Port of Cape Flattery Benthic Monitoring Baseline Survey

DPI QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES

QUEENSLAND GOVERNMENT

SEA RESEARCH

PORTS CORPORATION QUEENSLAND

• Wet-season (February) 1996

Ayling, A.M., Roelofs, A.J., McKenzie, L.J. and Lee Long, W.J.

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Cover Image
Aerial photograph of the Port of Cape Flattery.

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RESULTS

1 Approximately 265 ha of coral reef was recognised within the Cape Flattery port limits, divided into inshore reefs and fringing reefs. All but about 40 ha of this was algal dominated reef flat habitat. The reefs were narrow and shallow, with the inshore reefs extending to a maximum depth of between 6-10 m, and the fringing reefs to only 3-5 m.

2 The reef slope of both reef types supported rich coral communities (45-50% cover), typical of fringing and inshore reefs in the northern and central GBR.

3 Inshore reefs were dominated by acroporid corals, both *Acropora* spp and *Montipora* spp., while fringing reefs supported moderate acroporid cover, as well as substantial cover of faviids, poritids, *Turbinaria* spp. and soft corals.

4 Both reef types were moderately diverse with a total of 114 species of scleractinian coral recorded.

5 Fringing reefs in the GBR region are subject to very high natural levels of turbidity caused by the resuspension of coastal sediments by the prevailing SE winds and the corals are able to cope with these conditions. As a result it is unlikely that any port or land based activities in the Port of Cape Flattery area that affect siltation regimes will have an adverse effect on these coral reefs.

6 These coral reefs were typical of other coastal reef areas and can be expected to show substantial natural fluctuations on the order of several times a decade. While a suitable monitoring program could detect a change of 20% in total coral cover it may be difficult to separate these natural fluctuations from those potentially resulting from port activities.

7 Subtidal rock reefs fronting Cape Flattery itself were narrow and shallow. These reefs were algal dominated, with very low cover of hard corals, and supported high densities of grazing echinoids.

8 1111 $\pm$200 ha of seagrass habitats were surveyed between Cape Flattery and Lookout Point.

9 Eight species of seagrasses, from two Families, were found within the survey area.

10 Three types of seagrass meadow, representing three different habitats, were identified;

- a predominantly *Halodule/Thalassia* meadow in the sandy intertidal area bordered by the shoreline and fringing coral reef.
- a small isolated high biomass *Cymodocea/Thalassia* meadow at the mouth of Crystal Creek in sand/mud sediment.

- a large *Halodule/Halophila* meadow in muddy sediment offshore from the fringing reef in deeper water.

11 Mean above-ground seagrass biomass for the seagrass habitat was 9.79 $\pm$1.32 g dry wt m^{-2} (all sites and species pooled). *Thalassia hemprichii* had the highest above-ground seagrass biomass on average and *Halodule pinifolia* the least. *Halophila ovalis* was the most widely distributed species followed by *Halodule uninervis* (wide-leaf) and *Halodule uninervis* (thin-leaf). *Syringodium isoetifolium* was found only in small isolated patches.

12 31 % of sites where seagrass was present were located above LAT (lowest astronomical tide). No seagrass was found deeper than 7.5 m below Mean Sea Level (MSL). *Cymodocea* spp and *Thalassia hemprichii* were only found in shallow areas (<1.6 m below MSL).

13 Only 1 of the seagrass meadows between Cape Flattery and Lookout Point was considered suitable for monitoring change in above-ground seagrass biomass.

14 The rocky intertidal habitat around the edge of Cape Flattery covers only about 5 ha. This habitat is dominated by several species of barnacles and the common rock oyster *Saccostrea cuccullata*. It also supports several grazing gastropods and chitons, and a few predatory gastropods.

15 A cost effective monitoring program for the rocky intertidal habitat could detect changes of between 11 and 30% in the density of the major organisms with a power of 80%.

16 Mangrove stands, primarily *Rhizophora* spp., occur at both the north and south ends of Flattery Port Beach with a combined area of about 90 ha.

ISSUES

1. Fringing reefs are an important habitat at Cape Flattery, with 45% of the coast line within port limits supporting coral reefs. These reefs are apparently healthy and comparable to those in other coastal areas of the Great Barrier Reef (GBR). There is considerable concern among reef management agencies that fringing reefs in general are being degraded due to human effects on coastal catchments. Natural fluctuations in the coral cover of fringing reefs are substantial and make it difficult to determine the long term trends that may result from anthropogenic impacts, or from the wider effects of coastal water mass changes, without a monitoring program that extends over several decades.

2. Studies and case histories in other coral reef areas suggest that the coral reef habitat may be impacted by oil or diesel spills. However, overseas experience may not be a good guide to the reaction of GBR fringing reefs which are characterised by supporting unusually silt tolerant and low light tolerant corals.

3. The area of seagrass mapped in 1984 was 302 ha less than the present survey, probably because the former survey did not sample the reef flat

meadow. The position, shape and size of the meadows described in the 1984 survey were similar to the two offshore *Halodule/Halophila* meadows described in the present survey. Seagrass densities appear similar between the two surveys. although no statistical comparisons were possible due to different sampling methods.

4. Evidence from dugong feeding trails indicates these seagrass meadows are also important feeding habitat for dugong. The Cape Flattery seagrass habitats are considered a significant component of the regionally important dugong habitat within this section of the Great Barrier Reef World Heritage Area.

5. *Thalassia hemprichii* was the dominant species on the fringing reef platform between Cape Flattery and Lookout Point. *Thalassia hemprichii* is not common at other coastal localities in Queensland as it is more common on coral reef platforms. The influence of sediment type and nutrient availability on seagrass communities at Cape Flattery fringing reefs would be invaluable in understanding the status and assessing future impacts on this habitat.

6. The close proximity of sand mining operations to the seagrass habitats of Cape Flattery and the regular maritime use of the port warrants consideration of monitoring of changes in water quality in this region. The inshore areas of seagrass described in this study are particularly vulnerable to changes in water quality through their potentially higher degree of exposure to pollutants, than subtidal communities.

7. Due to its proximity to the main loading wharf, the low diversity, and relatively stable, rocky intertidal is probably the habitat most likely to receive an impact resulting from activities at the port (eg. shipping accident resulting in an oil spill). However, this is also the habitat in which ongoing monitoring would be most powerful and cost effective. It is also arguable that the effects of an oil spill would be short lived in this high energy habitat and recolonisation of any damaged areas would be relatively rapid.

8. Mangroves are probably the marine habitat most at risk of being seriously and long-term affected by port-associated oil and diesel spills. Any spill from either the main export jetty or the service wharf would be carried north by the prevailing southeasterly conditions and deposited in the mangrove stands that line about 40% of the coast between Cape Flattery and Lookout Point.

9. The present survey represents the first intensive study of marine communities for the Port of Cape Flattery and provides a baseline data set on which a monitoring program could be based to investigate changes in reef community structure, seagrass biomass and distribution, and rocky intertidal community structure.

10. Because of the crocodile attack experienced by one of the field workers during this study it is recommended that any monitoring program established in the Cape Flattery area should not utilise any methods that require extensive time spent in the water.

↳ 1. Introduction

1.1. Consultancy Brief

The Ports Corporation of Queensland (PCQ) is the port authority for the Port of Cape Flattery. The Port of Cape Flattery was developed specifically to facilitate exports of silica sand from the Cape Flattery Silica Mine. The port is operated on a day-to-day basis by Cape Flattery Silica Mines Pty Ltd. As part of its strategic planning process PCQ has developed an Environmental Management Plan (EMP) for the port. As part of this EMP Sea Research and the Queensland Department of Primary Industries (QDPI) Northern Fisheries Centre (NFC) were asked to undertake a survey of the biological communities found within Cape Flattery port limits. This survey had the aim of establishing baseline data to help measure any future changes in the biological communities that may result from the impacts of port operations or from future port development.

The major objectives of the study were originally set as:

❶ *To accurately map and describe, including species composition and community structure, the main intertidal and subtidal communities within the Cape Flattery port limits.*

❷ *Establish a quantitative summer (wet-season) and winter (dry-season) baseline for these communities within Cape Flattery port limits using parameters suitable for future quantitative monitoring.*

❸ *Determine the most suitable habitats for future monitoring programs, establish permanent monitoring sites within these communities which can be used for future monitoring, and where appropriate develop a Geographic Information System (GIS) for mapping and data display and interpretation.*

❹ *Recommend a future monitoring strategy and sampling design which is statistically defensible, including the levels of significance and assurance that can be achieved from the proposed monitoring, for each main community.*

The results of this monitoring will help identify any possible detrimental effects of port and mine operations and developments on benthic communities and assist in formulating management measures for the port and adjacent silica sand mine.

1.2. Site Description

Cape Flattery is located 200 kilometres north of Cairns on the Queensland east coast. The Cape Flattery port limits enclose an area of approximately 150 km^2 of marine habitat and include over 35 km of coastline between latitude 14° 50' S (Lookout Point) and 15° 00' S. The area has two main creeks, Crystal Creek and Blackwater Creek, in a catchment area of approximately 114 km^2 (Ports Corporation Queensland 1995).

The regions' climate is tropical and characterised by hot (wet) summers and warm (dry) winters. The catchment area receives a mean annual rainfall of 1535 mm, of which 70% falls in the four month period from January to April. Average maximum temperatures for the region range from 31.4°C in December/January and 25.4°C in July (pers. comm. Bureau of Meteorology, Brisbane, 1996). Prevailing wind patterns are typical for this section of the Queensland coast with strong south to south-easterly winds dominating the dry-season months and generally lighter northerly winds prevalent during the wet-season.

Silica sand, extracted from the nearby Cape Bedford - Cape Flattery dune-field, is the ports' only export at present. The mine is owned and operated by Cape Flattery Silica Mines Pty Ltd, which is a subsidiary of Mitsubishi Corporation of Japan. The silica sand mine is an open cut mine. Mined sand is transported to a processing mill and ultimately to the main export jetty on Cape Flattery via conveyor. Coal from the Laura coal fields has also been identified as a potential future export for the port. There is also a service wharf where line boats are moored and general cargo and petroleum for the mine are imported.

1.3. Habitat Types

Using aerial photographs, local knowledge, and preliminary reconnaissance the major community types within the port area were established as:

1. **Fringing and inshore coral reefs**. These include Four Foot Rock (GBRMPA ID no. 14-130), Decapolis Reef (ID no.14-131), both SE of Lookout Point, and several small fringing reef patches on the north side of Cape Flattery (ID no. 14-136 a & b). There is also good fringing reef development along the 12 km long Flattery Port Beach between Cape Flattery and Lookout Point, although this area lacks formal GBRMPA identification.

2. **Fringing rock reefs**. This distinctive inshore habitat type supports some corals but has no true reef structure. The Cape Flattery headland includes several km length of this habitat.

3. **Seagrass meadows**. The shallow shore off Flattery Port Beach supports intertidal and subtidal seagrass meadows.

4. **Subtidal sand and mud substratum**. The deeper subtidal sections within port limits support significant soft bottom communities. Although this habitat type makes up about 87% of the total area within port limits, at the suggestion of PCQ no surveys were carried out in this habitat beyond the area covered by the sub-tidal seagrass meadow.

5. **Intertidal rocky shore**. There is approximately 4 km of rocky shore on the eastern side of Cape Flattery.

6. **Intertidal sandy shore**. There are extensive silica sand beaches between Lookout Point and Crystal Creek, on the north face of Cape Flattery, and south of the main export jetty. No surveys were carried out in this relatively biologically simple habitat.

7. **Mangrove forests**. There are narrow fringes of mangroves at the head of the shoreline immediately north of Cape Flattery near the service wharf, and along the northern third of Flattery Port Beach.

The approximate area of each of these marine habitats within port limits is shown in Table 1.

1.4. Scope of this Report

The first baseline survey was carried out in February 1996 during the wet-season. A team from the Queensland Department of Primary Industries (QDPI) was subcontracted by Sea Research to assist with the seagrass meadow surveys and help during this first field survey was provided by A.J. Roelofs. This baseline survey was terminated when near completion due to an attack by a saltwater crocodile on one of the observers (A.M. Ayling) while surveying coral communities on a fringing reef near the service wharf. However, sufficient information had been gathered to complete the requirements of the first baseline and this report presents the results of this wet-season survey and makes suggestions regarding the composition, design, and possible future of any long-term monitoring program.

The report has been divided into three sections:

- Subtidal Coral Reefs and Rocky Reefs: This first section covers the subtidal coral and rocky reefs found within port limits.

- Seagrass Meadows: This section covers the seagrass meadows located within port limits.

- Intertidal Habitats: The third section briefly covers the intertidal habitats within port limits, including rocky shores and mangrove forests.

↳ 2. Subtidal Coral and Rocky Reefs

2.1. Methods

Field work for all surveys was conducted while the survey team was based at the Lizard Island Research Station on Lizard Island. The team commuted daily to the Cape Flattery area by fast boat, a round trip of about 70 km. All coral and rocky reef surveys were carried out using scuba gear.

Line intersect transects 20 m long were used as the basic unit for surveying subtidal benthic communities in both the coral reef habitats and on the rocky reefs. This technique has been used by many previous surveys on the GBR (Mapstone *et al*. 1989, Ayling and Ayling 1991a, Van Woesik 1992) and produces percentage cover data that are comparable to those from the Australian Institute of Marine Science (AIMS) long-term monitoring program. At each survey site five haphazardly positioned 20 m transects were recorded. Transects were positioned parallel to the shore line and were restricted to an approximately 50 m square area in the coral dominated parts of the reef, beneath the algal fringe where present (Ayling and Ayling 1996a). Each transect was marked by a 20 m fibreglass tape, and the length of intersection with all benthic organisms beneath the tape measured to the nearest cm. Organisms recorded were: all hard corals to at least generic level and including growth form where appropriate; soft corals and gorgonians; turfing algae; macroalgae; Millepora corals; ascidians; hydroids.

The line intersect transect technique was chosen in preference to video transects such as used in the AIMS long term monitoring program because it was more appropriate in the very low water visibility conditions encountered in this area (less than a metre on the fringing reefs). This technique is also not dependent on temperamental underwater video gear and does not require time consuming and costly lab analysis to extract percentage cover data.

Five coral reef sites were surveyed on inshore reefs: three on Decapolis Reef and two on Four Foot Rock. An additional five sites were surveyed on coastal fringing reefs: three on the fringing reefs immediately west of Cape Flattery near the service wharf and two on the fringing reef off Flattery Port Beach. Five sites were also surveyed on the rocky reefs of the Cape Flattery headland. The position of all sites was recorded using a portable GPS with an average error of approximately 40 m (Appendix 1).

A species list of all hard coral species seen during the transect surveys at each site was recorded. This list was expanded during a 30 min haphazard swim covering the depth range present in each site.

On the rocky reefs, where echinoids were common, their numbers were recorded in 20 x 1 m strip transects centred on each coral transect.

2.2. Results

As mentioned above, coral reefs in the port area include both inshore reefs and coastal fringing reefs. The inshore reefs are Decapolis Reef (GBRMPA ID no. 14-131) measuring approximately 850 x 650 m, and Four Foot Rock (ID no. 14-130) that is only around 50 m across (Figure 2). The total area of inshore reef within port limits is about 60 ha (Table 1). Both these reefs fall to a silty bottom at depths of 6-10 m below AHD (Australian Height Datum - approximately the level of the lowest spring tide). Narrow coastal fringing reefs front part of the north-facing portion of Cape Flattery itself (ID no. 14-136 a & b), and much of the east-facing part of Flattery Port Beach. A total length of about 12.3 km of fringing reef occurs within port limits, with an overall area of about 265 ha, of which only about 25 ha is coral dominated reef slope (Figure 2). The outer edge of these fringing reefs reaches the sand in a depth of 3-5 m below AHD. On the eastern face of Cape Flattery there is about 4.3 km length of rocky reef. This rocky reef is also relatively narrow, falling quickly to a flat sandy bottom in only 2-4 m depth, and only covering an area of about 11 ha.

As mentioned above, these reefs were mostly narrow and very shallow. All three reef types were dominated by macro-algal forests (primarily *Sargassum* spp.) in the upper 1-2 m below low tide level. On the rock reefs algal domination continued for the entire depth range of the reef, but on the inshore and fringing reefs the portions of the reef below 1-2 m depth were coral dominated. All the quantitative surveys were made in the lower, coral dominated, sections of these reefs, while on the rocky reefs the surveys were also made on the lower slopes, although these were algal dominated (Table 2).

There were significant differences in the abundance of all the benthic groups analysed both among habitats (inshore reefs, fringing reefs and rocky reefs), and among sites within each habitat (Table 3, Figure 3). The rocky reefs were dominated by *Sargassum* spp. algal forests (over 40% cover) and turfing algae (16.5% cover), but algal cover was significantly lower on the inshore reefs and fringing reefs (14-19% cover) (Figure 3, Table 2). Sponges were moderately common on fringing reefs (3.3% cover) but were rare on inshore reefs and rocky reefs (Figure 3). Hard corals were similarly abundant on both the inshore reefs and the fringing reefs with almost 50% cover, but were significantly lower on the rocky reefs with only 5% cover (Figure 3). Soft corals were common on fringing reefs with 12.4% cover but were much less abundant on inshore and rocky reefs.

Hard coral communities on the inshore reefs were dominated by acroporid corals (41% cover), primarily explanate *Montipora* spp. and corymbose plate *Acropora* spp. Of the other coral groups only fungiids and pocilloporids covered more than 1% of the substratum in this habitat (Table 2). On the fringing reefs a number of coral groups were important, including staghorn *Acropora* spp. (9.5%), explanate *Montipora* spp. (4.2%), poritid corals (4.3%), faviids (11.6%), *Turbinaria* spp (3.6%), pocilloporids (2%), agariciids (2%) and *Merulina ampliata* (1.4%). The rocky reef coral community was depauperate with only *Turbinaria* spp. (2.2%) and acroporids (1.2%) covering more than 1% of the substratum (Table 2).

Hard coral diversity was similar for both the inshore and fringing reef communities with 92 and 85 species respectively being recorded (Table 4). In contrast only 22 species were recorded from the algal dominated rocky reef habitat. The species from all three habitats were either widely distributed in the GBR region or else were common on other fringing reefs (Veron 1986, 1987; Ayling and Ayling 1995).

The rocky reefs supported large numbers of grazing echinoids, primarily the greenish spined species *Heterocentrotus trigonarius* which was recorded at mean densities of 1.9 (s.d. 2.5) per sq m, along with the occasional *Echinothrix diadema*. The former species was recorded at densities of over 200 per 20 x 1 m strip transect in some of the Cape Flattery sites. Echinoids were not a feature on the inshore and fringing reefs surveyed.

2.3. Power of a Coral Reef Monitoring Program

The pilot/baseline study data were used to make an estimate of the power of different coral reef monitoring designs for the Port of Cape Flattery area. The variability in hard coral cover among transects within each site, and among sites (range of site means 27-62%), was unusually high on the fringing and inshore reefs in this area and this had a detrimental effect on power. Power calculations were made using the effect size index (f) of Cohen (1988). Assuming a type 1 error of 0.1 and using a design with 20 sites of 5 random transects each, the power to detect a 20% change in total hard coral cover between the baseline and any subsequent survey would be 38%. Using this design, which would be about the maximum size possible from a practical viewpoint, the minimum change in coral cover that could be detected with 80% power would be 38%. A total of 68 sites would be needed to detect a 20% change with 80% power. The 20 site design would take about 5 days of field work to survey, whereas 68 sites would take a prohibitive 17 days.

However, if permanently marked transects were used the power to detect change would be much higher and a design incorporating 20 sites with 5 permanent transects per site would be adequate to detect a 20% change in total coral cover with 80% power (Mapstone *et al*. 1989, Ayling and Ayling 1991b).

2.4. Discussion.

Inshore and fringing coral reefs are an important habitat within the Cape Flattery port limits. Almost half of the shoreline within port limits is fronted by fringing reefs in addition to the approximately 60 ha of inshore reef (Decapolis and Four Foot Rock). These coral reefs are similar to inshore and fringing reefs in other regions of the GBR (Ayling and Ayling 1996a). All GBR fringing reef areas are algal dominated in shallow water, and most support 50% or more hard coral cover on the reef slope between 2-5 m below AHD. The inshore reefs are typical of other reefs in these categories for which data are available in that acroporid corals account for over 80% of coral cover (Ayling 1996a), whereas the Cape Flattery fringing reefs have a coral community composition characteristic of more silty fringing reef areas, with acroporids still dominant, but with faviids, *Turbinaria* spp. and poritids between them accounting for over 40% of coral cover (Ayling 1996a).

Coral diversity on the Cape Flattery coral reefs was similar to that measured using the same technique on 17 other fringing reef areas in the Cairns section of the GBR Marine Park (Ayling and Ayling 1995). On the Cape Flattery fringing reefs the presence of species such as *Moselya latistellata* and *Duncanopsammia axifuga* are also typical of very silty reef areas.

The subtidal rocky reefs on Cape Flattery itself are typical of rock reefs in other tropical coastal areas such as Cape Tribulation, Magnetic Island and Cape

Cleveland (A.M. Ayling personal observations). All such areas are algal dominated with low cover of hard corals and large numbers of grazing echinoids. The major impacts likely to be experienced by these reef areas are wave surge from cyclones and other strong wind episodes, coral bleaching caused by high water temperatures during calm summer periods, and freshwater inundation caused by heavy rain associated with cyclones or during the wet-season . Even a moderate strong wind episode with sustained wind speeds of around 40 knots can cause substantial damage to fringing reef coral communities leading to a 40% reduction in coral cover (Ayling and Ayling 1991a). Severe cyclonic conditions can completely devastate coral reefs (Done *et al*. 1991). Coral bleaching, which results when coral colonies expel their zooxanthellae when water temperatures exceed about 31°C, can cause considerable coral death in some cases (Ayling and Ayling 1991a, Harriot 1985). Freshwater inundation may cause complete coral death in the upper 3-5 m and partial death down to 8 m or so (Van Woesik 1992, A.M. Ayling personal observation)

There are also several possible impacts associated with port activities that may affect these fringing, inshore and rocky reefs. Siltation regimes may be affected by port activities or by associated land use in the catchment area. There have been a number of previous studies that have looked at the effect of siltation changes on GBR fringing reefs. These have included a long term study of the effects of sediment run-off from road construction on the Cape Tribulation fringing reefs (Ayling and Ayling 1991a, 1996b), and an intensive but relatively short term study of the effects of dredging over half a million cubic metres of spoil from Platypus Channel, leading to the Port of Townsville (Kaly *et al*. 1993). In neither case did the apparent increase in siltation levels have any measurable effect on coral cover on the adjacent fringing reefs. Fringing reefs in the GBR region are subject to very high natural levels of turbidity caused by the resuspension of coastal sediments by the prevailing SE winds and the corals are able to cope with these conditions. As a result it is unlikely that any port or land based activities in the Port of Cape Flattery area that affect siltation regimes will have an adverse effect on these coral reefs.

The other major possible impact likely to result from activities in the port area is spillage of oil or diesel. Although there have been no studies to date of the effects of a major oil spill on GBR fringing reefs, experience overseas suggests that such an incident would only have a moderate effect in the high energy fringing reef environment (Jernelov and Linden 1981, Jackson *et al* 1989).

In summary the rich inshore and fringing reefs present in the Port of Cape Flattery area are likely to undergo major natural fluctuations in coral cover on the scale of several times a decade (Ayling and Ayling 1991a). It is unlikely that changes caused by port impacts will be as substantial as these natural fluctuations. While it would be possible to detect changes in total coral cover in the order of 20% with a cost-effective annual monitoring program using permanent transects, it is doubtful that such a program could reliably separate natural change from any port induced effects.

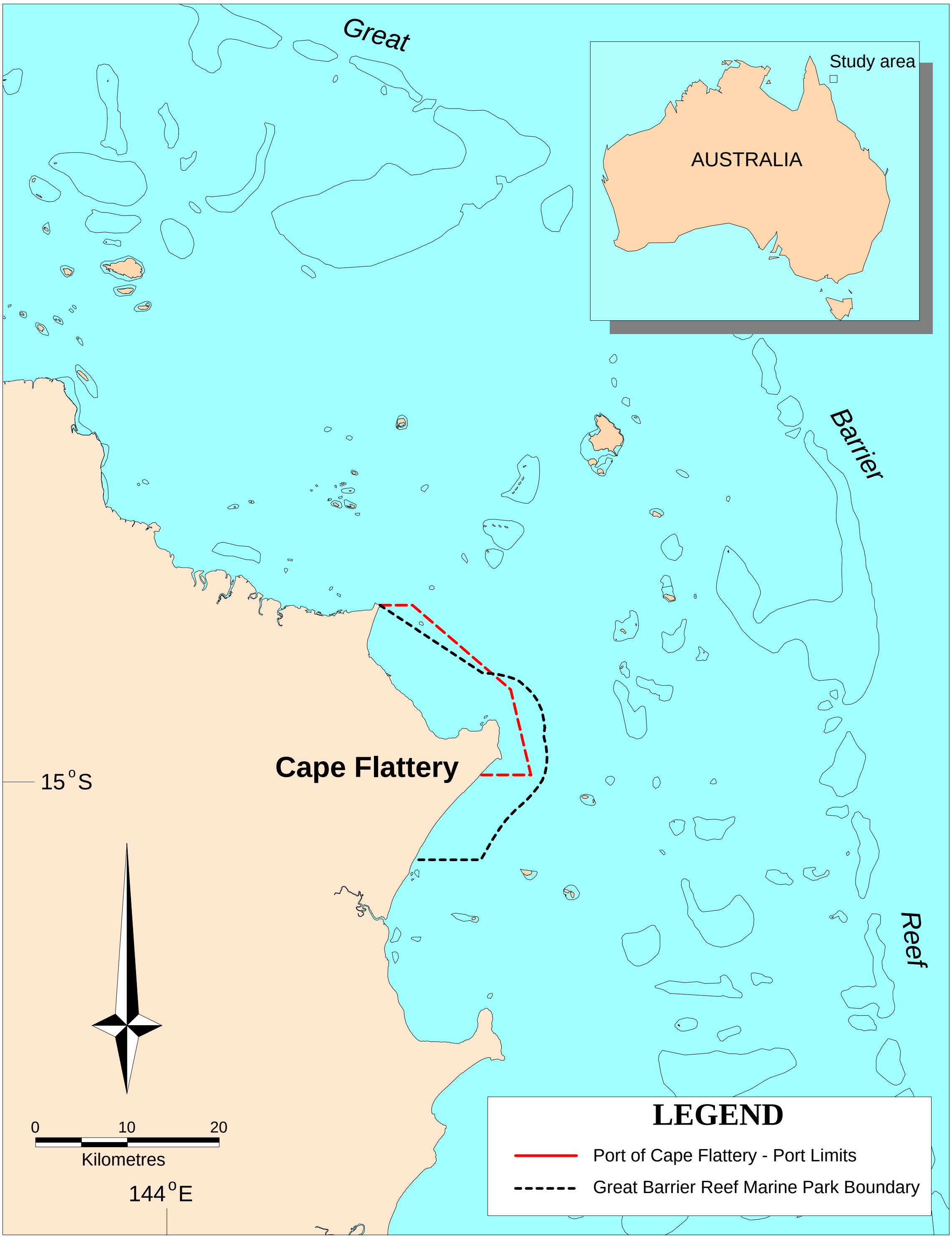

Figure 1. Location of study area.

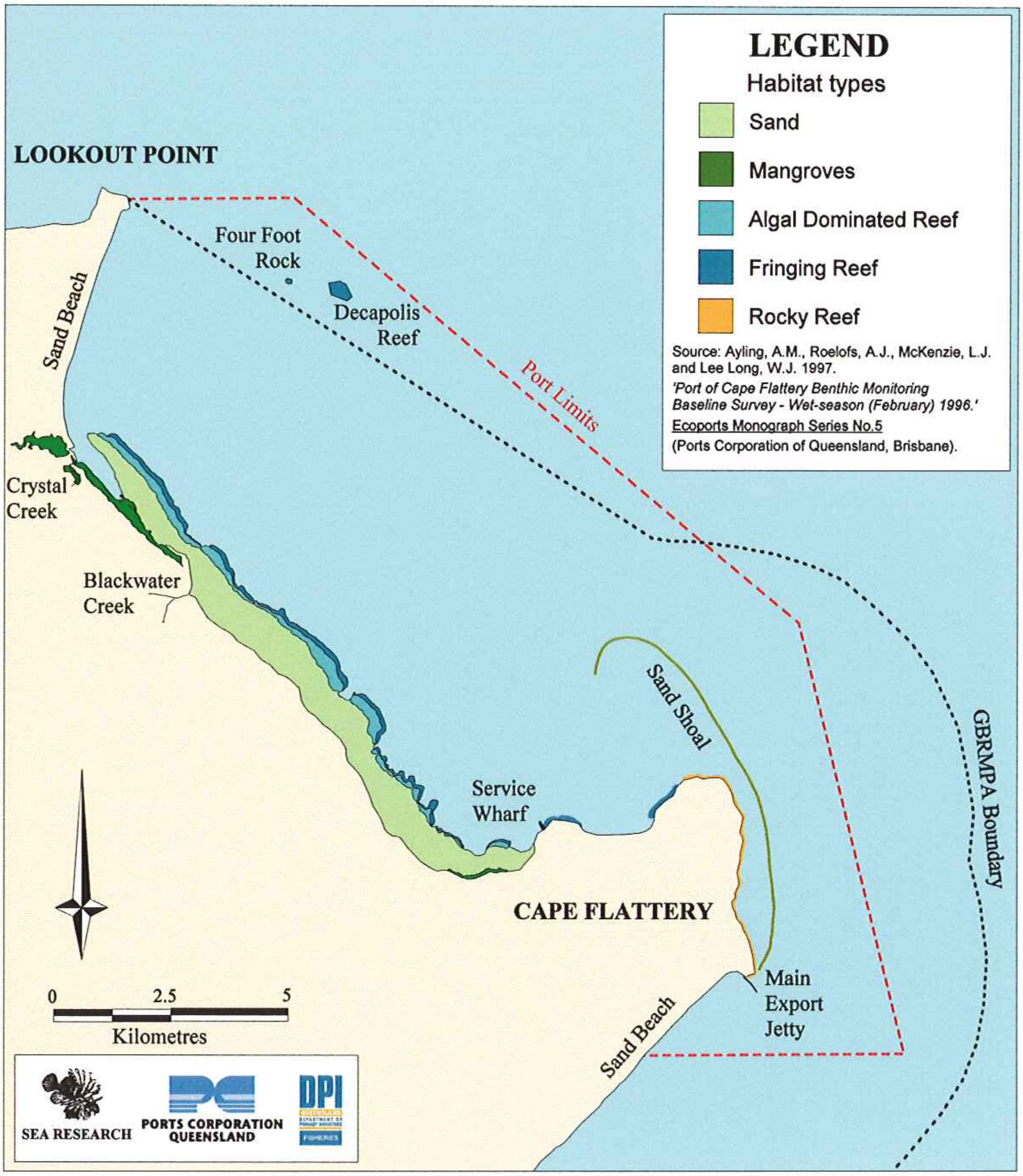

Figure 2 Cape Flattery port limits showing major habitat types

Major geographic features are shown along with the position of the important habitats. Seagrass meadows are shown in Figure 4.

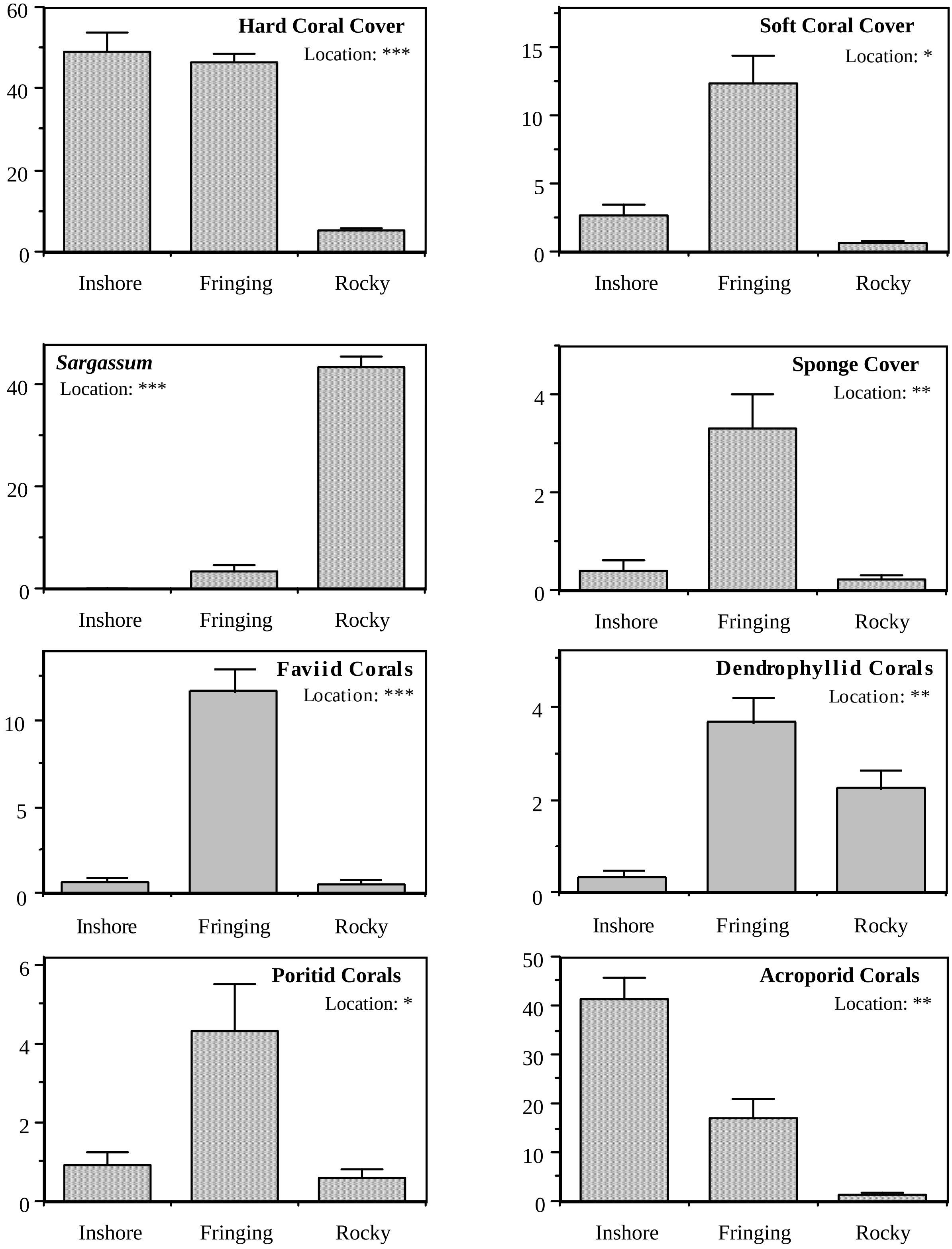

Figure 3. Distribution of encrusting organisms on Cape Flattery reef types.

Graphs show grand mean percentage cover from five sites in each reef type (location): Inshore Reefs (ie Decapolis); Fringing Reefs (ie 14-136); Rocky Reefs (along east side of Cape). Error bars are standard errors. Significance of tests for differences among locations are shown.

Table 1. Marine habitats within the Port of Cape Flattery.

Areas are approximate only.

Habitat	Area (ha)	Percentage of total
Port limits	15,010	100
Subtidal sand and mud	13,083	87.2
Seagrass meadows	1,111	7.4
Intertidal sand	385	2.6
Fringing coral reefs	265	1.8
Mangroves	90	0.6
Inshore coral reefs	60	0.4
Rocky reefs	11	<0.1
Intertidal rock	5	<0.1

Table 2. Summary of benthic abundance for the reef habitats.

Figures show mean and standard deviation (sd) from five groups of five random transects in each habitat.

Benthic group	Inshore		Fringing		Rocky	
	mean	sd	mean	sd	mean	sd
Sargassum spp.	0.1	*0.3*	3.4	*5.5*	43.4	*9.6*
Algal turf	18.7	*16.5*	9.9	*6.9*	16.5	*9.8*
Sponges	0.4	*1.0*	3.3	*3.4*	0.2	*0.6*
Total hard coral	48.8	*23.8*	46.2	*12.2*	5.2	*3.9*
Pocilloporidae	2.3	*2.3*	2.0	*1.7*	0.2	*0.4*
Acropora spp.	17.7	*11.6*	12.6	*13.6*	0.3	*0.6*
Montipora spp.	23.5	*17.6*	4.2	*5.1*	0.9	*1.6*
Poritidae	0.9	*1.6*	4.3	*5.9*	0.6	*1.1*
Agariciidae	0.1	*0.2*	2.0	*4.8*	0.0	*0.0*
Fungiidae	1.9	*2.4*	0.7	*1.3*	0.0	*0.0*
Pectiniidae	0.5	*1.1*	1.3	*1.5*	0.0	*0.0*
Merulinidae	0.4	*1.1*	1.7	*3.2*	0.0	*0.0*
Faviidae	0.6	*1.0*	11.6	*6.7*	0.5	*0.9*
Turbinaria spp.	0.3	*0.8*	3.6	*2.7*	2.2	*2.0*
Total soft coral	2.6	*4.2*	12.4	*10.2*	0.6	*1.3*

Table 3. Significance of differences among habitats and sites for reef benthic communities.

Results from 2 factor analysis of variance tests from five sites of five transects within each habitat. Degrees of freedom are 2/12 for habitat and 12/60 for site (habitat). Probability values for each test are shown.

Benthic Group	Habitat	Site (Habitat)
Total hard coral	<0.001	<0.001
Acroporidae	0.003	<0.001
Poritidae	0.031	0.035
Faviidae	<0.001	0.021
Turbinaria spp.	0.002	0.081
Sponges	0.001	<0.001
Total soft coral	0.019	<0.001

Table 4. Hard coral species lists.

Lists species recorded during surveys of twenty five 20 m transects, plus those seen during a 30 min haphazard swim covering the depth range present in the survey areas. X - indicates species present at that location; a number indicates number of species recorded in a genus or group. Location abbreviations: IR - inshore reefs; FR - fringing reefs; RR - rocky reefs.

Location:	**IR**	**FR**	**RR**		**IR**	**FR**	**RR**
Total No. Species	**92**	**85**	**22**	AGARICIIDAE			
				P. decussata		X	
FAMILY - Species:				*P. venosa*		X	
POCILLOPORIDAE				*P. varians*	X	X	
Pocillopora damicornis	X	X	X	*Pachyseris speciosa*	X	X	
P. verrucosa	X			*P. rugosa*	X		
P. eydouxi	X			FUNGIIDAE			
Seriatopora hystrix	X	X		*Fungia* (no. species)	4	1	
Stylophora pistillata	X	X		*Podabacia crustacea*	X	X	
ACROPORIDAE				OCULINIDAE			
Montipora (no. species)	9	6	2	*Galaxea astreata*	X	X	X
A. brueggemanni	X			*G fascicularis*	X		
A. humilis	X			PECTINIIDAE			
A. samoensis	X	X		*Echinophyllia aspera*	X	X	
A. digitifera	X			*Oxypora lacera*		X	
A. humilis	X			*Mycedium elephantotus*	X	X	
A. nobilis	X	X		*Pectinia lactuca*	X	X	
A. formosa	X	X		MUSSIDAE			
A. horrida	X			*Acanthastrea echinata*		X	
A. aspera		X		*Lobophyllia hemprichii*	X	X	
A. millepora	X		X	*Symphyllia recta*	X	X	
A. tenuis	X	X		MERULINIDAE			
A. cytherea	X	X		*Hydnophora exesa*	X	X	
A. hyacinthus	X			*H. microconus*	X		X
A. subulata	X	X		*Merulina ampliata*	X	X	
A. cerialis	X			*Scapophyllia cylindrica*	X		
A. nasuta	X			FAVIIDAE			
A. valida	X	X	X	*Favia* (no. species)	6	6	1
A. divaricata	X	X	X	*Favites* (no. species)	1	2	
A. elseyi	X	X		*Goniastrea* (no. species)	2	3	1
A. longicyathus	X	X		*Platygyra* (no. species)	3	3	1
A. willisae	X			*Oulophyllia crispa*	X	X	
A. sarmentosa	X			*Diploastrea heliopora*	X	X	
A. latistella	X			*Leptastrea* (no. species)	1	1	1
A. secale	X			*Cyphastrea serailia*	X	X	X
A. sp. 'terry'		X		*C. japonica*		X	
A. sp.		X		*Echinopora lamellosa*	X	X	
A.streopora myriophthalma	X	X		*E. gemmacea*		X	
PORITIDAE				*Plesiastrea versipora*		X	
Porites massive (no. species)	4	3	1	*Moseleya latistellata*		X	X
P. cylindrica	X			CARYOPHYLLIIDAE			
P. lichen	X	X		*Euphyllia ancora*		X	
P. annae	X			*E. glabrescens*		X	
P. rus	X			*Plerogyra sinuosa*	X	X	
Goniopora (no. species)	2	5		DENDROPHYLLIIDAE			
Alveopora (no. species)		2		*Duncanopsammia axifuga*		X	
SIDERASTREIDAE				*Turbinaria peltata*	X	X	X
Pseudosiderastrea tayami		X	X	*T. frondens*	X	X	X
Psammocora contigua	X	X	X	*T. stellulata*	X	X	X
P. superficialis	X	X	X	*T. bifrons*	X	X	X
Coscinarea columna	X	X					

➯ 3. Seagrass Meadows

3.1. General Seagrass Ecology

The importance of seagrass meadows as structural components of coastal ecosystems has been recognised during the past twenty years. This has resulted in more interest being focused on the biology and ecology of seagrasses. These marine angiosperms are important for stabilising coastal sediments; providing food and shelter for diverse organisms; as a nursery ground for many prawn and fish of commercial importance; and for nutrient trapping and recycling (Larkum *et al.* 1989; Edgar and Kirkman 1989).

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

Seagrass meadows in northern Queensland play a critical ecological role as a support for commercial species of penaeid prawns and fish (Coles and Lee Long 1985; Coles *et al*. 1993; Watson *et al*. 1993). Seagrasses are also essential food for dugong, *Dugong dugon* (Miller), and green sea turtles, *Chelonia mydas* (Linnaeus) (Lanyon *et al.* 1989). Coastal seagrasses are also important nutrient and sediment sinks (Short 1987), and play important roles in maintaining sediment stability and water clarity.

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

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

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

It is important to document seagrass species diversity and distribution and to identify areas requiring conservation measures to prevent significant areas and species being lost.

3.2. Methods

3.2.1. Survey Methods

The sampling approach was based on the need to monitor changes in the biomass and areal extent of seagrass within the Cape Flattery port limits. Survey sites (5 m radius) were sampled at intervals of approximately 100 m along transects which were set at 1 - 2 km apart and aligned perpendicular to the coastline. Spot sites were sampled between transects to establish continuity of meadows. Sampling was conducted between 20 - 21 February 1996. Estimates of above-ground seagrass biomass (3 replicates of a 0.25 m^2 quadrat), seagrass species composition, % cover of algae and sediment characteristics were recorded at each survey site. The relative proportion of biomass for each seagrass species within each survey quadrat was also recorded.

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

Seagrass species were identified according to Kuo and McComb (1989). Specimens of seagrass were collected for later taxonomic verification where necessary.

Sediment characteristics were described using visual estimates of grain size: shell grit, rock gravel (>2000µm), coarse sand (>500 µm), sand (>250 µm), fine sand (>63 µm) and mud (<63 µm).

A non-differential Global Positioning System (GPS) was used to determine geographic location of survey sites (±25 m). Depths of survey sites were recorded with a depth sounder standardised to depth below Mean Sea Level (MSL) and corrected to tidal plane datum (Queensland Department of Transport 1995).

3.2.2. Geographic Information System

All data from the survey were entered onto a Geographic Information System (GIS). A GIS base map using aerial photographic images (courtesy Beach Protection Authority, 28/9/91, 7620 m) was rectified to AMG zone 55 co-ordinates.

Boundaries of seagrass meadows were determined based on the GPS fix at each survey site, and where available on information from aerial photograph interpretation. Errors which should be considered when interpreting GIS maps include those associated with digitising and rectifying aerial photographs onto basemaps, the recency of aerial photographs to the survey date, and GPS fixes for survey sites. The error in determining the area of seagrass meadows in the present study was set from ± 7.5 m to ± 50 m depending on meadow. Other errors associated with mapping, such as GPS and position of diver under the vessel, were assumed to be embedded within this range.

3.2.3. Analysis

Standard parametric tests were used for analysis of data (Sokal and Rohlf 1987). All divers had significant linear regressions and r^2 >0.73 when calibrating above-ground biomass estimates against a set of harvested quadrats (Appendix 2).

3.3. Results

3.3.1. Seagrass Species, Distribution and Biomass

Seagrass was present at 77 (47%) of the 165 sites surveyed (Figure 4). Seagrass habitats within the Cape Flattery port limits covered an area of 1111 ±200 ha (Figure 4). Eight species of seagrasses, from two Families, were found within the survey area. *Halodule uninervis* was found in both the thin (narrow) and wide leaf forms:

Family Hydrocharitaceae
Halophila ovalis (Br.) D.J. Hook
Halophila spinulosa (R.Br.) Aschers. in Neumayer
Thalassia hemprichii (Enhrenb.) Aschers
Family Cymodoceaceae
Cymodocea rotundata Ehrenb. et Hempr. ex Aschers
Cymodocea serrulata (R.Br.) Aschers. and Magnus
Halodule pinifolia (Miki) den Hartog
Halodule uninervis (wide & thin leaf) (Forsk.) Aschers
Syringodium isoetifolium (Aschers.) Dandy

Three types of seagrass meadow representing three different habitats were identified in the present survey.

A predominantly *Halodule/Thalassia* meadow (473 ±59 ha) was present in the southern half of the survey area. The meadow was in the sandy intertidal area that is bordered by a fringing coral reef (Figure 4, Table 5). Seagrass species diversity for the meadow was high with 6 of the 8 species identified in the survey being present (Figure 5). *Halodule uninervis* (wide and thin leaf morph.) was only marginally more common than *Thalassia hemprichii* (Figure 5). Seagrass cover was patchy, although *Halophila ovalis* and *H. uninervis* (thin) were generally common inshore and the larger bladed *T. hemprichii* and *H. uninervis* (wide) were found closer to the fringing reef. Dugong feeding trails were observed within this meadow.

A small isolated *Cymodocea/Thalassia* meadow (31 ±3 ha) of high biomass was present at the mouth of Crystal Creek (Figure 4,Table 5). The meadow had a sand/mud sediment.

A large *Halodule/Halophila* meadow (574 ±113 ha) occurred offshore from the fringing reef in deeper water (2.3 - 7.5 m below MSL) and extended north along the shoreline to south of Lookout Point (Figure 4, Table 5). A smaller *Halodule/Halophila* meadow (33 ±26 ha) was found near the southern section of the survey. *Halodule uninervis* (wide and thin leaf morphs) was the most common species in the northern meadow, however it was only marginally more common than *Halophila spinulosa* in the small southern meadow (Figure 5). Sediment types found in these meadows varied from mostly sand in areas close to the reef and shoreline, to a muddy sediment further offshore.

Isolated patches of seagrass (*Halodule uninervis* (wide and thin), *Halophila ovalis and Halophila spinulosa*) were identified on the fringing coral reef and coral rubble habitats. These were very small in area and mostly associated with *Halimeda* and *Caulerpa* algae communities. Other isolated patches of seagrass were found near the main export jetty and along the eastern coastline of Cape Flattery itself (identified during the benthic fauna section of this survey)(Figure 4). Seagrass species identified at these sites included *Halophila ovalis*, *Halophila spinulosa* and *Halodule uninervis* (wide and thin). This area was not sampled quantitatively, however, due to weather and safety conditions.

Mean above-ground seagrass biomass for the seagrass habitat was 9.79 $\pm$1.32 g dry wt m^{-2} (all sites and species pooled). *Thalassia hemprichii* had the highest above-ground seagrass biomass on average and *Halodule pinifolia* the least (Figure 6, Table 6). *Halophila ovalis* was the most widely distributed species followed by *Halodule uninervis* (wide) and *Halodule uninervis* (thin) (Table 6). *Syringodium isoetifolium* was found only in small isolated patches.

3.3.2. Seagrass Depth Distribution

Cymodocea rotundata, *Cymodocea serrulata* and *Thalassia hemprichii* were only found in shallow areas (< 1.6 m below MSL). Other seagrass species found in this survey were not in depth zones (Figure 7). 31 % of sites where seagrass was present were located above LAT (lowest astronomical tide). No seagrass was found deeper than 7.5 m below MSL, although sites with depths greater than 9 m below MSL were not covered in this survey.

3.3.3. Comparison with East Coast Seagrass Survey - November 1984 (Coles *et al*. 1985))

A broadscale seagrass survey of Queenslands' east coast by QDPI in October/November 1984 mapped 809 ha of seagrass meadow and identified 5 species of seagrass from the Cape Flattery area. The 1984 seagrass area was 302 ha less than the present survey. The 1984 meadow comprised 684 ha of medium (10 -50 %) seagrass cover and 125 ha of sparse (<10 %) cover and was located offshore from the fringing coral reef to south of Lookout Point. The intertidal area, inshore of the fringing reef, was not sampled in the 1984 survey.

The position, shape and size of the meadows described in the 1984 survey were similar to the two offshore *Halodule/Halophila* meadows described in the present survey. Although sampling methods between the two surveys do not allow statistical comparisons in above-ground biomass of seagrass, it appears densities of seagrass were also similar.

Species of seagrass identified in the 1984 survey included; *Halophila ovalis*, *Halodule uninervis* (thin form only), *Halophila spinulosa*, *Halophila decipiens* and *Halophila minor (ovata). Halophila decipiens* and *Halophila minor* were not found in the present survey.

3.3.4. Future Monitoring Scheme and Sampling Design

3.3.4.1. General Considerations

A possible proposed seagrass monitoring program has been designed to ensure that any impacts and changes detected are:

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

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

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

An **estimate of variance** has been obtained from the baseline data set of the present wet-season (February 1996) survey. The **size of the change to be detected** has been realistically set. This required prior estimation of the variability observed in the data and consideration of the magnitude of change that would be *biologically* and/or *economically* important (Lee Long *et al.* 1996).

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

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

3.3.4.2. Sampling Design for Cape Flattery

The optimal use of available time and resources in monitoring changes in seagrass biomass at Cape Flattery would be to consider selected meadows rather than the entire port area. A fixed point design is considered inappropriate due to the dynamic nature of seagrass meadows.

The proposed monitoring scheme would survey the wet-season above-ground seagrass biomass for three years (eg. 1996/7, 1997/8, 1998/9). Within each primary meadow, seagrass biomass would be estimated at *r* randomly selected sites and *q* quadrats (replicates) within each site. The analysis of variance to compare above-ground biomass over the three years will be of the form:

ANOVA 1.

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

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

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

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

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

The wet-season (February) 1996 survey provides information about the primary meadows being considered. For the survey the number of sites varied between meadows, although the number of quadrats/site was always 3. For illustrative purposes assume that, for a particular meadow, there were *n* sites and *m* quadrats. Then the analysis of variance table is of the form

ANOVA 2.

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

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

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

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

$$qr = \frac{2(t_0 + t_1)^2 (s^2 + qs_S^2)}{d^2}$$ *equation* (2)

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

Rearranging (2) gives

$$t_1 = \sqrt{\frac{qrd^2}{2(s^2 + qs_s^2)}} - t_0$$ *equation* (3)

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

The wet-season (February) 1996 survey identified 4 primary meadows within port limits on the basis of species composition and biomass. Given the quadrat and site variance components for each primary meadow, the number of sites and quadrats per site has been set so that the least percentage change in mean biomass will be detected at the 90% level (Type I of 10 %) with the highest assurance of detecting a true difference.

Sampling schemes for summer monitoring (determined from Tables 11 to 14, Appendix 2) could be determined for most meadows (Table 7). Only meadow #3 however, would be adequate for future monitoring as the other meadows are too small sized for the required number of sites to be sampled.

3.4. Discussion

3.4.1. Distribution and Abundance of Cape Flattery Seagrasses

The total area of seagrass meadows at Cape Flattery is similar to that mapped from initial QDPI broad-scale surveys. The area of shallow, intertidal meadow however was found in the present survey to be larger than expected. Shallow, intertidal seagrasses appear to support greater populations of juvenile penaeid prawns than does deep water habitat (Derbyshire *et al.* 1995) and the intertidal meadows at Cape Flattery are likely to be important to regional commercial prawn fisheries.

Evidence from dugong feeding trails indicates these seagrass meadows are also important feeding habitat for dugong. The Cape Flattery seagrass community is considered a significant component of the regionally important dugong habitat within this section of the GBR Marine Park. The region however, is probably not as significant locally to dugong as the nearby extensive Lookout Point and deepwater seagrass habitats.

Seagrass species composition varied according to depth, shelter, and sediment type. Dense growth of *Cymodocea serrulata* and *Cymodocea rotundata* occurred in a sheltered intertidal site near mangroves at the mouth of Crystal Creek. This distribution differs from the western Gulf of Carpentaria where *Cymodocea serrulata* dominate subtidally (Poiner *et al.* 1987).

Thalassia hemprichii was the dominant species on the fringing reef platform. *Thalassia hemprichii* is not common at other coastal localities in Queensland (Coles *et al.* 1987; Lee Long *et al.* 1993). It is more common on coral reef platforms with carbonate sediments and low concentrations of phosphate. Knowledge of the influence of sediment type and nutrient availability on seagrass communities at Cape Flattery fringing reefs would be useful in understanding the status and assessing future impacts on this habitat.

Most of the differences in seagrass species diversity and total seagrass meadow area detected between the 1984 and the present survey can be explained by the sampling methods used, the areas surveyed, the time of and the time between surveys. The present survey covered the intertidal area inshore of the fringing reef (not sampled in 1984) and also had a higher sampling intensity (n = 165 sites) than the 1984 survey (n = 22 sites). This would explain the absence of an inshore intertidal seagrass meadow in 1984 as well as the species *Cymodocea rotundata*, *Cymodocea serrulata* and *Thalassia hemprichii* not being detected during that survey. *Syringodium isoetifolium* and *Halodule pinifolia* were also absent in the 1984 survey. The distribution of these species in the present survey was only in isolated patches and therefore could easily have been missed in the broadscale 1984 survey.

3.4.2. Seagrass Depth Distribution

Seagrass depth distribution at Cape Flattery is typical of tropical Queensland seagrass coastal communities with the highest species diversity generally occurring in the shallow inshore habitats and lower diversity in deeper water. *Halodule* and *Halophila* species were dominant in the deeper areas at Cape Flattery, however, inshore from the fringing reef, *Thalassia hemprichii* and *Cymodocea* species were more common. *Halophila* species are able to cope with low light intensities which typically occur in deeper areas and in turbid waters, and probably out-compete other seagrass species in this habitat (Young and Kirkman 1975; Josselyn *et al*. 1986).

3.4.3. Seagrass Monitoring

The Cape Flattery area supports a large and diverse seagrass habitat area and represents a regionally significant coastal seagrass community. The close proximity of mining operations to the seagrass habitat and the regular maritime use of the port warrants consideration of changes in water quality in this region. The inshore areas of seagrass described in this study are particularly vulnerable to changes in water quality through their higher degree of exposure to pollutants than subtidal communities. Potential influences on distribution and abundance of seagrasses along the Queensland coast may include dredging, freshwater and sediment runoff from the land, and agriculture in addition to natural fluctuations in plant populations. Current routine activities at both the Cape Flattery Silica Mine and the port, however, pose little threat to seagrasses.

The present survey represents the first intensive study of seagrasses for the Cape Flattery region and provides a baseline data set on which a monitoring program could be based to investigate changes in seagrass biomass and distribution.

While baseline data has now been established and a possible future monitoring program designed, at the time of publication PCQ did not propose to proceed with post-baseline monitoring. This is due primarily to the absence of port activities which are likely to pose a threat to these seagrasses. The baseline data and possible future monitoring design can be held in reserve and activated should a genuine need for monitoring be identified in the future.

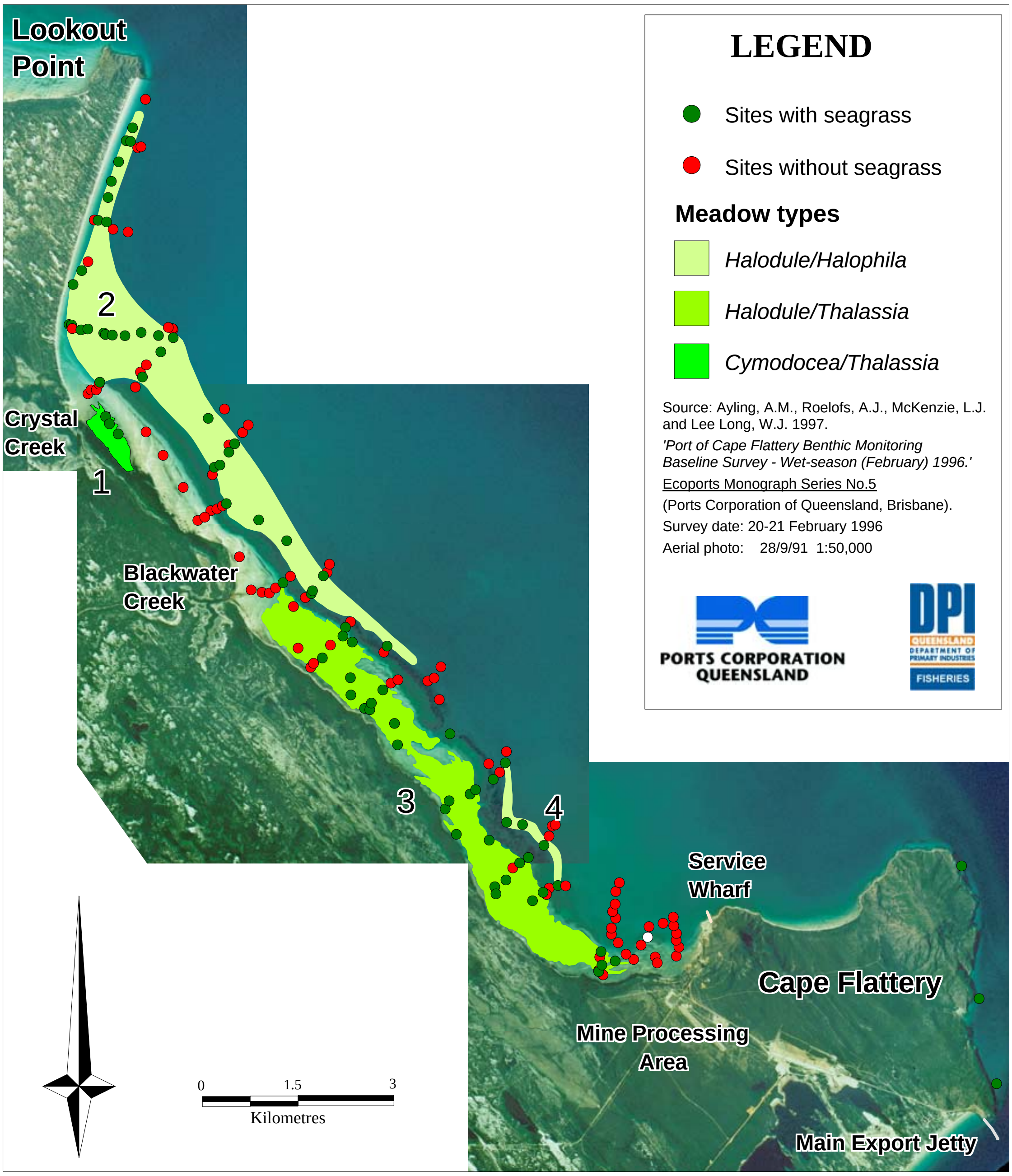

Figure 4 Location of survey sites and seagrass meadows between Cape Flattery and Lookout Point - February 1996

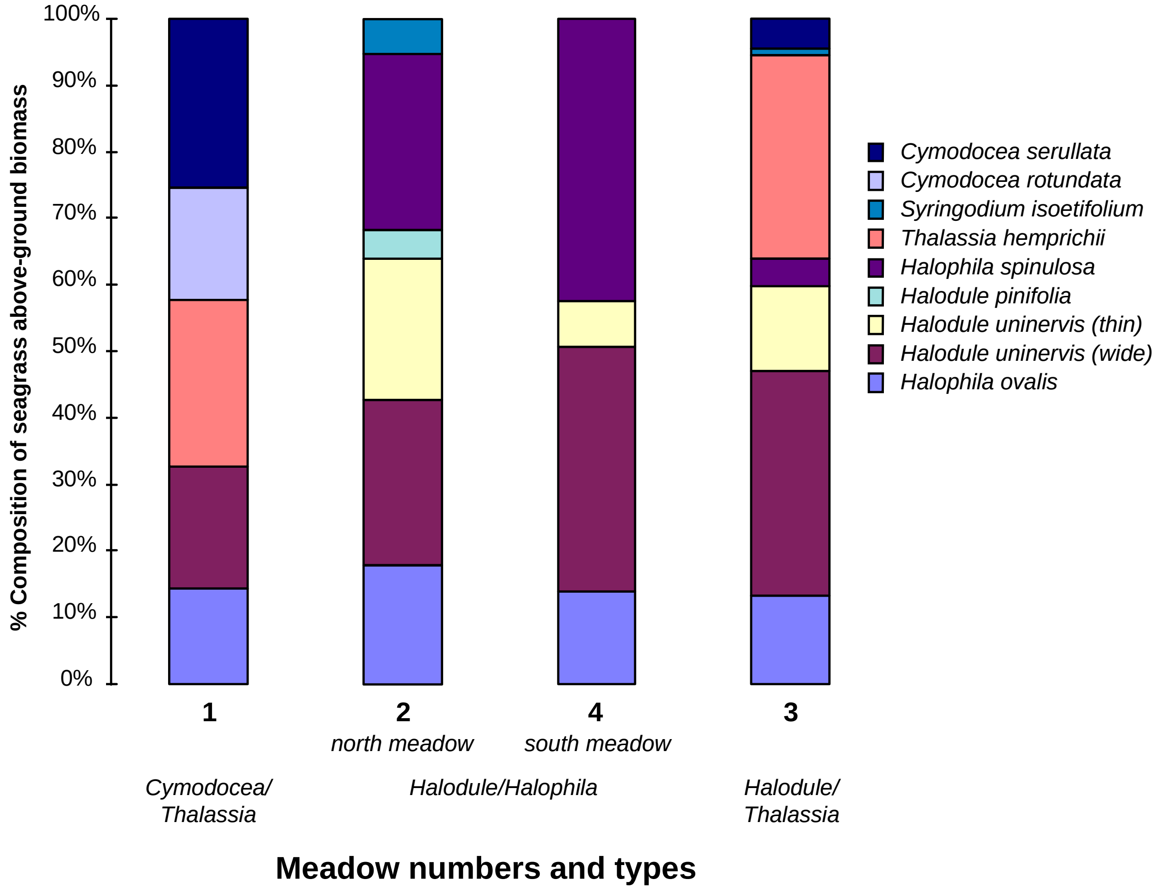

Figure 5. Species composition of each seagrass meadow from Cape Flattery to Lookout Point, February 1996.

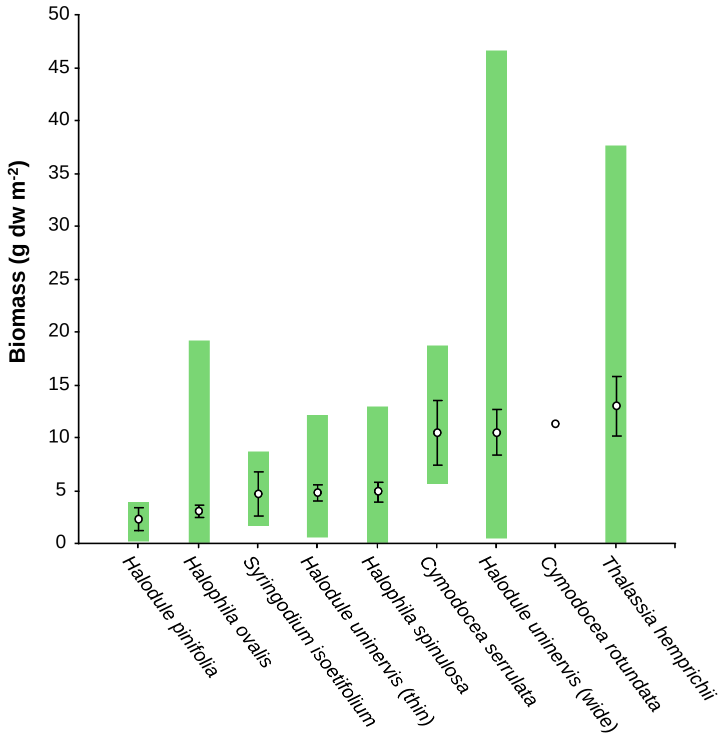

Figure 6. Means, standard errors and ranges of above-ground biomass of each seagrass species for sites where that species was present from Cape Flattery to Lookout Point, February 1996.

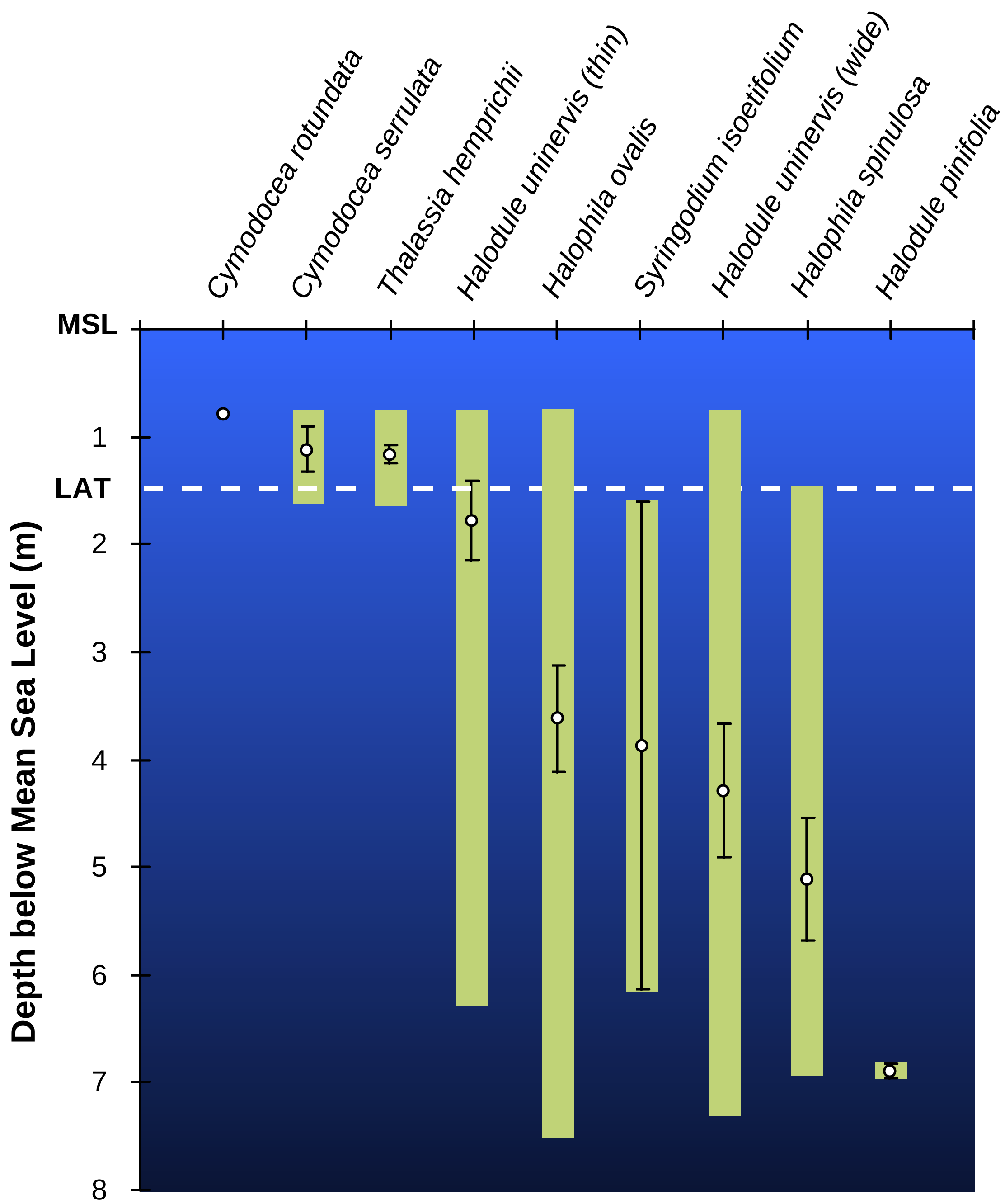

Figure 7. Means, standard errors and ranges of depths of occurrence for seagrasses from Cape Flattery to Lookout Point, February 1996.

Table 5. Species composition, mean above-ground biomass and distribution of Cape Flattery seagrass meadows.

Meadow	**Meadow ID**	**Number of sites**	**Seagrass Species**	**Biomass (g W.m-2)** ***range***	**Area (ha)** ***range***	**Depth (m below MSL)** ***range***	**Substrate**
Halodule/Halophila north	2	42	*Halophila ovalis, Halodule uninervis* (thin and wide), *Halodule pinifolia, Halophila spinulosa, Syringodium isoetifolium*	3.86 ±0.33 *0 - 17.11*	574 *463 - 687*	5.90 *2.30 - 7.51*	sand - sand/mud
Halodule/Halophila south	4	5	*Halophila ovalis, Halodule uninervis* (thin and wide), *Halophila spinulosa*	10.15 ±2.42 *0 - 29.37*	33 *9 - 58*	5.09 *2.50 - 6.35*	sand - sand/mud
Cymodocea / Thalassia	1	3	*Cymodocea rotundata, Cymodocea serrulata, Halophila ovalis, Halodule uninervis* (wide), *Thalassia hemprichii*	22.34 ±5.55 *0 - 37.70*	31 *29 - 34*	0.78 *na*	sand/mud
Halodule/Thalassia	3	34	*Halophila ovalis, Halodule uninervis* (thin and wide), *Halodule pinifolia, Halophila spinulosa, Thalassia hemprichii*	15.96 ±1.53 *0 - 66.70*	473 *415 - 532*	1.26 *0.77 - 2.65*	sand

Table 6. Frequency of occurrence and mean above-ground biomass of each seagrass species at Cape Flattery.

Species	# sites present	Mean biomass ($\bar{x}$ ±SE) (g dry wt. m^{-2})
Halophila ovalis	41	3.11 ±0.53
Halophila spinulosa	20	4.88 ±0.85
Thalassia hemprichii	14	12.99 ±2.79
Cymodocea rotundata	1	11.31
Cymodocea serrulata	6	10.47 ±3.02
Halodule pinifolia	3	2.27 ±1.06
Halodule uninervis (wide)	28	10.54 ±.2.07
Halodule uninervis (thin)	24	4.84 ±0.70
Syringodium isoetifolium	3	4.68 ±2.09

Table 7. Estimate of the number of sites and quadrats per site, such that the percentage change in the mean biomass will be detected at at least the 90% level with at least 90% assurance of detecting a true difference (From Appendix 2), for each of the meadows present at Cape Flattery in summer.

Meadow ID	Description	% change detectable	# Sites	# Quadrats
1		70	30	2
2		*Not possible*		
3		70	35	2
4		50	40	3

↳ 4. Intertidal Communities

4.1. Rocky Shores.

Intertidal communities were sampled at three locations around Cape Flattery: south, central and north. At each location ten haphazardly positioned 50 cm square quadrats were surveyed in the mid intertidal region. Major organisms such as oysters and gastropods were counted in each quadrat, while small barnacles were sub-sampled in five 5x5 cm areas in each quadrat. The position of each location was recorded using a portable GPS unit (appendix 1).

These surveys were made in the mid-tide to low tide section of the rocky shore in the barnacle/oyster zone. The common rock oyster *Saccostrea cuccullata* was abundant along the entire rocky shore, with mean densities of around 150 per 0.25 sq m quadrat. There were no significant location differences in oyster density (Figure 4). All species of barnacle recorded in these surveys were significantly more abundant on the south end of the rocky shore line and decreased markedly in density toward the north. The large barnacle *Tetraclita* sp. was only found at the southern site. It is possible that these marked density changes resulted from a gradation in exposure along the 4.3 km of rocky shore on the southeast face of Cape Flattery, from the more exposed southern end near the main export jetty to the eastern-most tip of the Cape. Grazing neritids *Nerita* spp. were more abundant in the central location than to the north and south, while the other grazers: the small limpets *Patelloida* spp. and a chiton (probably *Liolophura gaimardi*), showed no significant differences among the three locations (Figure 4).

The effect size index (f) of Cohen (1988) was used to calculate power for a rocky intertidal monitoring program. Because of the high variability in the density of most of the intertidal organisms the power of the baseline design was not very high and for regular monitoring it is suggested that five fixed locations of 10 quadrats be used. For this design u = 1 and n' = 46, and hence for 80% power the effect size index (f) = 0.25. The minimum detectable change with such a design for the major intertidal species would range from 11% for oyster density to 32% for limpet density (Table 5). Given that this design will detect a change of 20% or less for the two most abundant species it is suggested that this should be acceptable for any on-going monitoring.

Although no comparable data are available from other rocky shores in the Cairns Section of the GBR Marine Park, the species involved are widely distributed in tropical Queensland and it is unlikely that the Cape Flattery communities are in any way unusual. It is suggested that this rocky intertidal community is the most likely to be impacted by port activities, being immediately adjacent to the main export jetty, and being accessible to any floating oil or other contaminants.

4.2. Mangroves.

The extent and width of the mangrove fringe was mapped using aerial photographs of the port area. A thin mangrove strip fronts about 5.4 km of the Flattery Port Beach, with about 1.25 km of *Rhizophora* spp. mangroves along the south corner of the beach (approximately 5 ha), and the remainder, mostly

Rhizophora dominated, along the northern beach in the vicinity of the two creek mouths (approximately 85 ha). These mangrove communities are similar to those at other areas up and down the coast (Lovelock 1993). Mangroves are particularly susceptable to oil pollution as they trap the oil in the low energy area within the mangrove stands (Getter *et al*. 1984). Two historical diesel spills from the vicinity of service wharf have impacted the *Rhizophora* stands in the southern corner of the beach. The impacts and recovery are currently being assessed by Norm Duke of the AIMS. They are also likely to be affected by poor land use practices within the catchment of the port. Monitoring of mangrove condition and extent is best done visually or with aerial photographs.

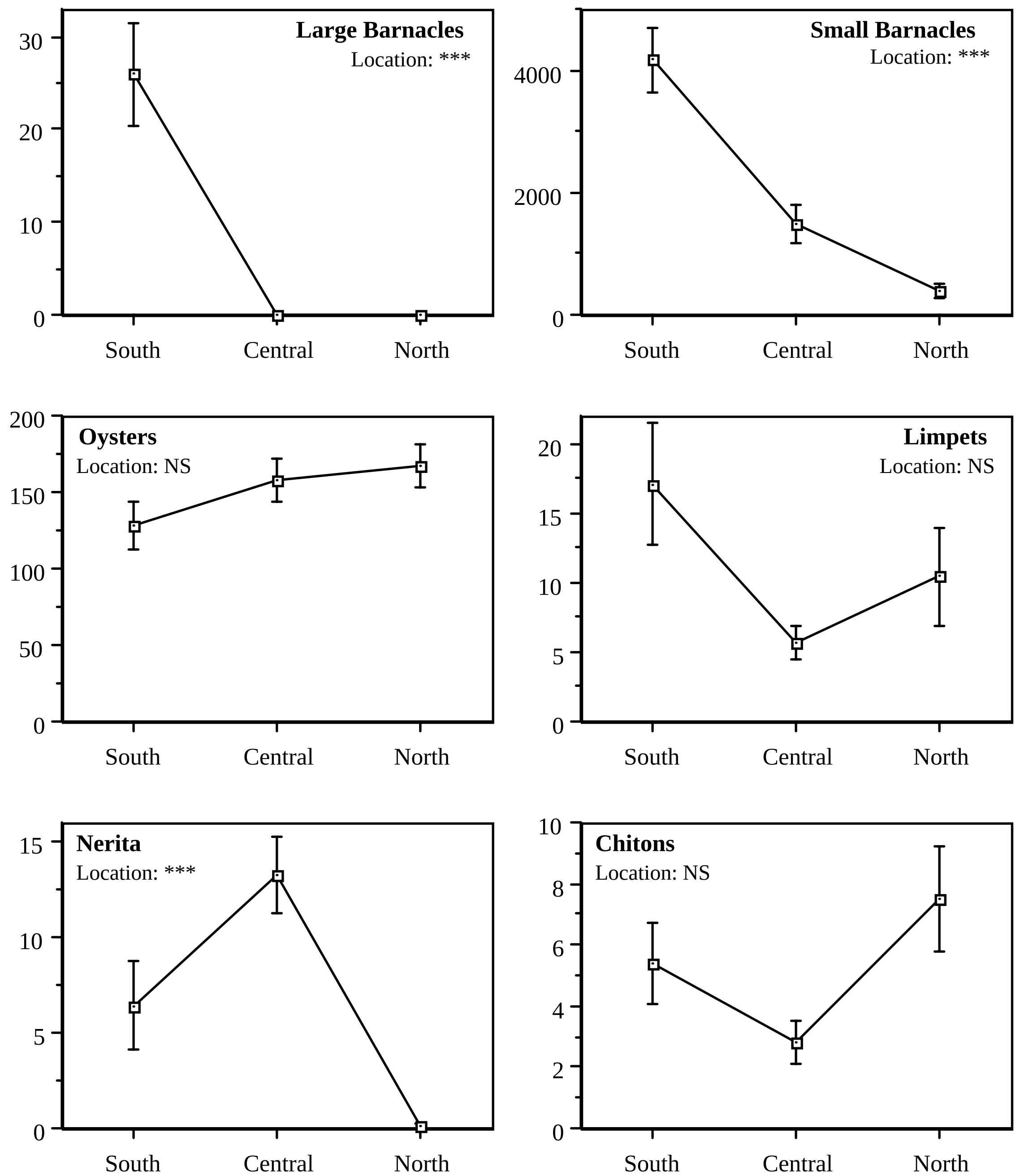

Figure 8. Distribution of intertidal organisms on Cape Flattery rocky shores

Graphs show mean density from ten 0.25 sq m quadrats at each location. Error bars are standard errors. Significance of tests for differences among locations are shown. Large barnacles: *Tetraclita* sp.; Small barnacles: *Chthamalus/Euraphia* spp.; Oysters: *Saccostrea cuccullata*; Limpets: *Patelloida* spp.; Nerita: *Nerita* spp.; Chitons: probably *Liolophura gaimardi*.

Table 8. Minimum detectable change for intertidal species.

The change shown could be detected with 80% power using a design of 5 fixed locations of ten 0.25 sq m quadrats. Mean density per 0.25 sq m quadrat is shown.

Species		Mean density	% change
Barnacles	*Chthamalus/Euraphia* spp.	2015.0	20
Oysters	*Saccostrea cuccullata*	151.4	11
Limpets	*Patelloida* spp.	11.1	32
Chitons	*Liolophura gaimardi*	5.2	29
Nerita	*Nerita* spp.	6.6	30

5. General Discussion

The Port of Cape Flattery area supports marine communities similar to those found along much of the north Queensland coast. In the immediate area there are four similar large bays between Lookout Point and Cape Melville. All of these support extensive seagrass meadows and mangrove forests and have similar or more extensive reef areas. The Cape Flattery area is not unique either in quality, quantity or unusual associations of marine communities. However, it certainly supports significant areas of fringing reef and seagrass meadows and port management practices should take account of this.

It was intended that this wet-season survey be the first of two baselines, the second to be conducted during the dry-season, and that a program of on-going monitoring should flow on from these two baseline surveys. However, the incident of a crocodile attack on one of the observers while scuba diving on a fringing reef during the first baseline led to a reassessment of this program. Given that the Cape Flattery mine personnel report that crocodiles are regularly seen in the port area, it was thought that spending extensive periods of time in the water carrying out scuba surveys on fringing reefs and rocky reefs posed an unacceptable risk. Although a statistically acceptable monitoring design for coral reefs in the area has been suggested in this report it is not recommended that this be implemented. Spending over 30 hours annually underwater in this environment is probably not sensible procedure.

Monitoring of the Port of Cape Flattery seagrass meadows using snorkel divers is considered inappropriate for the same safety reasons. The wet-season sampling design for Cape Flattery indicates that only Meadow 3 could be monitored effectively. This meadow is largely intertidal which suggests it could be monitored during extremely low tides, without the use of divers, and perhaps using a repeated measures sampling design. This would require a mode of transport other than speedboat. Hovercraft have been used for intertidal seagrass sampling in other locations (Rasheed *et al*. 1996), however, it is doubtful the difficult terrain of the site would allow their effective use here. Helicopters are another, more expensive, transport alternative. Without much improved safety for snorkel divers, a different field technique or a different sampling design, monitoring of the Port of Cape Flattery seagrass is not considered feasible at this stage.

An intertidal monitoring program could be safely conducted on the Cape Flattery rocky shores. The monitoring program suggested here would require about 2-3 days field work and could probably be carried out using a fast boat while based in Cooktown to make it more cost effective. The condition of mangrove stands in the port area could be checked at the same time.

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↳ APPENDIX 1 - CORAL SURVEY SITE POSITIONS

Table 9. Position of survey sites for coral and rock reefs and intertidal habitats.

Habitat/Site	Latitude	Longitude
Inshore Reef		
Decapolis 1	176° to beacon	
Decapolis 2	202° to beacon	
Decapolis 3	308° to beacon	
Four Foot 1: nth of:	14°51.087' S	145°15.774' E
Four Foot 2: sth of:	14°51.087' S	145°15.774' E
Fringing Reefs		
Site 1 50 m west of:	14°57.194' S	145°18.751' E
Site 2 50 m east of:	14°57.194' S	145°18.751' E
Site 3 50 m west of:	14°57.010' S	145°20.107'E
Site 4 50 m east of:	14°57.010' S	145°20.107'E
Site 5	14°57.390' S	145°18.192'E
Rocky Reefs		
Site 1 100 m nth of:	14°56.704' S	145°20.868' E
Site 2 100 m sth of:	14°56.704' S	145°20.868' E
Site 3 100 m nth of:	14°57.966' S	145°21.121' E
Site 4 100 m sth of:	14°57.966' S	145°21.121' E
Site 5	14°58.793' S	145°21.247' E
Intertidal Rock		
Location 1	14°56.704' S	145°20.868' E
Location 2	14°57.966' S	145°21.121' E
Location 3	14°58.793' S	145°21.247' E

↳ APPENDIX 2 - OBSERVERS CALIBRATION TABLES

Table 10. Results of linear regressions of each diver's biomass estimation with harvested above-ground biomass (g dry wt. m-2).

Diver	r^2	*F*	*p*
A.J. Roelofs	0.99	213.64	0.001
A.M. Ayling	0.80	12.19	0.040
W. Nott	0.89	23.10	0.017

APPENDIX 3 - SAMPLING STRATEGY TABLES

Table 11. Expected rates of Type II error given the number of sites and quadrats within sites for Meadow 1 at Cape Flattery.

The mean, quadrat variance component and site variance component from the February 1996 survey are 22.34, 13.2974 and 352.02023 g DW m^{-2} respectively. NP = Not Possible to obtain an error value <1.

a) tests over three times, total decline = 30%

	# Quadrats/site								
# Sites	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
5	NP	NP	NP	NP	NP	NP	NP	NP	NP
10	NP	NP	NP	NP	NP	NP	NP	NP	NP
15	NP	NP	NP	NP	NP	NP	NP	NP	NP
20	NP	NP	NP	NP	NP	NP	NP	NP	NP
25	NP	NP	NP	NP	NP	NP	NP	NP	NP
30	NP	NP	NP	NP	NP	NP	NP	NP	NP
35	NP	NP	NP	NP	NP	NP	NP	NP	NP
40	NP	NP	NP	NP	NP	NP	NP	NP	NP
45	0.982	0.978	0.976	0.975	0.974	0.973	0.973	0.973	0.972
50	0.909	0.905	0.903	0.901	0.901	0.9	0.899	0.899	0.899

b) tests over three times, total decline = 50%

	# Quadrats/site								
Sites	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
5	NP	NP	NP	NP	NP	NP	NP	NP	NP
10	NP	NP	NP	NP	NP	NP	NP	NP	NP
15	0.947	0.951	0.953	0.954	0.955	0.956	0.956	0.956	0.957
20	0.848	0.843	0.841	0.839	0.839	0.838	0.837	0.837	0.837
25	0.676	0.672	0.669	0.668	0.667	0.666	0.666	0.665	0.665
30	0.536	0.531	0.529	0.527	0.526	0.526	0.525	0.525	0.525
35	0.421	0.417	0.415	0.413	0.413	0.412	0.411	0.411	0.411
40	0.329	0.325	0.323	0.322	0.321	0.321	0.32	0.32	0.32
45	0.256	0.252	0.25	0.249	0.249	0.248	0.248	0.247	0.247
50	0.198	0.195	0.193	0.192	0.192	0.191	0.191	0.19	0.19

c) tests over three times, total decline = 70%

	# Quadrats/site								
Sites	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
5	NP	NP	NP	NP	NP	NP	NP	NP	NP
10	0.887	0.883	0.881	0.879	0.878	0.878	0.877	0.877	0.876
15	0.565	0.561	0.558	0.557	0.556	0.555	0.555	0.554	0.554
20	0.352	0.348	0.345	0.344	0.343	0.343	0.342	0.342	0.342
25	0.214	0.211	0.209	0.208	0.208	0.207	0.207	0.207	0.206
30	0.128	0.126	0.125	0.124	0.123	0.123	0.123	0.123	0.123
35	0.076	0.074	0.073	0.073	0.072	0.072	0.072	0.072	0.072
40	0.044	0.043	0.042	0.042	0.042	0.042	0.042	0.041	0.041
45	0.025	0.025	0.024	0.024	0.024	0.024	0.024	0.024	0.024
50	0.015	0.014	0.014	0.014	0.014	0.013	0.013	0.013	0.013

Table 12. Expected rates of Type II error given the number of sites and quadrats within sites for Meadow 2 at Cape Flattery.

The mean, quadrat variance component and site variance component from the February 1996 survey are 3.86, 5.4772 and 30.0174 g DW m^{-2} respectively. NP = Not Possible to obtain an error value <1.

a) tests over three times, total decline = 30%

	# Quadrats/site								
Sites	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
5	NP	NP	NP	NP	NP	NP	NP	NP	NP
10	NP	NP	NP	NP	NP	NP	NP	NP	NP
15	NP	NP	NP	NP	NP	NP	NP	NP	NP
20	NP	NP	NP	NP	NP	NP	NP	NP	NP
25	NP	NP	NP	NP	NP	NP	NP	NP	NP
30	NP	NP	NP	NP	NP	NP	NP	NP	NP
35	NP	NP	NP	NP	NP	NP	NP	NP	NP
40	NP	NP	NP	NP	NP	NP	NP	NP	NP
45	NP	NP	NP	NP	NP	NP	NP	NP	NP
50	NP	NP	NP	NP	NP	NP	NP	NP	NP

b) tests over three times, total decline = 50%

	# Quadrats/site								
Sites	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
5	NP	NP	NP	NP	NP	NP	NP	NP	NP
10	NP	NP	NP	NP	NP	NP	NP	NP	NP
15	NP	NP	NP	NP	NP	NP	NP	NP	NP
20	NP	NP	NP	NP	NP	NP	NP	NP	NP
25	NP	NP	NP	NP	NP	NP	NP	NP	NP
30	NP	NP	NP	NP	NP	NP	NP	NP	NP
35	NP	NP	NP	NP	NP	NP	NP	NP	NP
40	NP	NP	NP	NP	NP	NP	NP	NP	NP
45	NP	0.973	0.982	0.988	0.992	0.995	0.997	0.998	1
50	0.975	0.956	0.947	0.941	0.936	0.934	0.931	0.93	0.928

c) tests over three times, total decline = 70%

	# Quadrats/site								
Sites	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
5	NP	NP	NP	NP	NP	NP	NP	NP	NP
10	NP	NP	NP	NP	NP	NP	NP	NP	NP
15	NP	NP	NP	NP	NP	NP	NP	NP	NP
20	NP	NP	NP	NP	NP	NP	NP	NP	NP
25	0.998	0.979	0.969	0.963	0.959	0.956	0.954	0.952	0.951
30	0.869	0.848	0.838	0.831	0.827	0.824	0.822	0.82	0.818
35	0.753	0.732	0.721	0.715	0.71	0.707	0.705	0.703	0.701
40	0.651	0.63	0.619	0.612	0.608	0.604	0.602	0.6	0.599
45	0.561	0.54	0.529	0.522	0.518	0.515	0.513	0.511	0.509
50	0.482	0.461	0.451	0.444	0.44	0.437	0.435	0.433	0.432

Table 13. Expected rates of Type II error given the number of sites and quadrats within sites for meadow 3 at Cape Flattery.

The mean, quadrat variance component and site variance component from the February 1996 survey are 15.96, 27.444 and 215.99753 g DW m^{-2} respectively. NP = Not Possible to obtain an error value <1.

a) tests over three times, total decline = 30%

	# Quadrats/site								
Sites	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
5	NP	NP	NP	NP	NP	NP	NP	NP	NP
10	NP	NP	NP	NP	NP	NP	NP	NP	NP
15	NP	NP	NP	NP	NP	NP	NP	NP	NP
20	NP	NP	NP	NP	NP	NP	NP	NP	NP
25	NP	NP	NP	NP	NP	NP	NP	NP	NP
30	NP	NP	NP	NP	NP	NP	NP	NP	NP
35	NP	NP	NP	NP	NP	NP	NP	NP	NP
40	NP	NP	NP	NP	NP	NP	NP	NP	NP
45	NP	NP	NP	NP	NP	NP	NP	NP	NP
50	NP	NP	NP	NP	NP	NP	NP	NP	NP

b) tests over three times, total decline = 50%

	# Quadrats/site								
Sites	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
5	NP	NP	NP	NP	NP	NP	NP	NP	NP
10	NP	NP	NP	NP	NP	NP	NP	NP	NP
15	NP	NP	NP	NP	NP	NP	NP	NP	NP
20	0.994	0.992	0.985	0.981	0.978	0.976	0.975	0.974	0.973
25	0.846	0.831	0.824	0.819	0.816	0.814	0.812	0.811	0.81
30	0.707	0.692	0.684	0.68	0.677	0.674	0.673	0.671	0.67
35	0.589	0.573	0.566	0.561	0.558	0.556	0.554	0.553	0.552
40	0.487	0.473	0.465	0.461	0.458	0.456	0.454	0.453	0.452
45	0.402	0.388	0.381	0.377	0.374	0.372	0.37	0.369	0.368
50	0.33	0.317	0.311	0.307	0.304	0.302	0.301	0.3	0.299

c) tests over three times, total decline = 70%

	# Quadrats/site								
Sites	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
5	NP	NP	NP	NP	NP	NP	NP	NP	NP
10	0.956	0.97	0.976	0.98	0.983	0.985	0.987	0.988	0.989
15	0.738	0.723	0.715	0.71	0.707	0.705	0.703	0.702	0.701
20	0.513	0.498	0.49	0.486	0.483	0.48	0.479	0.478	0.476
25	0.35	0.337	0.331	0.327	0.324	0.322	0.321	0.319	0.319
30	0.236	0.225	0.22	0.217	0.214	0.213	0.212	0.211	0.21
35	0.158	0.149	0.144	0.142	0.14	0.139	0.138	0.137	0.137
40	0.104	0.097	0.094	0.092	0.091	0.09	0.089	0.088	0.088
45	0.068	0.063	0.061	0.059	0.058	0.057	0.057	0.056	0.056
50	0.044	0.04	0.039	0.038	0.037	0.036	0.036	0.036	0.036

Table 14. Expected rates of Type II error given the number of sites and quadrats within sites for meadow 4 at Cape Flattery.

The mean, quadrat variance component and site variance component from the February 1996 survey are 10.15, 53.7389 and 40.1428 g DW m^{-2} respectively. NP = Not Possible to obtain an error value <1.

a) tests over three times, total decline = 30%

	# Quadrats/site								
Sites	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
5	NP	NP	NP	NP	NP	NP	NP	NP	NP
10	NP	NP	NP	NP	NP	NP	NP	NP	NP
15	NP	NP	NP	NP	NP	NP	NP	NP	NP
20	NP	NP	NP	NP	NP	NP	NP	NP	NP
25	NP	NP	NP	NP	NP	NP	NP	NP	0.944
30	NP	NP	0.959	0.993	0.984	0.966	0.952	0.941	0.932
35	NP	0.991	0.936	0.9	0.875	0.856	0.841	0.83	0.82
40	0.996	0.897	0.84	0.802	0.776	0.756	0.741	0.729	0.719
45	0.914	0.811	0.752	0.713	0.686	0.666	0.651	0.639	0.629
50	0.838	0.732	0.672	0.633	0.606	0.586	0.57	0.558	0.548

b) tests over three times, total decline = 50%

	# Quadrats/site								
Sites	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
5	NP	NP	NP	NP	NP	NP	NP	NP	NP
10	NP	NP	0.88	0.911	0.934	0.951	0.964	0.975	0.983
15	0.987	0.888	0.829	0.791	0.764	0.745	0.729	0.717	0.707
20	0.774	0.666	0.605	0.566	0.539	0.519	0.504	0.492	0.483
25	0.601	0.493	0.435	0.399	0.374	0.356	0.343	0.332	0.324
30	0.462	0.362	0.309	0.278	0.256	0.241	0.23	0.221	0.214
35	0.353	0.263	0.218	0.191	0.174	0.162	0.153	0.146	0.14
40	0.267	0.189	0.152	0.13	0.117	0.107	0.1	0.095	0.091
45	0.201	0.135	0.105	0.088	0.078	0.07	0.065	0.061	0.058
50	0.151	0.096	0.072	0.059	0.051	0.046	0.042	0.039	0.037

c) tests over three times, total decline = 70%

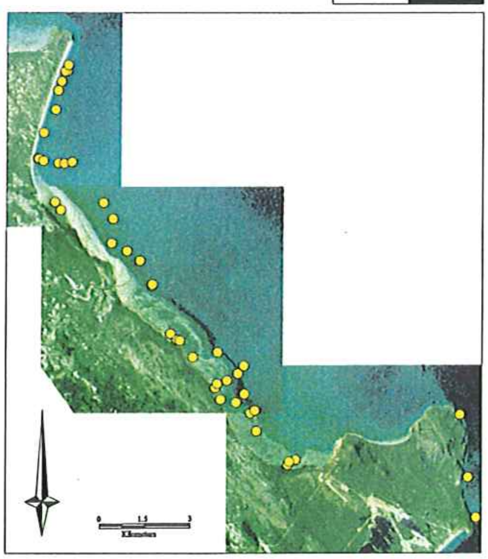
	# Quadrats/site								
Sites	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
5	NP	0.763	0.809	0.839	0.861	0.877	0.89	0.9	0.909
10	0.814	0.706	0.644	0.605	0.577	0.557	0.542	0.53	0.52
15	0.491	0.388	0.334	0.302	0.28	0.264	0.252	0.243	0.236
20	0.288	0.207	0.168	0.145	0.13	0.12	0.113	0.107	0.103
25	0.165	0.107	0.082	0.068	0.059	0.053	0.049	0.046	0.043
30	0.093	0.055	0.039	0.031	0.026	0.023	0.021	0.019	0.018
35	0.051	0.027	0.018	0.014	0.011	0.01	0.009	0.008	0.007
40	0.028	0.013	0.008	0.006	0.005	0.004	0.003	0.003	0.003
45	0.015	0.006	0.004	0.003	0.002	0.002	0.001	0.001	0.001
50	0.008	0.003	0.002	0.001	0.001	0.001	0.001	0	0

APPENDIX 4 - SEAGRASSES

Plates 1 - 9

The following plant specimens are typical of seagrass species collected from sites in the Port of Cape Flattery.

Plate 1. *Halophila ovalis*



● ***Halophila ovalis***

Source: Ayling, A.M., Roelofs, A.J., McKenzie, L.J. and Lee Long, W.J. 1997.
'Port of Cape Flattery Benthic Monitoring Baseline Survey - Wet-season (February) 1996.'
Ecoports Monograph Series No.5
(Ports Corporation of Queensland, Brisbane).
Survey date: 20-21 February 1996
Aerial photo: 28/9/91 1:50,000

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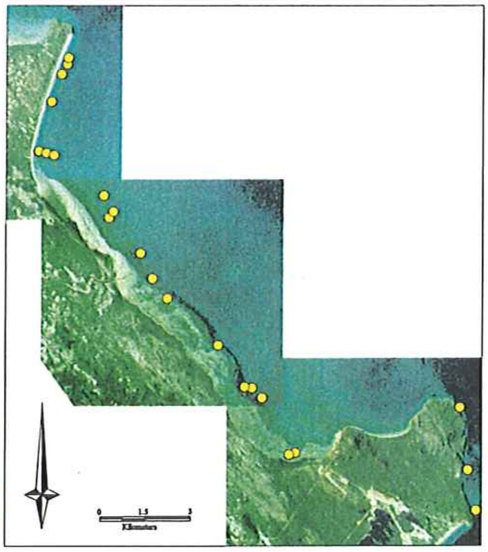
Plate 2. *Halophila spinulosa*



○ ***Halophila spinulosa***

Source: Ayling, A.M., Roelofs, A.J., McKenzie, L.J. and Lee Long, W.J. 1997.
'Port of Cape Flattery Benthic Monitoring Baseline Survey - Wet-season (February) 1996.'
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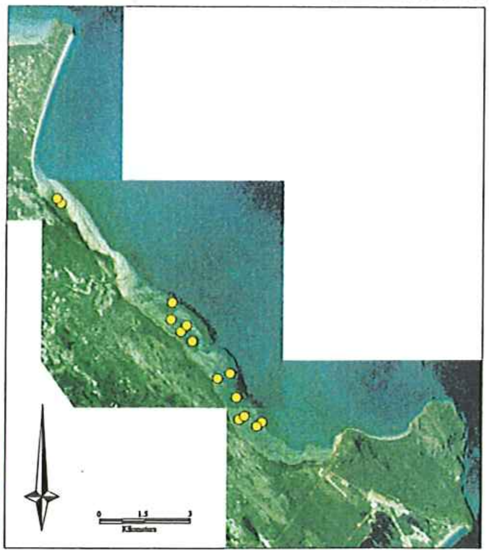
Plate 3. *Thalassia hemprichii*



● ***Thalassia hemprichii***

Source: Ayling, A.M., Roelofs, A.J., McKenzie, L.J. and Lee Long, W.J. 1997.
'Port of Cape Flattery Benthic Monitoring Baseline Survey - Wet-season (February) 1996.'
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(Ports Corporation of Queensland, Brisbane).
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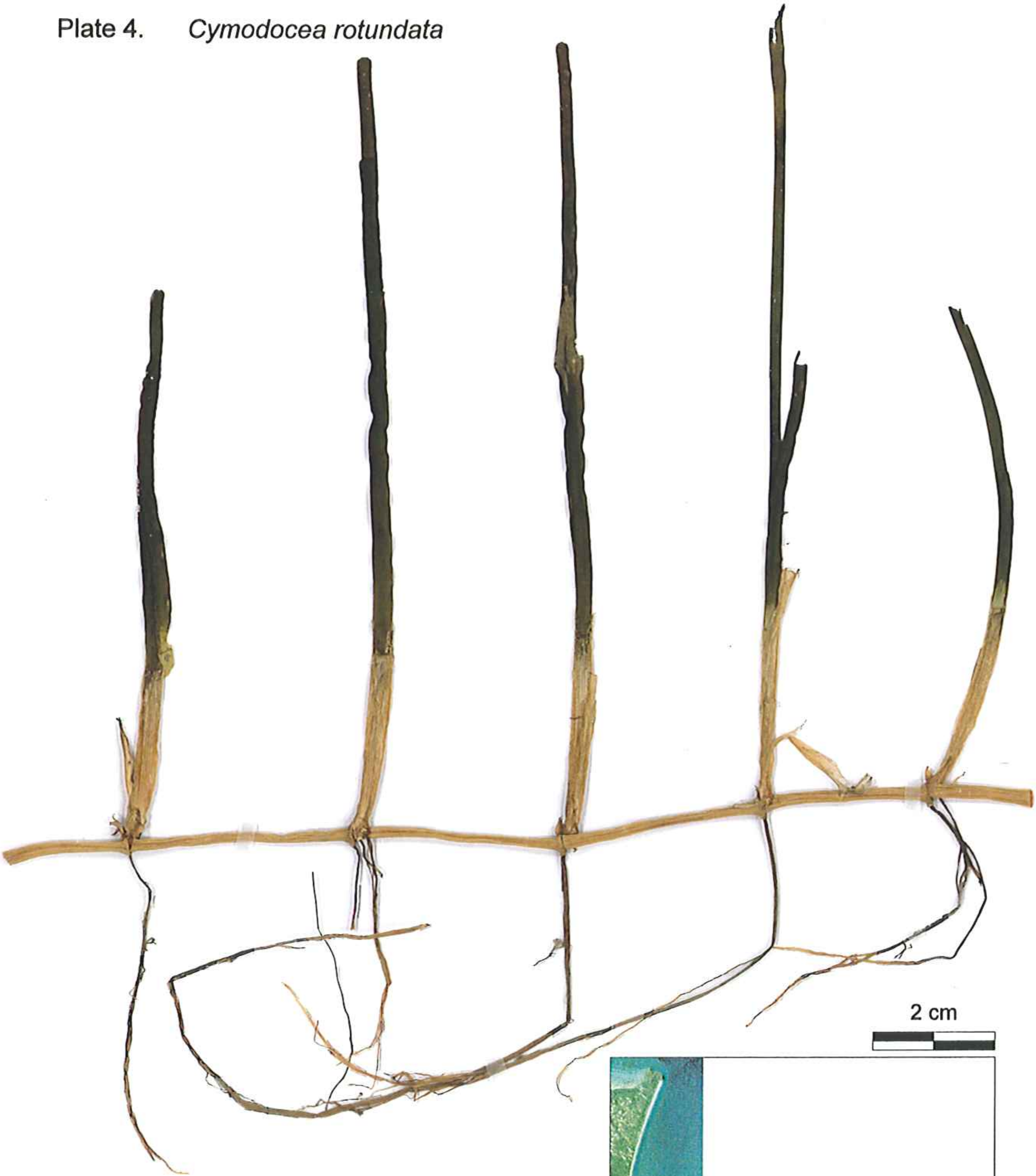
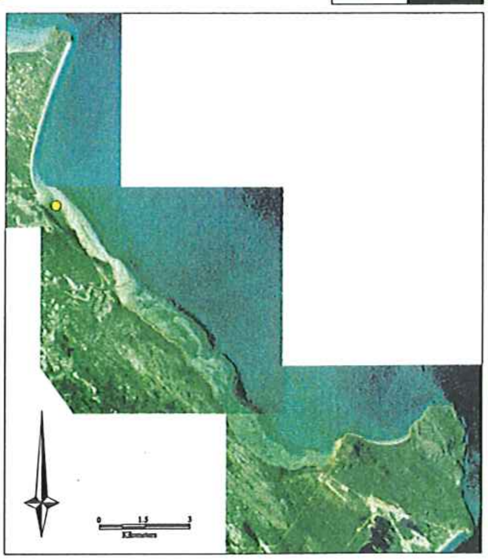
Plate 4. *Cymodocea rotundata*





○ ***Cymodocea rotundata***

Source: Ayling, A.M., Roelofs, A.J., McKenzie, L.J. and Lee Long, W.J. 1997.
'Port of Cape Flattery Benthic Monitoring Baseline Survey - Wet-season (February) 1996.'
Ecoports Monograph Series No.5
(Ports Corporation of Queensland, Brisbane).
Survey date: 20-21 February 1996
Aerial photo: 28/9/91 1:50,000

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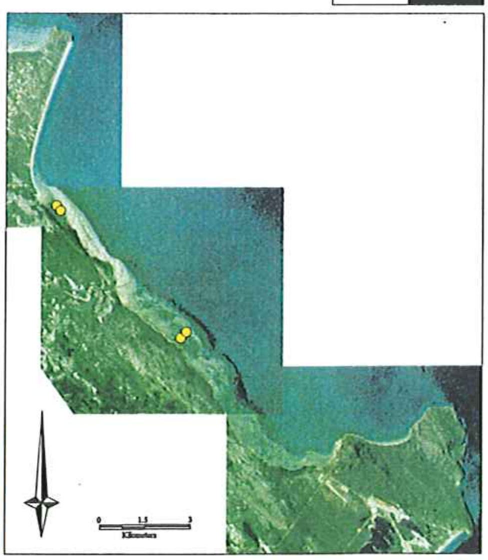
Plate 5. *Cymodocea serrulata*

2 cm



○ ***Cymodocea serrulata***

Source: Ayling, A.M., Roelofs, A.J., McKenzie, L.J. and Lee Long, W.J. 1997.
'Port of Cape Flattery Benthic Monitoring Baseline Survey - Wet-season (February) 1996.'
Ecoports Monograph Series No.5
(Ports Corporation of Queensland, Brisbane).
Survey date: 20-21 February 1996
Aerial photo: 28/9/91 1:50,000

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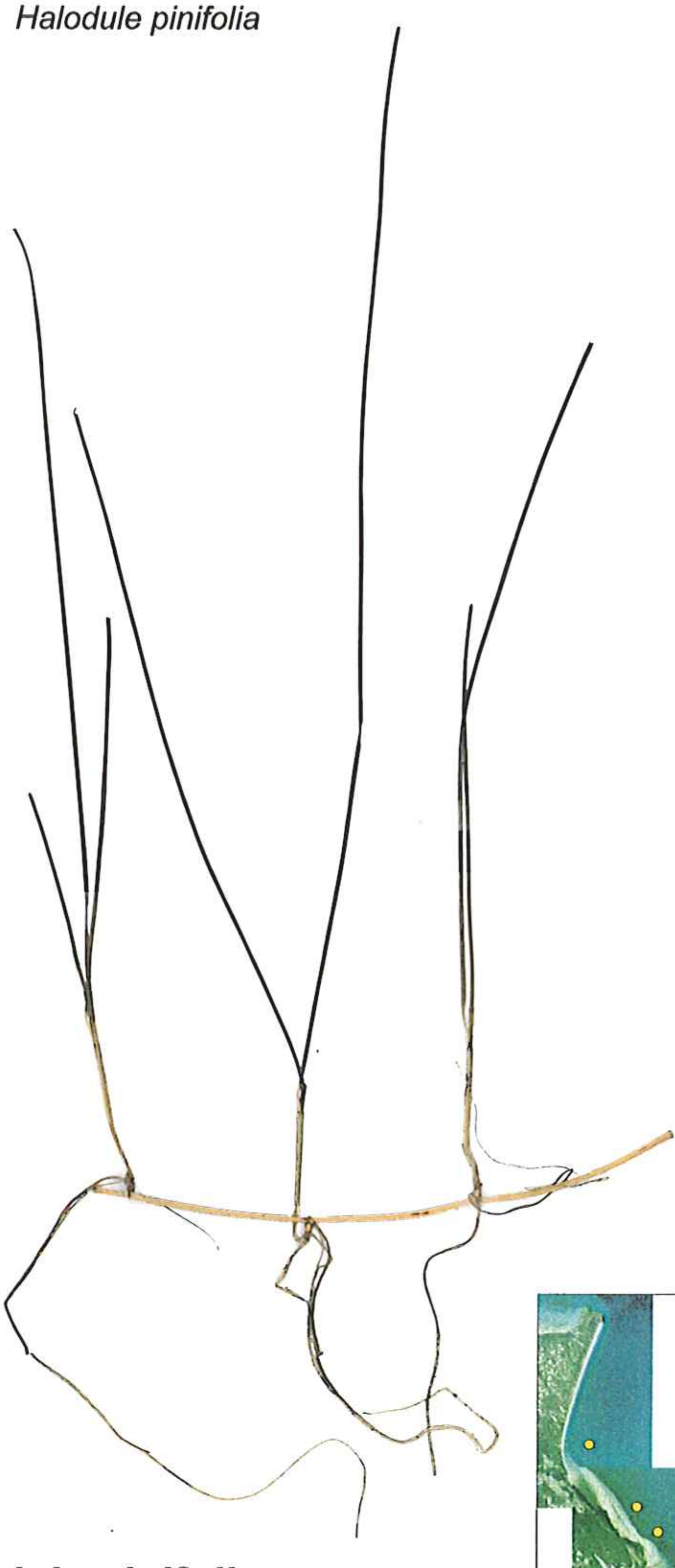
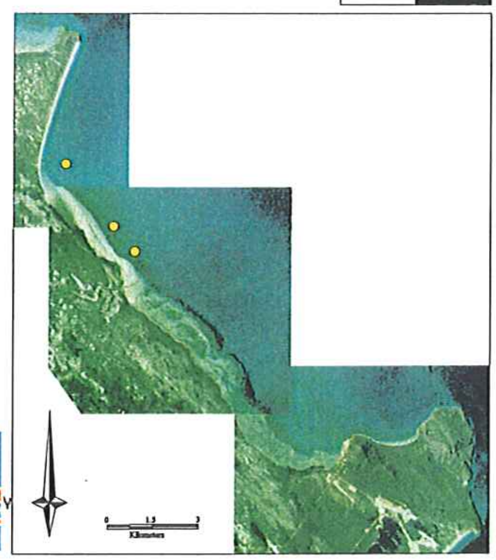
Plate 6. *Halodule pinifolia*



2 cm



○ ***Halodule pinifolia***

Source: Ayling, A.M., Roelofs, A.J., McKenzie, L.J. and Lee Long, W.J. 1997.
'Port of Cape Flattery Benthic Monitoring Baseline Survey - Wet-season (February) 1996.'
Ecoports Monograph Series No.5
(Ports Corporation of Queensland, Brisbane).
Survey date: 20-21 February 1996
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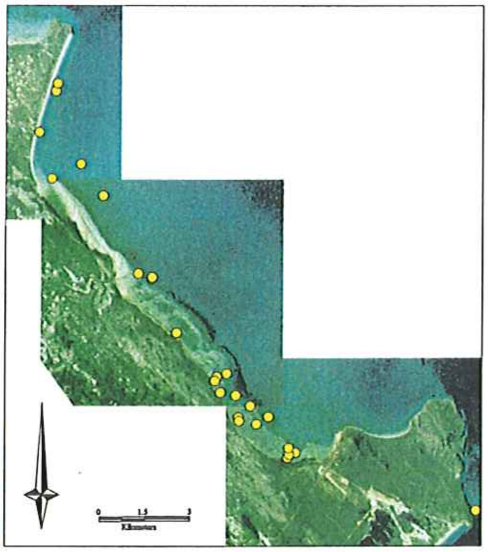
Plate 7. *Halodule uninervis (thin)*

2 cm



○ ***Halodule uninervis (thin)***

Source: Ayling, A.M., Roelofs, A.J., McKenzie, L.J. and Lee Long, W.J. 1997.
'Port of Cape Flattery Benthic Monitoring Baseline Survey - Wet-season (February) 1996.'
Ecoports Monograph Series No.5
(Ports Corporation of Queensland, Brisbane).
Survey date: 20-21 February 1996
Aerial photo: 28/9/91 1:50,000

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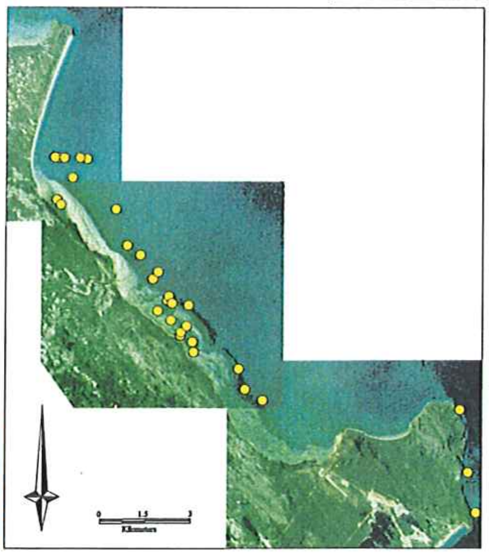
Plate 8. *Halodule uninervis (wide)*



○ ***Halodule uninervis (wide)***

Source: Ayling, A.M., Roelofs, A.J., McKenzie, L.J. and Lee Long, W.J. 1997.
'Port of Cape Flattery Benthic Monitoring Baseline Survey - Wet-season (February) 1996.'
Ecoports Monograph Series No.5
(Ports Corporation of Queensland, Brisbane).
Survey date: 20-21 February 1996
Aerial photo: 28/9/91 1:50,000

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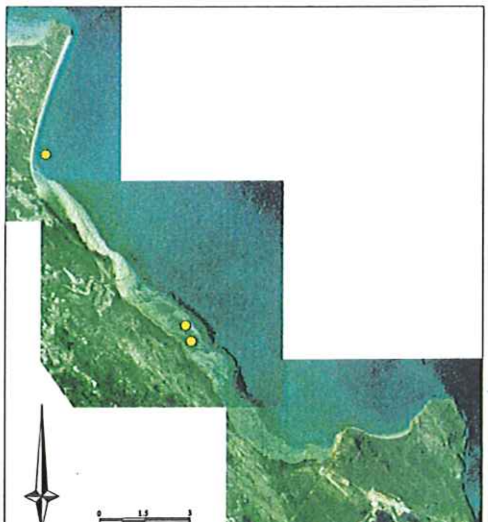
Plate 9. *Syringodium isoetifolium*



Syringodium isoetifolium

Source: Ayling, A.M., Roelofs, A.J., McKenzie, L.J. and Lee Long, W.J. 1997.
'Port of Cape Flattery Benthic Monitoring Baseline Survey - Wet-season (February) 1996.'
Ecoports Monograph Series No.5
(Ports Corporation of Queensland, Brisbane).
Survey date: 20-21 February 1996
Aerial photo: 28/9/91 1:50,000

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