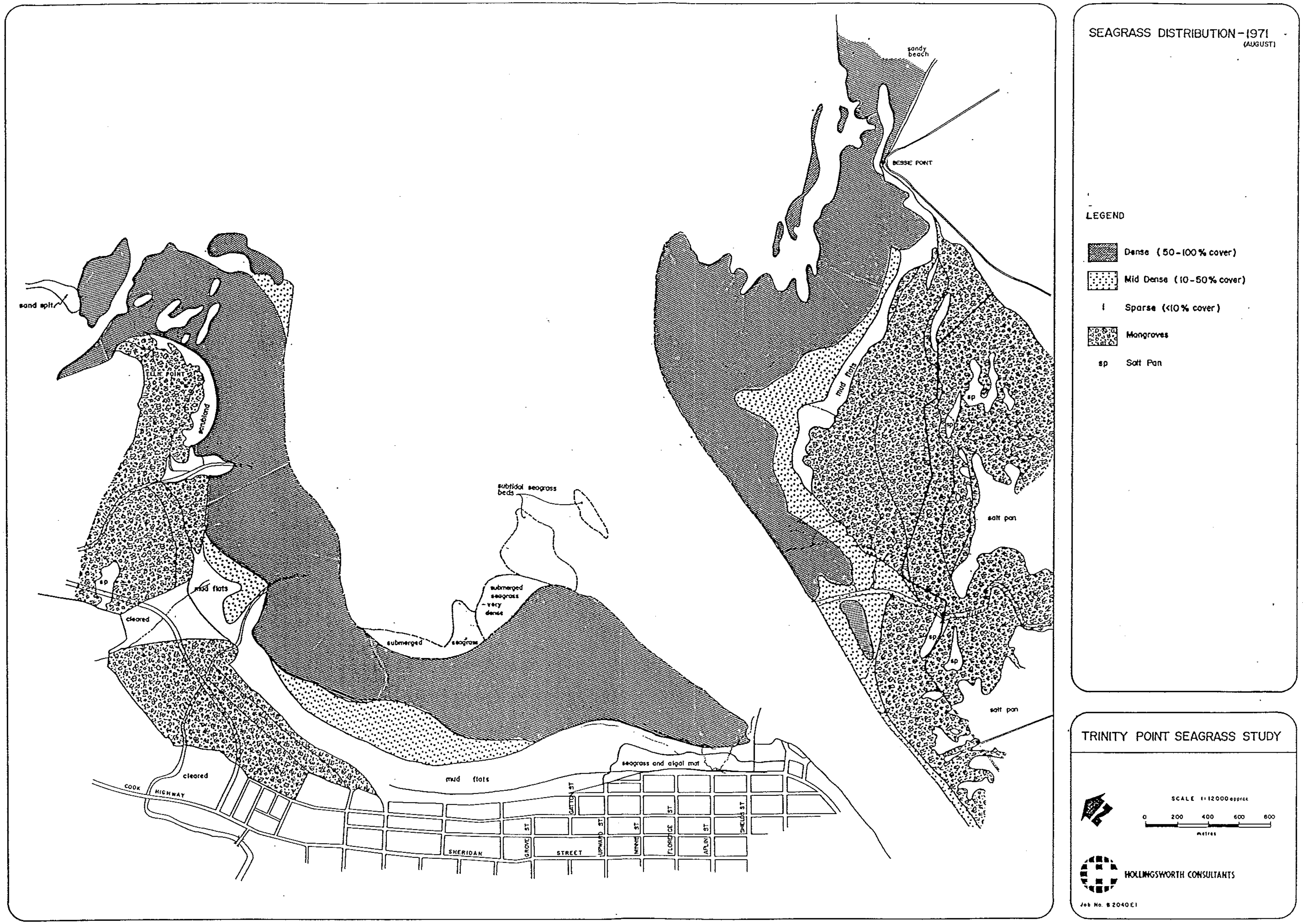


Figure 11. Seagrass distribution mapped from 1971 aerial photographs.

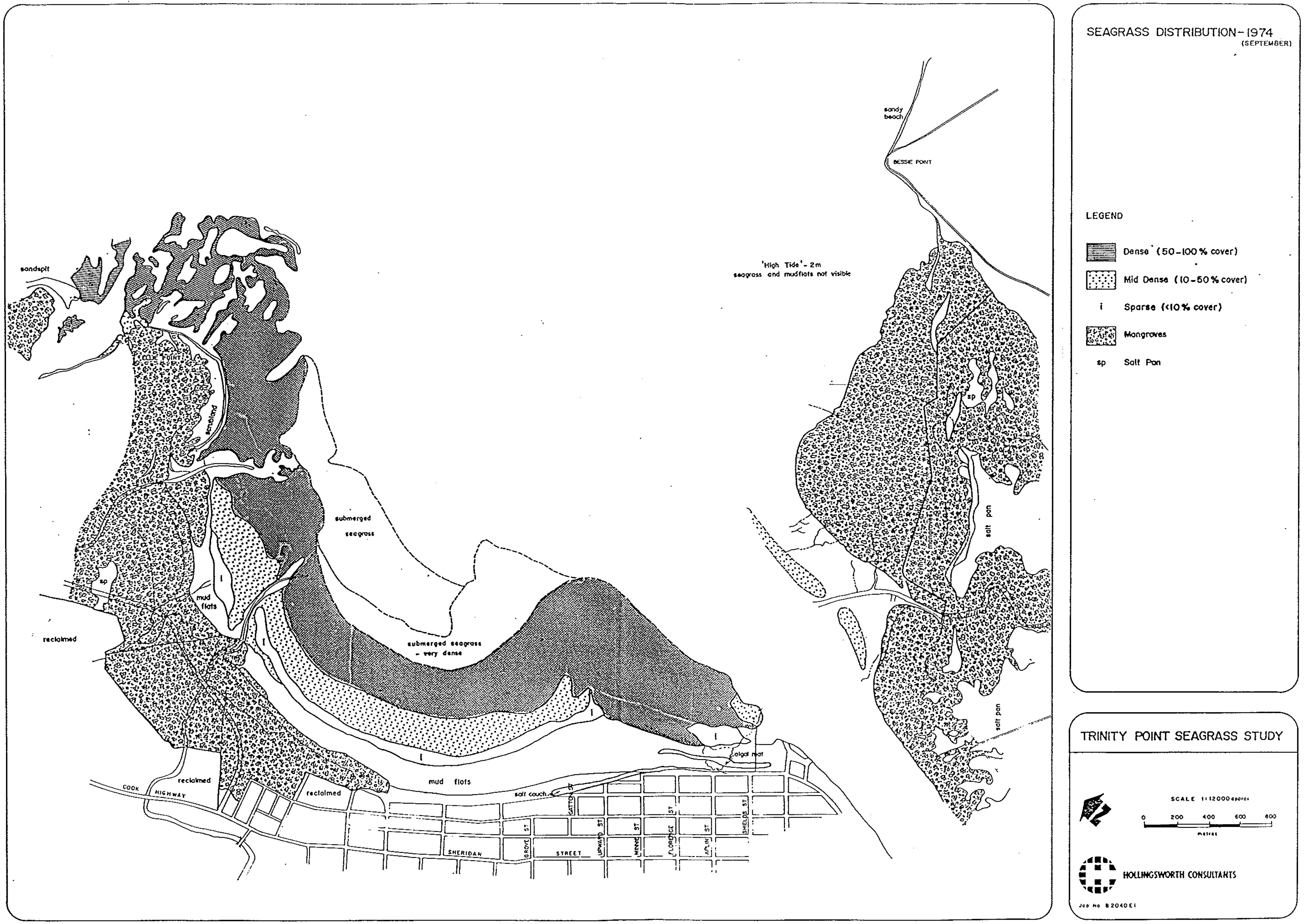


Figure 12. Seagrass distribution mapped from 1974 aerial photographs.

Figure 29. Seagrass distribution mapped from 1979 aerial photographs.

Figure 30. Seagrass distribution mapped from 1983 aerial photographs.

APPENDIX 9

A compilation of scientific and common names used in this report.

Table 20. List of common and corresponding scientific names used in the report.

SCIENTIFIC NAME	COMMON NAME
Ablennes hians	Giant long-tom
Acanthopagrus australis	Silver bream
Acanthopagrus berda	Black bream
Acanthurus xanthopterus	Ring-tailed surgeonfish
Acentrogobius c.f. multifasciatus	Goby
Aesopia heterhinus	Sole
Aetobatus narinari	Eagle ray
Aetomyleus sp.	Frog ray
Agriosphraena barracuda	Giant barracuda
Alectis indica	Diamond trevally
Ambassis nalua	Perchlet
Ambassis telkara	Perchlet
Amblygobius sp.1	Goby
Amblyrhynchotes spinosissimus	Pufferfish
Anodontostoma chacunda	Mud herring
Apistops caloundra	Scorpionfish
Aploactinidae sp.1	Velvetfish
Apogon brevicaudatus	Cardinalfish
Apogon ellioti	Cardinalfish
Apogon hartzfeldi	Cardinalfish
Apogon nigripinnis	Cardinalfish
Apogon poecilopterus	Cardinalfish
Apogon quadrifasciatus	Cardinalfish
Apogon rupelli	Cardinalfish
Apogon sp.1	Cardinalfish
Apogon spp.	Cardinalfishes
Arenigobius sp.1	Goby
Arius c.f. argyropleuron	Fork-tailed catfish
Arius proximus	Fork-tailed catfish
Arius sp.1	Fork-tailed catfish
Arius thalassinus	Fork-tailed catfish
Arnoglossus waitei	Flounder
Arothron hispidus	Stars and stripes toadfish
Arothron immaculatus	Narrow-lined toadfish
Arrhamphus sclerolepis	Snub-nosed garfish
Atelomycterus macleayi	Cat shark
Atherinomorus c.f. endrachtensis	Hardyhead
Atypopenaeus formosus	Orange prawn
Atypopenaeus stenodactylus	Periscope prawn
Bombonia spicifer	Pipefish
Bothidae sp.1	Flounder
Bothidae sp.2	Flounder
Callionymus macdonaldi?	Dragonet
Callionymus sp.1	Dragonet
Callionymus spp.	Dragonets
Canthigaster margaritatus	Ocellated toby
Carangidae sp.1	Trevally
Caranx ignoblis	Lowly trevally
Caranx sexfasciatus	Trevally
Caranx sp.1	Trevally
Carcharhinus sealei	Shark
Caulerpa sp.	Algae
Centriscus scutatus	Razorfish

Table 20 continued.

SCIENTIFIC NAME	COMMON NAME
Centrogenys vaigiensis	False scorpionfish
Chaetoderma penicilligera	Leatherjacket
Chaetodontidae sp.1	Butterflyfish
Chanos chanos	Milkfish
Charcharhinus c.f. sorrah	Shark
Cheilodipterus sp.1	Cardinalfish
Chelonodon patoca	Toadfish
Chirocentrus dorab	Wolf herring
Choerodon sp.1	Wrasse
Choerodon sp.2	Wrasse
Conger labiatus	Conger eel
Ctenogobius nebulosus	Goby
Ctenogobius sp.1	Goby
Cymbacephalus nematophthalmus	Fringe-eyed flathead
Cymodocea rotundata	Seagrass
Cymodocea serrulata	Seagrass
Cynoglossus bilineatus	Tongue sole
Cynoglossus heterolepis	Tongue sole
Cynoglossus puncticeps	Tongue sole
Cynoglossus sp.1	Tongue sole
Dasyatis sephen	Cowtail ray
Dexilichthys muelleri	Sole
Dorippe c.f. australiensis	Crab
Dorippe sp.1	Crab
Drepane punctata	Sicklefish
Echeneis naucrates	Remora
Eleutheronema tetradactylum	Blue salmon
Elops australis	Giant herring
Engraulidae sp.	Anchovy
Engyprosopon grandisquama	Flounder
Epinephalus merra	Wire netting cod
Epinephalus spp.	Groupers
Epinephalus tuavina	Estuarine cod
Escualosa thoracata	Herring
Foa brachygramma	Cardinalfish
Fowleria c.f. variagata	Cardinalfish
Gazza minuta	Ponyfish
Gerres abbreviatus	Silver biddy
Gerres argyreus	Darnley Island silverbelly
Gerres filamentosus	Silver biddy
Gerres oyeana	Silver biddy
Gerres poieti	Silver biddy
Gerres punctatus	Silver biddy
Gerres sp.1	Silver biddy
Glossamia aprion aprion	Mouth almighty
Glossogobius giuris	Flat-headed goby
Glossogobius sp.1	Goby
Gnathanodon speciosus	Golden trevally
Gobiidae sp.1	Goby
Gobiidae sp.2	Goby
Gobiidae sp.3	Goby
Gobiidae spp.	Gobies
Grapsidae sp.1	Mangrove crab

Table 20 continued.

SCIENTIFIC NAME	COMMON NAME
Gymnothorax favagineus	Moray eel
Gymnothorax reticularis	Moray eel
Gymnothorax sp.1	Moray eel
Haemulidae spp.	Grunters
Halodule pinifolia	Seagrass
Halodule uninervis (thin)	Seagrass
Halodule uninervis (wide)	Seagrass
Halophila decipiens	Seagrass
Halophila ovalis	Seagrass
Halophila tricostata	Seagrass
Halophryne diemensis	Banded frogfish
Harengula macrolepis	Northern herring
Hemirhamphidae sp.1	Garfish
Hemirhamphus far	Five-spot garfish
Heniochus acuminatus	Feather-fin bullfish
Herklotsichthys koningsbergeri	Spotted herring/sardine
Himantura granulata	Mangrove ray
Himantura uarnak	Leopard ray
Hyperlophus vittatus	Herring
Hypoatherina temminckii	Hardyhead
Hypodytes carinatus	Waspfish
Hyporhamphus australis	Sea garfish
Hyporhamphus dussumieri	Dussumier's garfish
Hyporhamphus quoyi	Short-nosed garfish
Hyporhamphus sp.1	Garfish
Inegocia isacanthus	Flathead
Labridae sp.	Wrasse
Lactarius lactarius	False trevally
Lactoria cornuta	Boxfish
Lates calcarifer	Barramundi
Leiognathus bindus	Ponyfish
Leiognathus decorus	Ponyfish
Leiognathus equulus	Ponyfish
Leiognathus fasciatus	Ponyfish
Leiognathus leuciscus	Ponyfish
Leiognathus moretoniensis	Ponyfish
Leiognathus sp.1	Ponyfish
Leiognathus splendens	Ponyfish
Leiognathus spp.	Ponyfish
Lethrinus lentjan	Purple-headed emperor
Lethrinus nebulosus	Spangled emperor
Lethrinus nematacanthus	Thread-fin emperor
Lethrinus sp.1	Emperor
Liza dussumieri	Flat-tailed mullet
Liza vaigiensis	Diamond-scaled mullet
Lobotes surinamensis	Triple-tail
Lutjanus argentimaculatus	Mangrove jack
Lutjanus erythropterus	Small-mouthed nannygai
Lutjanus fulviflammus	Moses perch
Lutjanus russelli	Fingermark
Lutjanus sp.1	Sea perch
Matuta granulosa	Box crab
Matuta lunaris	Box crab

Table 20 continued.

SCIENTIFIC NAME	COMMON NAME
Megalops cyprinoides	Oxeye Herring
Metapenaeopsis novaguineae	Northern velvet prawn
Metapenaeopsis palmensis	Southern velvet prawn
Metapenaeopsis rosea	Rosy prawn
Metapenaeus bernettae	York prawn
Metapenaeus dalli	Western school prawn
Metapenaeus eboracensis	Greentail prawn
Metapenaeus endeavouri	True endeavour prawn
Metapenaeus ensis	False endeavour prawn
Metapenaeus insolitus	Greasyback prawn
Micrognathus sp?	Pipefish
Monacanthus chinensis	Fan-bellied leatherjacket
Monodactylus argenteus	Diamond butterfish
Mugil cephalus	Sea mullet
Mugil georgii	Creek mullet
Muraenesox sp.	Pike eel
Nematalosa come	Hair-back mud herring
Nibea soldado	Silver jewfish
Ocypodidae sp.1	Ghost crab
Ophiocara aporos	Snake-headed gudgeon
Otolithes ruber	Three-toothed jewfish
Oxyeleotris lineolatus	Sleepy cod
Paracentropogon longispinis	Waspfish
Parachaetodon ocellatus	Butterflyfish
Paramonacanthus sp.1	Leatherjacket
Parapenaeopsis cornuta	Coral prawn
Parapenaeopsis tenella	Smoothshell prawn
Parapercis cylindrica	Grubfish
Parapercis spp.	Grubfishes
Paraplagusia guttata	Tongue sole
Parthenope sp.1	Crab
Parvigobius sp.	Goby
Pelates quadrilineatus	Trumpeter
Pellona ditchela	Ditchelee herring
Penaeus esculentus	Brown tiger prawn
Penaeus indicus	Red legged banana prawn
Penaeus latisulcatus	Western king prawn
Penaeus longistylus	Red spot king prawn
Penaeus merguiensis	Common banana prawn
Penaeus monodon	Leader prawn
Penaeus semisulcatus	Grooved tiger prawn
Penaeus sp.	Tiger prawn
Pentapodus sp.4	Monocle bream
Periophthalmodon barbarus	Mud-skipper
Periophthalmus koelreuteri	Mud-skipper
Periophthalmus sp.	Mud-skipper
Petroscirtes sp.1	Blenny
Platax tiera	Batfish
Platycephalidae spp.	Flathead
Platycephalus fuscus	Dusky flathead
Platycephalus indicus	Bar-tailed flathead
Plectorhincus gibbosus	Brown sweetlip
Plotosus anguillaris	Striped catfish

Table 20 continued.

SCIENTIFIC NAME	COMMON NAME
Polydactylus heptadactylus	Seven-fingers tasselfish
Polydactylus multiradiatus	Threadfin
Polydactylus sheridani	King salmon
Polydactylus sp.1	Threadfin
Pomacentrus sp.	Yellow-tailed damselfish
Pomadasys kaakan	Grunter
Pomadasys maculatus	Grunter
Pomadasys opercularis	Spotted grunter
Pomadasys sp.1	Grunter
Portunidae spp.	Swimming crabs
Portunus andersoni	Swimming crab
Portunus orbitosinus	Swimming crab
Portunus pelagicus	Sand crab
Pranesus lacunosa	Hardyhead
Pranesus olgilbyi	Hardyhead
Protonibea diacanthus	Black jewfish
Psammoperca vaigiensis	Sand bass
Psettodes erumei	Halibut
Pseudomonacanthus elongatus	Leatherjacket
Pseudomonacanthus peronii	Leatherjacket
Pseudomugil signifer	Blue-eye
Pseudorhombus arsius	Flounder
Pseudorhombus elevatus	Flounder
Pseudorhombus jenynsii	Flounder
Pseudorhombus sp.1	Flounder
Pterois volitans	Butterfly cod
Repomuscenus belcheri	Dragonet
Rhabdamia sp.1	Cardinalfish
Rhinobatus batillum	Shovelnose ray
Rhinobatus spp.	Shovelnose rays
Rhinogobius sp.1	Goby
Rhynchorhampus georgi	Long-nosed garfish
Sardinella sp.1	Sardine
Saurida nebulosa	Grinner/rock whiting
Scaienidae sp.1	Jewfish
Scarus sp.1	Parrotfish
Scoliodon palasorah	Little blue shark
Scomberoides commersonianus	Queenfish
Scomberoides tala	Deep queenfish
Scomberoides tol	Slender queenfish
Scylla serrata	Mud crab
Secutor insidator	Ponyfish
Secutor ruconius	Ponyfish
Sicyonia cristata	Rigeback prawn
Siganus canaliculatus	Spinefoot
Siganus fuscescens	Spinefoot
Siganus guttatus	Golden-lined spinefoot
Siganus sp.1	Spinefoot
Siganus spinus	Black spinefoot
Sillago maculata	Winter whiting
Sillago sihama	Northern whiting
Sillago spp.	Whiting
Siphamia versicolor	Cardinalfish

Table 20 continued.

SCIENTIFIC NAME	COMMON NAME
Sphaeroides laevigatus	Toadfish
Sphaeroides pleurostictus	Toadfish
Sphyraena flavicauda	Barracuda
Sphyraena jello	Pickhandle barracuda
Sphyrna lewini	Hammerhead shark
Spratelloides delicatulus	Northern blue sprat
Stegastoma fasciatum	Zebra shark
Stigmatogobius sp.	Goby
Stolephorus c.f. tysoni	Anchovy
Stolephorus carpentariae	Anchovy
Stolephorus devisi	Anchovy
Stolephorus indicus	Anchovy
Stolephorus spp.	Anchovy
Strongylura strongylura	Black-spot long-tom
Suggrundus sp.1	Flathead
Synanceia horrida	Coastal stonefish
Synanceia verrucosa	Reef stonefish
Synaptura setifer	Sole
Syngnathidae spp.	Seahorses
Terapon jarbua	Trumpeter
Terapon puta	Trumpeter
Teraponidae spp.	Trumpeters
Tetrabrachium ocellatum	Smoth anglerfish
Tetraodontidae sp.1	Toadfish
Tetraodontidae sp.2	Toadfish
Thalamita parvidens	Swimming crab
Thalamita sima	Swimming crab
Thalamita sp.1	Swimming crab
Thalamita sp.2	Swimming crab
Thalassia hemprichii	Seagrass
Thryssa hamiltonii	Anchovy
Thryssa setirostris	Anchovy
Thryssa spp.	Anchovies
Torquigener sp.1	Toadfish
Torquigener whitleyi	Toadfish
Toxotes chatareus	Archerfish
Trachinotus blochii	Snub-nosed dart
Trachinotus russelli	Swallowtail
Trachypenaeus curvirostris	Southern rough prawn
Trachypeneaus anchoralis	Northern rough prawn
Trachypeneaus fulvus	Brown rough prawn
Tragulichthys jaculiferus	Porcupinefish
Triacanthus biaculeatus	Tripodfish
Trixiphichthys weberi	Tripodfish
Tylosurus crocodilus	Choram long-tom
Tylosurus leiura	Hornpike long-tom
Upeneus c.f. tragula	Goatfish
Upeneus sp.1	Goatfish
Upeneus vittatus	Goatfish
Valamugil buchanani	Mullet
Valamugil cunnesius	Mullet
Valamugil seheli	Blue-tailed mullet
Xanthidae sp.	Crab

Table 20 continued.

SCIENTIFIC NAME	COMMON NAME
Xenaploactis sp.1	Velvetfish
Yongeichthys criniger	Hair-finned goby
Zabidius novemaculeatus	Batfish
Zenarchopterus buffonis	Buffon's garfish
Zostera capricorni	Seagrass
c.f. Arenigobius sp.	Goby

Table 21. List of common and corresponding scientific names used in the report.

COMMON NAME	SCIENTIFIC NAME
Algae	Caulerpa sp.
Anchovies	Thryssa spp.
Anchovy	Engraulidae sp.
Anchovy	Stolephorus c.f. tysoni
Anchovy	Stolephorus carpentariae
Anchovy	Stolephorus devisi
Anchovy	Stolephorus indicus
Anchovy	Stolephorus spp.
Anchovy	Thryssa hamiltonii
Anchovy	Thryssa setirostris
Archerfish	Toxotes chatareus
Banded frogfish	Halophryne diemensis
Bar-tailed flathead	Platycephalus indicus
Barracuda	Sphyraena flavicauda
Barramundi	Lates calcarifer
Batfish	Platax tiera
Batfish	Zabidius novemaculeatus
Black bream	Acanthopagrus berda
Black jewfish	Protonibea diacanthus
Black spinefoot	Siganus spinus
Black-spot long-tom	Strongylura strongylura
Blenny	Petroscirtes sp.1
Blue salmon	Eleutheronema tetradactylum
Blue-eye	Pseudomugil signifer
Blue-tailed mullet	Valamugil seheli
Box crab	Matuta granulosa
Box crab	Matuta lunaris
Boxfish	Lactoria cornuta
Brown rough prawn	Trachypeneaus fulvus
Brown sweetlip	Plectorhincus gibbosus
Brown tiger prawn	Penaeus esculentus
Buffon's garfish	Zenarchopterus buffonis
Butterfly cod	Pterois volitans
Butterflyfish	Chaetodontidae sp.1
Butterflyfish	Parachaetodon ocellatus
Cardinalfish	Apogon brevicaudatus
Cardinalfish	Apogon ellioti
Cardinalfish	Apogon hartzfeldi
Cardinalfish	Apogon nigripinnis
Cardinalfish	Apogon poecilopterus
Cardinalfish	Apogon quadrifasciatus
Cardinalfish	Apogon rupelli
Cardinalfish	Apogon sp.1
Cardinalfish	Cheilodipterus sp.1
Cardinalfish	Foa brachygramma
Cardinalfish	Fowleria c.f. variagata
Cardinalfish	Rhabdamia sp.1
Cardinalfish	Siphamia versicolor
Cardinalfishes	Apogon spp.
Cat shark	Atelomycterus macleayi
Choram long-tom	Tylosurus crocodilus
Coastal stonefish	Synanceia horrida
Common banana prawn	Penaeus merguiensis

Table 21 continued.

COMMON NAME	SCIENTIFIC NAME
Conger eel	Conger labiatus
Coral prawn	Parapenaeopsis cornuta
Cowtail ray	Dasyatis sephen
Crab	Dorippe c.f. australiensis
Crab	Dorippe sp.1
Crab	Parthenope sp.1
Crab	Xanthidae sp.
Creek mullet	Mugil georgii
Darnley Island silverbelly	Gerres argyreus
Deep queenfish	Scomberoides tala
Diamond butterfish	Monodactylus argenteus
Diamond trevally	Alectis indica
Diamond-scaled mullet	Liza vaigiensis
Ditchelee herring	Pellona ditchela
Dragonet	Callionymus macdonaldi?
Dragonet	Callionymus sp.1
Dragonet	Repomuscenus belcheri
Dragonets	Callionymus spp.
Dusky flathead	Platycephalus fuscus
Dussumier's garfish	Hyporhamphus dussumieri
Eagle ray	Aetobatus narinari
Emperor	Lethrinus sp.1
Estuarine cod	Epinephalus tuavina
False endeavour prawn	Metapenaeus ensis
False scorpionfish	Centrogenys vaigiensis
False trevally	Lactarius lactarius
Fan-bellied leatherjacket	Monacanthus chinensis
Feather-fin bullfish	Heniochus acuminatus
Fingermark	Lutjanus russelli
Five-spot garfish	Hemirhamphus far
Flat-headed goby	Glossogobius giuris
Flat-tailed mullet	Liza dussumieri
Flathead	Inegocia isacanthus
Flathead	Platycephalidae spp.
Flathead	Suggrundus sp.1
Flounder	Arnoglossus waitei
Flounder	Bothidae sp.1
Flounder	Bothidae sp.2
Flounder	Engyprosopon grandisquama
Flounder	Pseudorhombus arsius
Flounder	Pseudorhombus elevatus
Flounder	Pseudorhombus jenynsii
Flounder	Pseudorhombus sp.1
Fork-tailed catfish	Arius c.f. argyropleuron
Fork-tailed catfish	Arius proximus
Fork-tailed catfish	Arius sp.1
Fork-tailed catfish	Arius thalassinus
Fringe-eyed flathead	Cymbacephalus nematophthalmus
Frog ray	Aetomyleus sp.
Garfish	Hemirhamphidae sp.1
Garfish	Hyporhamphus sp.1
Ghost crab	Ocypodidae sp.1
Giant barracuda	Agriosphraena barracuda

Table 21 continued.

COMMON NAME	SCIENTIFIC NAME
Giant herring	Elops australis
Giant long-tom	Ablennes hians
Goatfish	Upeneus c.f. tragula
Goatfish	Upeneus sp.1
Goatfish	Upeneus vittatus
Gobies	Gobiidae spp.
Goby	Acentrogobius c.f. multifasciatus
Goby	Amblygobius sp.1
Goby	Arenigobius sp.1
Goby	Ctenogobius nebulosus
Goby	Ctenogobius sp.1
Goby	Glossogobius sp.1
Goby	Gobiidae sp.1
Goby	Gobiidae sp.2
Goby	Gobiidae sp.3
Goby	Parvigobius sp.
Goby	Rhinogobius sp.1
Goby	Stigmatogobius sp.
Goby	c.f. Arenigobius sp.
Golden trevally	Gnathanodon speciosus
Golden-lined spinefoot	Siganus guttatus
Greasyback prawn	Metapenaeus insolitus
Greentail prawn	Metapenaeus eboracensis
Grinner/rock whiting	Saurida nebulosa
Grooved tiger prawn	Penaeus semisulcatus
Groupers	Epinephalus spp.
Grubfish	Parapercis cylindrica
Grubfishes	Parapercis spp.
Grunter	Pomadasys kaakan
Grunter	Pomadasys maculatus
Grunter	Pomadasys sp.1
Grunters	Haemulidae spp.
Hair-back mud herring	Nematalosa come
Hair-finned goby	Yongeichthys criniger
Halibut	Psettodes erumei
Hammerhead shark	Sphyrna lewini
Hardyhead	Atherinomorus c.f. endrachtensis
Hardyhead	Hypoatherina temminckii
Hardyhead	Pranesus lacunosa
Hardyhead	Pranesus olgilbyi
Herring	Escualosa thoracata
Herring	Hyperlophus vittatus
Hornpike long-tom	Tylosurus leiura
Jewfish	Scaienidae sp.1
King salmon	Polydactylus sheridani
Leader prawn	Penaeus monodon
Leatherjacket	Chaetoderma penicilligera
Leatherjacket	Paramonacanthus sp.1
Leatherjacket	Pseudomonacanthus elongatus
Leatherjacket	Pseudomonacanthus peronii
Leopard ray	Himantura uarnak
Little blue shark	Scoliodon palasorah
Long-nosed garfish	Rhynchorhampus georgi

Table 21 continued.

COMMON NAME	SCIENTIFIC NAME
Lowly trevally	Caranx ignoblis
Mangrove crab	Grapsidae sp.1
Mangrove jack	Lutjanus argentimaculatus
Mangrove ray	Himantura granulata
Milkfish	Chanos chanos
Monocle bream	Pentapodus sp.4
Moray eel	Gymnothorax favagineus
Moray eel	Gymnothorax reticularis
Moray eel	Gymnothorax sp.1
Moses perch	Lutjanus fulviflammus
Mouth almighty	Glossamia aprion aprion
Mud crab	Scylla serrata
Mud herring	Anodontostoma chacunda
Mud-skipper	Periophthalmodon barbarus
Mud-skipper	Periophthalmus koelreuteri
Mud-skipper	Periophthalmus sp.
Mullet	Valamugil buchanani
Mullet	Valamugil cunnesius
Narrow-lined toadfish	Arothron immaculatus
Northern blue sprat	Spratelloides delicatulus
Northern herring	Harengula macrolepis
Northern rough prawn	Trachypeneaus anchoralis
Northern velvet prawn	Metapenaeopsis novaguineae
Northern whiting	Sillago sihama
Ocellated toby	Canthigaster margaritatus
Orange prawn	Atypopenaeus formosus
Oxeye Herring	Megalops cyprinoides
Parrotfish	Scarus sp.1
Perchlet	Ambassis nalua
Perchlet	Ambassis telkara
Periscope prawn	Atypopenaeus stenodactylus
Pickhandle barracuda	Sphyraena jello
Pike eel	Muraenesox sp.
Pipefish	Bombonia spicifer
Pipefish	Micrognathus sp?
Ponyfish	Gazza minuta
Ponyfish	Leiognathus bindus
Ponyfish	Leiognathus decorus
Ponyfish	Leiognathus equulus
Ponyfish	Leiognathus fasciatus
Ponyfish	Leiognathus leuciscus
Ponyfish	Leiognathus moretoniensis
Ponyfish	Leiognathus sp.1
Ponyfish	Leiognathus splendens
Ponyfish	Leiognathus spp.
Ponyfish	Secutor insidator
Ponyfish	Secutor ruconius
Porcupinefish	Tragulichthys jaculiferus
Pufferfish	Amblyrhynchotes spinosissimus
Purple-headed emperor	Lethrinus lentjan
Queenfish	Scomberoides commersonianus
Razorfish	Centriscus scutatus
Red legged banana prawn	Penaeus indicus

Table 21 continued.

COMMON NAME	SCIENTIFIC NAME
Red spot king prawn	Penaeus longistylus
Reef stonefish	Synanceia verrucosa
Remora	Echeneis naucrates
Rigeback prawn	Sicyonia cristata
Ring-tailed surgeonfish	Acanthurus xanthopterus
Rosy prawn	Metapenaeopsis rosea
Sand bass	Psammoperca vaigiensis
Sand crab	Portunus pelagicus
Sardine	Sardinella sp.1
Scorpionfish	Apistops caloundra
Sea garfish	Hyporhamphus australis
Sea mullet	Mugil cephalus
Sea perch	Lutjanus sp.1
Seagrass	Cymodocea rotundata
Seagrass	Cymodocea serrulata
Seagrass	Halodule pinifolia
Seagrass	Halodule uninervis (thin)
Seagrass	Halodule uninervis (wide)
Seagrass	Halophila decipiens
Seagrass	Halophila ovalis
Seagrass	Halophila tricostata
Seagrass	Thalassia hemprichii
Seagrass	Zostera capricorni
Seahorses	Syngnathidae spp.
Seven-fingers tasselfish	Polydactylus heptadactylus
Shark	Carcharhinus sealei
Shark	Charcharhinus c.f. sorrah
Short-nosed garfish	Hyporhamphus quoyi
Shovelnose ray	Rhinobatus batillum
Shovelnose rays	Rhinobatus spp.
Sicklefish	Drepane punctata
Silver biddy	Gerres abbreviatus
Silver biddy	Gerres filamentosus
Silver biddy	Gerres oyeana
Silver biddy	Gerres poieti
Silver biddy	Gerres punctatus
Silver biddy	Gerres sp.1
Silver bream	Acanthopagrus australis
Silver jewfish	Nibea soldado
Sleepy cod	Oxyeleotris lineolatus
Slender queenfish	Scomberoides tol
Small-mouthed nannygai	Lutjanus erythropterus
Smoothshell prawn	Parapenaeopsis tenella
Smoth anglerfish	Tetrabrachium ocellatum
Snake-headed gudgeon	Ophiocara aporos
Snub-nosed dart	Trachinotus blochii
Snub-nosed garfish	Arrhamphus sclerolepis
Sole	Aesopia heterhinus
Sole	Dexilichthys muelleri
Sole	Synaptura setifer
Southern rough prawn	Trachypenaeus curvirostris
Southern velvet prawn	Metapenaeopsis palmensis
Spangled emperor	Lethrinus nebulosus

Table 21 continued.

COMMON NAME	SCIENTIFIC NAME
Spinefoot	Siganus canaliculatus
Spinefoot	Siganus fuscescens
Spinefoot	Siganus sp.1
Spotted grunter	Pomadasys opercularis
Spotted herring/sardine	Herklotsichthys koningsbergeri
Stars and stripes toadfish	Arothron hispidus
Striped catfish	Plotosus anguillaris
Swallowtail	Trachinotus russelli
Swimming crab	Portunus andersoni
Swimming crab	Portunus orbitosinus
Swimming crab	Thalamita parvidens
Swimming crab	Thalamita sima
Swimming crab	Thalamita sp.1
Swimming crab	Thalamita sp.2
Swimming crabs	Portunidae spp.
Thread-fin emperor	Lethrinus nematacanthus
Threadfin	Polydactylus multiradiatus
Threadfin	Polydactylus sp.1
Three-toothed jewfish	Otolithes ruber
Tiger prawn	Penaeus sp.
Toadfish	Chelonodon patoca
Toadfish	Sphaeroides laevigatus
Toadfish	Sphaeroides pleurostictus
Toadfish	Tetraodontidae sp.1
Toadfish	Tetraodontidae sp.2
Toadfish	Torquigener sp.1
Toadfish	Torquigener whitleyi
Tongue sole	Cynoglossus bilineatus
Tongue sole	Cynoglossus heterolepis
Tongue sole	Cynoglossus puncticeps
Tongue sole	Cynoglossus sp.1
Tongue sole	Paraplagusia guttata
Trevally	Carangidae sp.1
Trevally	Caranx sexfasciatus
Trevally	Caranx sp.1
Triple-tail	Lobotes surinamensis
Tripodfish	Triacanthus biaculeatus
Tripodfish	Trixiphichthys weberi
True endeavour prawn	Metapenaeus endeavouri
Trumpeter	Pelates quadrilineatus
Trumpeter	Terapon jarbua
Trumpeter	Terapon puta
Trumpeters	Teraponidae spp.
Velvetfish	Aploactinidae sp.1
Velvetfish	Xenaploactis sp.1
Waspfish	Hypodytes carinatus
Waspfish	Paracentropogon longispinis
Western king prawn	Penaeus latisulcatus
Western school prawn	Metapenaeus dalli
Whiting	Sillago spp.
Winter whiting	Sillago maculata
Wire netting cod	Epinephalus merra
Wolf herring	Chirocentrus dorab

Table 21 continued.

COMMON NAME	SCIENTIFIC NAME
Wrasse	Choerodon sp.1
Wrasse	Choerodon sp.2
Wrasse	Labridae sp.
Yellow-tailed damselfish	Pomacentrus sp.
York prawn	Metapenaeus bernettae
Zebra shark	Stegastoma fasciatum

APPENDIX 10

Assumptions used in estimating the weight and value of penaeid prawns on seagrass beds and mudflats in the Cairns Harbour and the resulting dollar values predicted by the model.

Data

Data used consisted of numbers of prawns of three species, Penaeus esculentus, Penaeus semisulcatus and Metapenaeus endeavouri. These species form the major proportion of the commercial catch and were 96% of the commercial prawns caught in Cairns Harbour beam trawl samples.

Numbers used were estimates of the numbers of prawns per hectare on seagrass beds from beam trawl samples taken at the time of the new moon each month or from mud flat samples in February and December 1988 (Appendix 2). Samples from seagrass were from four sites (two trawls at each), two sites within the lease site, one at Hills Creek and one at number 18 channel marker. Sex ratios used were those recorded for juvenile prawns sampled and measured.

Commercial Fishing Effort

To model prawn harvest a proportion of the total year's fishing effort was assigned to each month based on data from log books kept by east coast endorsed fishermen working in the northern sector of the fishery. No effort was assigned to January and February as a trawl fishery closure is effective in these months.

Recruitment

We assumed that all recruitment, growth and mortality parameters remain identical from year to year. All prawns from survey data were included in the simulation model for the first month (April). Following this, only prawns smaller than 10mm carapace length (C.L.) were considered to be newly settled and therefore added to the model. Prawns above this size were assumed to have already been residents on the seagrass bed from the previous month. All prawns were subjected to growth and natural mortality processes throughout the simulation. In addition when prawns reached a predetermined size they were subjected to fishing mortality. Catch values were calculated by summing the values of all prawns caught monthly. In any simulation, the total annual catch included prawns which survived the model from the previous year. This allowed a more realistic representation of the normal state of the fishery.

Growth

Prawn size data are carapace lengths (C.L.) in one millimetre size classes. Sex ratios, natural and fishing mortality were varied with each increment in size. Prices paid for prawns are size and species related. The prawns leaving the Cairns Harbour seagrass beds are assumed to leave at the same time for each size class at all places within the Harbour.

Sampling assumptions

In calculating density of prawns, all seagrass beds with a cover of greater than 10% were considered to have a similar carrying capacity. Mud flat prawn densities were calculated from mud flat/seagrass bed prawn number ratios recorded during this study. This ratio was assumed to be constant throughout the year. Average values of sampling gear efficiency were used to determine density of prawns and applied for all bottom types trawled. Other parameter estimates are:

Growth parameter estimates

Assuming Von Bertalanffy Growth model (1938):

Length at time t $= L_{inf}[1 - e^{-k(\text{time } t - t_o)}$

Metapenaeus endeavouri

	k	L_{inf}
Male	0.14	37mm C.L.
Female	0.16	45mm C.L.

Assumed similar to Penaeus esculentus from Kirkwood and Somers (1984).

Penaeus esculentus

	k	L_{inf}
Male	0.22	35mm C.L.
Female	0.22	43mm C.L.

From Penaeus esculentus Torres Strait tagging studies (QDPI).

Penaeus semisulcatus

	k	L_{inf}
Male	0.24	38mm C.L.
Female	0.10	60mm C.L.

From Penaeus semisulcatus data in Kirkwood and Somers (1984).

Length/weight relationship

Using Weight (g) = a x Length (C.L.in mm)^b

Metapenaeus endeavouri

	a	b
Male	0.0017	2.79
Female	0.0015	2.81

From measurements of Metapenaeus endeavouri at Northern Fisheries Research Centre (QDPI).

Penaeus esculentus

	a	b
Male	0.0024	2.72
Female	0.0026	2.67

From measurements of Penaeus esculentus at Northern Fisheries Research Centre (QDPI).

Penaeus semisulcatus

	a	b
Male	0.0017	2.81
Female	0.0021	2.73

From measurements of Penaeus semisulcatus at Sea Farm (Chris Robertson pers. comm., 1988).

Natural mortality (M)

The same values were used for all three species:

C.L. (mm)	M (monthly)
< 9	0.30
10 - 14	0.25
15 +	0.20

These values were largely obtained from penaeid averages from Garcia (1984).

Fishing mortality

The same values were used for all three species. We assumed no recruitment occurred until 26mm cl (under this size F=0). At 26mm C.L. there was knife-edge recruitment and F=0.2 for all sizes 26mm C.L. and larger. This sets fishing mortality equal to natural mortality which is usually the preferred exploitation rate.

Length/grading conversion and wholesale buying price

Metapenaeus endeavouri

C.L. (mm)	Grading	Price/kg
< 24	none	$ 0.00
24 - 24	31 - 40/lb	$ 0.00
25 - 29	21 - 30/lb	$ 7.00
30 - 38	10 - 20/lb	$ 9.00
39 +	< 10/lb	$ 15.25

Prices from Torres Seafood, Cairns, 26 May 1988.

Penaeus esculentus and Penaeus semisulcatus

C.L. (mm)	Grading	Price/kg
< 23	none	$ 0.00
23 - 24	31 - 40/lb	$ 0.00
25 - 29	21 - 30/lb	$ 10.50
30 - 38	10 - 20/lb	$ 15.80
39 +	< 10/lb	$ 19.40

Prices from G. Williams, Cairns, 26 May 1988.

Dollar value of prawns originating from Cairns Harbour seagrass and mudflats.

Table 22a. Cumulative and monthly catch values per hectare of the brown tiger prawn, Penaeus esculentus originating from Cairns Harbour seagrasses.

Monthly* Effort		Prawns Left	Sex R F/M	New Rec.	Deaths Nat.	Deaths Fish	Catch Value $ Cum.	Catch Value $ Increm.	Catch (kg)	Wt(g)/ Prawn	$/ Prawn	Mort. R. F/M
AP	0.07	5656	0.97	5656	1021	398	70.73	70.73	6.63	16.67	0.18	0.39
MA	0.10	4253	0.95	1508	1104	570	184.42	113.69	10.42	18.27	0.20	0.52
JU	0.05	4087	0.73	519	892	254	246.65	62.23	5.25	20.66	0.25	0.29
JU	0.07	3460	0.89	241	673	309	338.77	92.12	6.99	22.66	0.30	0.46
AU	0.13	2720	1.01	259	513	476	485.69	146.92	11.15	23.46	0.31	0.93
SE	0.06	1991	0.83	4100	1400	183	543.80	58.11	4.39	24.06	0.32	0.14
OC	0.07	4508	1.14	3559	1855	198	605.58	61.88	4.54	22.93	0.32	0.11
NO	0.05	6014	1.07	2413	1801	172	645.78	40.11	3.13	18.14	0.24	0.10
DE	0.01	6453	1.12	1906	1717	52	654.28	8.50	0.80	15.38	0.17	0.04
JA	NIL	6590	1.01	3010	2034	0	654.28		****	NO CATCH	****	
FE	NIL	7566	1.24	4220	2535	0	654.28		****	NO CATCH	****	
MA	0.39	9251	1.07	817	1715	2644	1232.96	578.68	47.83	18.10	0.22	1.55

Catch Total	(kg)	101.2	Price Average ($)	(kg)	12.20
	($)	1232.96		(each)	0.24
Deaths Natural		17259	Average Prawn Weight (g)		19.25
Fishing		5256	Carapace Length	(mm)	26.66
Yield/Recruit	(g)	3.59			
	($)	0.05			

* Monthly effort is expressed as a proportion of the total annual fishing effort.

Table 22b. Cumulative and monthly catch values per hectare of the grooved tiger prawn, <u>Penaeus</u> <u>semisulcatus</u> originating from Cairns Harbour seagrasses.

Monthly* Effort		Prawns Left	Sex R F/M	New Rec.	Deaths Nat.	Deaths Fish	Catch Value $ Cum.	Catch Value $ Increm.	Catch (kg)	Wt(g)/ Prawn	$/ Prawn	Mort. R. F/M
AP	0.07	21172	1.06	21172	2242	446	20.70	20.70	3.98	8.94	0.05	0.20
MA	0.10	9097	1.26	1548	1970	919	84.80	64.10	10.59	11.53	0.07	0.47
JU	0.05	7756	1.12	92	1421	503	152.44	67.63	7.65	15.21	0.14	0.36
JU	0.07	5923	1.13	0	1009	645	286.77	134.34	12.32	19.11	0.21	0.64
AU	0.13	4268	1.12	92	701	915	568.73	281.96	21.14	23.11	0.31	1.31
SE	0.06	2744	1.17	459	588	303	591.52	122.79	8.31	27.40	0.41	0.52
OC	0.07	2312	1.54	213	470	262	819.77	128.25	8.33	31.80	0.49	0.56
NO	0.05	1794	1.26	267	390	139	897.90	78.13	4.93	35.41	0.57	0.36
DE	0.01	1531	1.18	1445	649	24	912.76	14.86	0.87	36.95	0.63	0.04
JA	NIL	2304	1.09	4959	1728	0	912.76		****	NO CATCH	****	
FE	NIL	5535	1.08	12044	4297	0	912.76		****	NO CATCH	****	
MA	0.39	13282	1.21	3854	3618	1620	1240.97	328.21	25.11	15.51	0.21	0.45

Catch Total	(kg)	103.3	Price Average	(kg)	12.03
	($)	1240.97		(each)	0.22
Deaths Natural		19083	Average Prawn Weight	(g)	17.88
Fishing		5776	Carapace Length	(mm)	25.51
Yield/Recruit	(g)	2.24			
	($)	0.03			

* Monthly effort is expressed as a proportion of the total annual fishing effort.

Table 22c. Cumulative and monthly catch values per hectare of the endeavour prawn, _Metapenaeus endeavouri_ originating from Cairns Harbour seagrasses.

Monthly* Effort		Prawns Left	Sex R F/M	New Rec.	Deaths Nat.	Deaths Fish	Catch Value $ Cum.	Catch Value $ Increm.	Catch (kg)	Wt(g)/ Prawn	$/ Prawn	Mort. R. F/M
AP	0.07	15131	0.91	15131	1844	538	60.46	60.46	8.46	15.72	0.12	0.30
MA	0.10	7056	0.86	6276	2878	730	148.34	87.87	11.84	16.22	0.13	0.26
JU	0.05	9724	0.95	5514	3427	350	192.39	44.05	5.81	16.61	0.13	0.11
JU	0.07	11461	0.87	2180	2941	491	253.81	61.43	8.12	16.54	0.13	0.17
AU	0.13	10209	0.88	4490	3133	898	357.47	102.66	13.97	15.56	0.12	0.29
SE	0.06	10668	1.03	5002	3434	434	401.70	45.22	6.39	14.72	0.11	0.13
OC	0.07	11802	1.17	1784	2786	551	456.63	55.93	7.96	14.45	0.11	0.20
NO	0.05	10249	1.06	7267	3828	437	501.16	43.53	6.27	14.34	0.10	0.12
DE	0.01	13251	1.07	5865	4236	99	511.72	10.56	1.46	14.75	0.11	0.03
JA	NIL	14780	0.98	1989	3493	0	511.72		****	NO CATCH	****	
FE	NIL	13277	1.01	3131	3375	0	511.72		****	NO CATCH	****	
MA	0.39	13034	1.08	3280	2931	3981	993.49	481.78	64.34	16.17	0.13	1.36

Catch Total	(kg)	134.7	Price Average	(kg)	7.38
	($)	993.49		(each)	0.12
Deaths Natural		38305	Average Prawn Weight	(g)	15.82
Fishing		8511	Carapace Length	(mm)	25.47
Yield/Recruit	(g)	2.18			
	($)	0.02			

* Monthly effort is expressed as a proportion of the total annual fishing effort.

Table 22d. Summary for all species of prawns originating from Cairns Harbour seagrass beds.

Catch Total	(kg)		339.1
	($)		3467.42
Deaths Natural			74647
Fishing			19543
Yield/Recruit	(g)		2.49
	($)		0.03
Price Average	($)	(kg)	10.23
		(each)	0.18
Average Prawn Weight		(g)	17.35
C.L.		(mm)	25.80

Table 23a. Cumulative and monthly catch values per hectare of the brown tiger prawn, Penaeus esculentus originating from the intertidal mudflats of Cairns Harbour.

Monthly* Effort		Prawns Left	Sex R F/M	New Rec.	Deaths Nat.	Deaths Fish	Catch Value $ Cum.	Catch Value $ Increm.	Catch (kg)	Wt(g)/ Prawn	$/ Prawn	Mort. R. F/M
AP	0.07	2942	0.97	2942	530	207	36.77	36.77	3.45	16.67	0.18	0.40
MA	0.10	2224	0.95	784	573	297	96.13	59.35	5.43	18.29	0.20	0.52
JU	0.05	2137	0.74	270	463	132	128.63	32.50	2.74	20.69	0.25	0.29
JU	0.07	1812	0.90	125	350	161	176.92	48.29	3.66	22.71	0.30	0.46
AU	0.13	1426	1.01	135	267	248	253.76	76.84	5.83	23.49	0.31	0.94
SE	0.06	1046	0.84	2132	726	95	284.19	30.43	2.30	24.11	0.32	0.14
OC	0.07	2356	1.14	1851	965	104	317.00	32.82	2.40	23.09	0.32	0.11
NO	0.05	3138	1.07	1255	935	90	338.14	21.14	1.64	18.24	0.24	0.10
DE	0.01	3367	1.12	991	891	27	342.59	4.45	0.42	15.42	0.17	0.04
JA	NIL	3440	1.01	1565	1056	0	342.59	****	NO CATCH		****	
FE	NIL	3949	1.24	2194	1319	0	342.59	****	NO CATCH		****	
MA	0.39	4825	1.07	425	892	1378	645.38	302.79	24.98	18.13	0.22	1.55

Catch Total	(kg)	52.9	Price Average	(kg)	12.22
	($)	645.38		(each)	0.24
Deaths Natural		8967	Average Prawn Weight	(g)	19.29
Fishing		2740	Carapace Length	(mm)	26.68
Yield/Recruit	(g)	3.61			
	($)	0.05			

* Monthly effort is expressed as a proportion of the total annual fishing effort.

Table 23b. Cumulative and monthly catch values per hectare of the grooved tiger prawn, Penaeus semisulcatus originating from the intertidal mudflats of Cairns Harbour.

Monthly* Effort		Prawns Left	Sex R F/M	New Rec.	Deaths Nat.	Deaths Fish	Catch Value $ Cum.	Catch Value $ Increm.	Catch (kg)	Wt(g)/ Prawn	$/ Prawn	Mort. R. F/M
AP	0.07	1370	1.02	1370	109	22	0.92	0.92	0.19	8.74	0.05	0.20
MA	0.10	475	1.28	77	97	46	4.08	3.17	0.52	11.51	0.07	0.47
JU	0.05	410	1.15	5	71	26	7.76	3.67	0.40	15.63	0.15	0.37
JU	0.07	318	1.17	0	50	33	14.90	7.14	0.64	19.63	0.22	0.65
AU	0.13	235	1.18	5	35	47	29.48	14.58	1.09	23.35	0.32	1.32
SE	0.06	158	1.26	23	29	15	35.60	6.13	0.42	27.11	0.40	0.54
OC	0.07	136	1.64	11	23	13	42.29	6.68	0.43	32.12	0.50	0.59
NO	0.05	111	1.45	13	20	8	46.70	4.41	0.28	36.56	0.59	0.38
DE	0.01	97	1.42	72	33	1	47.54	0.84	0.05	37.86	0.65	0.04
JA	NIL	134	1.26	248	82	0	47.54	****	NO CATCH		****	
FE	NIL	300	1.15	602	214	0	47.54	****	NO CATCH		****	
MA	0.39	688	1.24	193	179	83	67.56	20.03	1.44	17.41	0.25	0.47

Catch Total	(kg)	5.5	Price Average	(kg)	12.38
	($)	67.56		(each)	0.24
Deaths Natural		944	Average Prawn Weight	(g)	18.65
Fishing		293	Carapace Length	(mm)	25.82
Yield/Recruit	(g)	2.09			
	($)	0.03			

* Monthly effort is expressed as a proportion of the total annual fishing effort.

Table 23c. Cumulative and monthly catch values per hectare of the endeavour prawn, *Metapenaeus endeavouri* originating from the intertidal mudflats of Cairns Harbour.

Monthly* Effort	Prawns Left	Sex R F/M	New Rec.	Deaths Nat.	Deaths Fish	Catch Value $ Cum.	Catch Value $ Increm.	Catch (kg)	Wt(g)/ Prawn	$/ Prawn	Mort. R. F/M
AP 0.07	3746	0.90	3746	147	43	4.92	4.92	0.69	15.81	0.12	0.30
MA 0.10	591	0.87	502	228	59	12.10	7.18	0.97	16.35	0.13	0.26
JU 0.05	806	0.96	441	272	28	15.70	3.60	0.47	16.67	0.13	0.11
JU 0.07	946	0.88	174	235	40	20.92	5.22	0.68	17.00	0.13	0.18
AU 0.13	846	0.89	359	249	74	29.57	8.64	1.17	15.86	0.12	0.30
SE 0.06	882	1.03	400	274	36	33.44	3.87	0.54	15.15	0.11	0.14
OC 0.07	973	1.17	143	222	45	38.18	4.74	0.67	14.86	0.11	0.21
NO 0.05	849	1.07	581	305	36	41.93	3.74	0.53	14.83	0.11	0.12
DE 0.01	1090	1.07	469	338	8	42.81	0.89	0.12	15.06	0.11	0.03
JA NIL	1213	0.99	159	279	0	42.81	****	NO CATCH		****	
FE NIL	1093	1.01	250	267	0	42.81	****	NO CATCH		****	
MA 0.39	1076	1.08	262	232	323	83.06	40.25	5.33	16.52	0.13	1.40

Catch Total	(kg)	11.2	Price Average	(kg)	7.44
	($)	83.06		(each)	0.13
Deaths Natural		3049	Average Prawn Weight	(g)	16.15
Fishing		692	Carapace Length	(mm)	25.64
Yield/Recruit	(g)	1.50			
	($)	0.02			

* Monthly effort is expressed as a proportion of the total annual fishing effort.

Table 23d. Summary for all species of prawns originating from the intertidal mudflats of Cairns Harbour.

Catch Total	(kg)		69.5
	($)		796.01
Deaths Natural			12960
Fishing			3725
Yield/Recruit	(g)		2.81
	($)		0.04
Price Average	($)	(kg)	11.46
		(each)	0.22
Average Prawn Weight		(g)	18.66
C.L.		(mm)	26.42

APPENDIX 11

Species of fish caught in beam trawls from Cairns Harbour, Bowen to Water Park Point and Mornington Island, and targeted species of fish found in Cairns Harbour and Trinity Inlet.

Table 24. Fish species caught in Cairns Harbour, Bowen to Water Park Point, and Mornington Island.

CAIRNS HARBOUR	BOWEN TO WATER PARK POINT	MORNINGTON ISLAND
AMBASSIDAE		
Ambassis nalua		
Ambassis telkara		
	APLOACTINIDAE	
	Aploactinidae sp.1	
	Xenaploactis sp.1	
APOGONIDAE	APOGONIDAE	APOGONIDAE
Apogon ellioti	Apogon brevicaudatus	Apogon rupellii
Apogon quadrifasciatus	Apogon ellioti	Cheilodipterus sp.1
Apogon sp.1	Apogon hartzfeldi	Rhabdamia sp.1
Foa brachygramma	Apogon nigripinnis	
	Apogon poecilopterus	
	Apogon spp.	
	Foa brachygramma	
	Fowleria c.f. variegata	
	Siphamia versicolor	
ATHERINIDAE	ATHERINIDAE	
Atherinomorus c.f. endrachtensis	Hypoatherina temminckii	
	Pranesus lacunosa	
	Pranesus ogilbyi	
	BLENNIDAE	
	Petroscirtes sp.1	
BOTHIDAE	BOTHIDAE	
Engyprosopon grandisquama	Arnoglossus waitei	
	Bothidae sp.1	
	Bothidae sp.2	
CALLIONYMIDAE	CALLIONYMIDAE	
Callionymus sp.1	Callionymus macdonaldi?	
Repomuscenus belcheri	Callionymus spp.	
	Repomuscenus belcheri	
	CARANGIDAE	
	Carangidae sp.1	
	Gnathanodon speciosus	
CENTRISCIDAE	CENTRISCIDAE	
Centriscus scutatus	Centriscus scutatus	
CENTROPOMIDAE	CENTROPOMIDAE	CENTROPOMIDAE
Psammoperca vaigiensis	Psammoperca vaigiensis	Psammoperca vaigiensis
CHAETODONTIDAE	CHAETODONTIDAE	CHAETODONTIDAE
Chaetodontidae sp.1	Parachaetodon ocellatus	Parachaetodon ocellatus
CLUPEIDAE	CLUPEIDAE	CLUPEIDAE
Anodontostoma chacunda	Spatelloides delicatulus	Hilsa sp.1
Escualosa thoracata		Spratelloides delicatulus
Herklotsichthys koningsbergeri		
Sardinella sp.1		

Table 24 continued.

CONGRIDAE	CONGRIDAE	
Conger labiatus	Conger labiatus	
CYNOGLOSSIDAE	CYNOGLOSSIDAE	
Cynoglossus puncticeps	Cynoglossus puncticeps	
Paraplagusia guttata	Paraplagusia guttata	
	DIODONTIDAE	
	Tragulichthys jaculiferus	
ENGRAULIDAE	ENGRAULIDAE	ENGRAULIDAE
Stolephorus devisi	Stolephorus sp.1	Engraulidae sp.
Stolephorus c.f. tysoni	Stolephorus sp.2	Stolephorus indicus
Stolephorus spp.		Stolephorus sp.
Thryssa hamiltonii		
Thryssa spp.		
EPHIPPIDAE		
Drepane punctata		
Zabidius novemaculeatus		
GERREIDAE	GERREIDAE	GERREIDAE
Gerres abbreviatus	Gerres sp.1	Gerres oyeana
Gerres filamentosus		Gerres sp.1
Gerres poieti		Gerres sp.2
Gerres sp.1		
GOBIIDAE	GOBIIDAE	GOBIIDAE
Amblygobius sp.1	Acentrogobius c.f. multifasciatus	Yongeichthys criniger
Glossogobius sp.1	Arenigobius sp.1	
Gobiidae spp.	Ctenogobius sp.1	
Rhinogobius sp.1	Gobiidae sp.3	
Yongeichthys criniger	c.f. Arenigobius sp.	
HAEMULIDAE		
Haemulidae sp.1		
Pomadasys kaakan		
Pomadasys maculatus		
Pomadasys opercularis		
Pomadasys sp.1		
HEMIRHAMPHIDAE	HEMIRHAMPHIDAE	
Arrhamphus sclerolepis	Hemirhampnidae sp.1	
Hyporhamphus australis	Hyporhamphus sp.1	
Hyporhamphus quoyi		
	LABRIDAE	LABRIDAE
	Choerodon sp.1	Choerodon sp.1
		Choerodon sp.2
		Labridae sp.

Table 24 continued.

LEIOGNATHIDAE	LEIOGNATHIDAE	LEIOGNATHIDAE
Gazza minuta	Leiognathus bindus	Leiognathus sp.1
Leiognathus bindus	Leiognathus leuciscus	Leiognathus sp.2
Leiognathus decorus	Leiognathus c.f. moretoniensis	
Leiognathus equulus	Leiognathus sp.1	
Leiognathus splendens		
Leiognathus spp.		
Secutor ruconius		
LETHRINIDAE	LETHRINIDAE	LETHRINIDAE
Lethrinus lentjan	Lethrinus nematacanthus	Lethrinus sp.1
Lethrinus sp.1		Lethrinus sp.2
LUTJANIDAE	LUTJANIDAE	
Lutjanus erythropterus	Lutjanus russelli	
Lutjanus fulviflammus		
Lutjanus russelli		
Lutjanus sp.1		
MONACANTHIDAE	MONACANTHIDAE	MONACANTHIDAE
Paramonacanthus sp.1	Chaetoderma penicilligera	Paramonacanthus sp.1
	Monacanthus chinensis	Pseudomonacanthus elongatus
	Pseudomonacanthus peronii	
	MUGILOIDIDAE	
	Parapercis cylindrica	
	Parapercis spp.	
	MULLIDAE	
	Upeneus c.f. tragula	
MURAENIDAE	MURAENIDAE	
Gymnothorax sp.1	Gymonthorax reticularis	
	NEMIPTERIDAE	
	Pentapodus sp.4	
	OSTRACIIDAE	
	Lactoria cornuta	
PARALICHTHYIDAE	PARALICHTHYIDAE	
Pseudorhombus elevatus	Pseudorhombus sp.1	
PLATYCEPHALIDAE	PLATYCEPHALIDAE	PLATYCEPHALIDAE
Cymbacephalus nematophthalmus	Cymbacephalus nematophthalmus	Cymbacephalus nematophthalmus
Inegocia isacanthus		Platycephalidae sp.1
Platycephalidae spp.		Suggrundus sp.1
Platycephalus indicus		
Suggrundus sp.1		
POLYNEMIDAE		
Polydactylus heptadactylus		
Polydactylus multiradiatus		
Polydactylus sp.1		
	SCARIDAE	
	Scarus sp.1	

Table 24 continued.

SCIAENIDAE Nibea soldado		
SCORPAENIDAE Paracentropogon longispinis	SCORPAENIDAE Apistops caloundra Hypodytes carinatus Paracentropogon longispinis	SCORPAENIDAE Paracentropogon longispinis
SERRANIDAE Centrogenys vaigiensis	SERRANIDAE Centrogenys vaigiensis	SERRANIDAE Centrogenys vaigiensis
SIGANIDAE Siganus canaliculatus Siganus fuscescens Siganus guttatus Siganus spinus Siganus spp.	SIGANIDAE Siganus fuscescens Siganus c.f. canaliculatus	SIGANIDAE Siganus canaliculatus Siganus fuscescens
SILLIGANIDAE Sillago sihama Sillago sp.1	SILLIGANIDAE Sillago sp.1 Sillago sp.2	SILLIGANIDAE Sillago sp.1 Sillago sp.3
SOLEIDAE Dexilichthys muelleri		
SPHYRAENIDAE Sphyraena jello		SPHYRAENIDAE Sphyraena flavicauda
SYNGNATHIDAE Bombonia spicifer	SYNGNATHIDAE Micrognathus sp? Syngnathidae sp.1	
	SYNODONTIDAE Synodus sageneus	
TERAPONIDAE Pelates quadrilineatus Terapon puta Teraponidae spp.	TERAPONIDAE Pelates quadrilineatus	TERAPONIDAE Pelates quadrilineatus Pelates sexlineatus Terapon puta
TETRABRACHIIDAE Tetrabrachium ocellatum		
TETRAODONTIDAE Amblyrhynchotes spinosissimus Arothron immaculatus Canthigaster margaritatus Chelonodon patoca Tetraodontidae sp.1 Tetraodontidae sp.2 Torquigener sp.1	TETRAODONTIDAE Arothron immaculatus Torquigener whitleyi	TETRAODONTIDAE Tetraodontidae sp.1
TRIACANTHIDAE Trixiphichthys weberi		

Table 25. Targeted bait species of fish found in Cairns Harbour and Trinity Inlet.

Herklotsichthys koningsbergeri	Spotted herring/sardine
Hemirhamphus far	Five-spot garfish
Hyporhamphus australis	Sea garfish
Mugil cephalus	Sea mullet
Mugil georgii	Creek mullet
Valamugil buchanani	Mullet
Valamugil cunnesius	Mullet

Table 26. Targeted traditional species of fish found in Cairns Harbour and Trinity Inlet.

Mugil cephalus	Sea mullet
Siganus guttatus	Golden-lined spinefoot
Siganus spinus	Black spinefoot

Table 27. Targeted commercial species of fish found in Cairns Harbour and Trinity Inlet.

Acanthopagrus australis	Silver Bream
Acanthopagrus berda	Black Bream
Arrhamphus sclerolepis	Snub-nosed garfish
Carcharhinus sealei	Shark
Hemirhamphus far	Five-spot garfish
Hyporhamphus australis	Sea garfish
Hyporhamphus dussumieri	Dussumier's garfish
Hyporhamphus quoyi	Short-nosed garfish
Lates calcarifer	Barramundi
Lethrinus nebulosus	Spangled emperor
Lutjanus argentimaculatus	Mangrove Jack
Lutjanus erythropterus	Small-mouthed Nannygai
Lutjanus russelli	Fingermark
Polydactylus sheridani	King Salmon
Protonibea diacanthus	Black Jewfish
Rhynchorhamphus georgi	Long-nosed garfish
Scoliodon palasorrah	Little Blue Shark
Scomberoides commersonianus	Queenfish
Scomberomorus commerson	Mackerel
Scomberomorus queenslandicus	Mackerel
Scomberomorus semifasciatus	Mackerel
Valamugil seheli	Blue-tailed mullet
Zenarchopterus buffonis	Buffon's garfish

Table 28. Targeted recreational species of fish found in Cairns Harbour and Trinity Inlet.

Acanthopagrus australis	Silver bream
Acanthopagrus berda	Black bream
Agrioposphyraena barracuda	Giant barracuda
Caranx sexfasciatus	Great trevally
Drepana punctata	Sicklefish
Eleutheronema tetradacylum	Blue salmon
Epinephalus merra	Wire netting cod
Epinephalus tauvina	Estuary cod
Gnathanodon speciosus	Golden trevally
Lates calcarifer	Barramundi
Lethrinus nebulosus	Spangled emperor
Lobotes surinamensis	Trippletail
Lutjanus argentimaculatus	Mangrove jack
Lutjanus erythropterus	Small-mouthed nannygai
Lutjanus russelli	Fingermark
Nibea soldado	Silver jewfish
Platycephalus fuscus	Dusky flathead
Platycephalus indicus	Bar-tailed flathead
Plectorhincus gibbosus	Brown sweetlip
Polydactylus sheridani	King salmon
Pomadasys kaakan	Grunter
Pomadasys opercularis	Spotted grunter
Protonibea diacanthus	Black jewfish
Scomberoides commersonianus	Queenfish
Scomberomorus commerson	Mackerel
Scomberomorus queenslandicus	Mackerel
Scomberomorus semifasciatus	Mackerel
Sillago maculata	Winter whiting
Sillago sihama	Northern whiting
Sphyraena jello	Pickhandle barracuda

Table 29. Targeted aquarium species of fish found in Cairns Harbour and Trinity Inlet.

Aetobatus narinari	Eagle ray
Aetomyleus sp.	Frog ray
Alectis indica	Diamond trevally
Arius c.f. argyropleuron	Fork-tailed catfish
Arius proximus	Fork-tailed catfish
Arius thalassinus	Fork-tailed catfish
Arius sp.1	Fork-tailed catfish
Atelomycterus macleayi	Cat shark
Bombonia spicifer	Pipefish
Callionymus sp.1	Dragonet
Centriscus scutatus	Razorfish
Centrogenys vaigiensis	False scorpionfish
Chaetodontidae sp.1	Butterflyfish
Dasyatis sephen	Cowtail ray
Drepane punctata	Sicklefish
Epinephalus tauvina	Estuarine cod
Epinephalus sp.	Groupers
Gymnothorax favagineus	Moray eel
Gymnothorax sp.1	Moray eel
Halophryne diemensis	Banded frogfish
Heniochus acuminatus	Feather-fin bullfish
Himantura granulata	Mangrove ray
Himantura uarnak	Leopard ray
Lates calcarifer	Barramundi
Lutjanus argentimaculatus	Mangrove jack
Monacanthus chinensis	Fan-bellied leatherjacket
Monodactylus argenteus	Diamond butterfish
Paracentropogon longispinis	Waspfish
Paramonacanthus sp.1	Leatherjacket
Periophthalmus koelreuteri	Mud-skipper
Platax tiera	Batfish
Plotosus anguillaris	Striped catfish
Psammoperca vaigiensis	Sand bass
Pterois volitans	Butterfly cod
Repomuscenus belcheri	Dragonet
Rhinobatus batillum	Shovelnose ray
Rhinobatus spp.	Shovelnose rays
Siganus guttatus	Golden-lined spinefoot
Stegasoma fasciatum	Zebra shark
Synanceia horrida	Coastal stonefish
Synanceia verrucosa	Reef stonefish
Syngnathidae spp.	Seahorses
Tetrabrachium ocellatum	Smooth anglerfish
Toxotes chatareus	Archerfish
Zabidius novemaculeatus	Batfish

N.B. Some species (e g. rays) targeted as juveniles only.

APPENDIX 12

Fisheries habitat modification and restoration

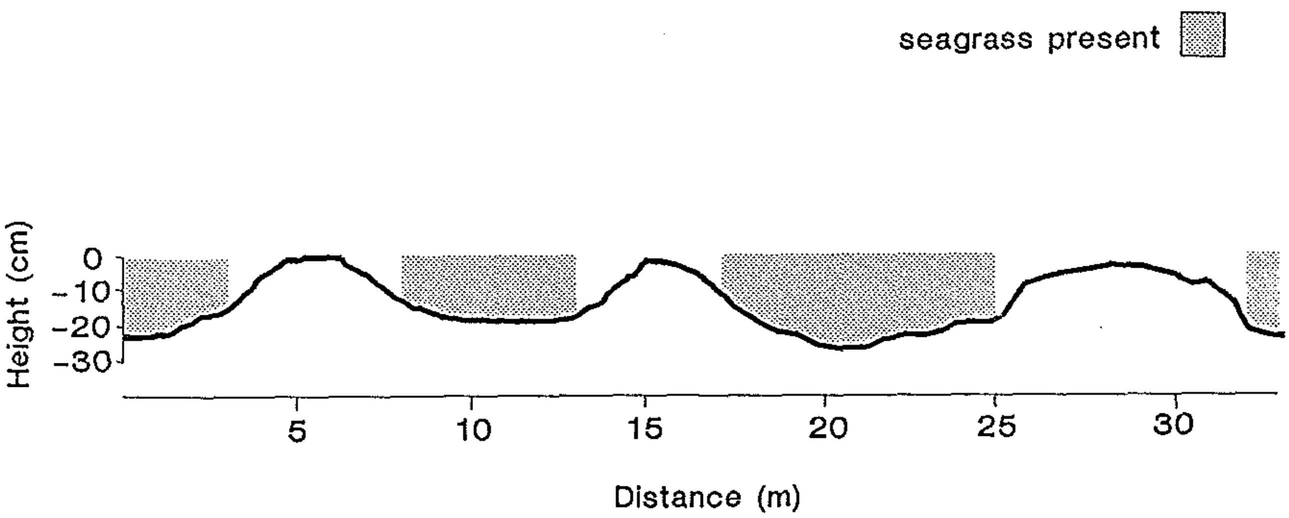


Figure 31. Representative mudflat profile showing effect of topographic depressions on seagrass distribution in the upper intertidal region.

Seagrass transplantation experiments using sandbag retainer walls in Trinity Bay mudflat.

Seagrass transplantation experiments in an unnatural depression in Trinity Bay mudflat.

The tetrahedron - shaped module to be used in the artificial reef program.