BRISBANE'S PORT
Environmental Study



VOL 1 - BASELINE DATA 1991-1992

PORT OF BRISBANE

BRISBANE'S PORT ENVIRONMENTAL STUDY

VOLUME 1 -
Baseline Data, 1991-1992
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FOREWORD

The following is a compilation of field studies conducted on six major components of the habitat system in and around Moreton Bay during 1991/92.

The purpose of these studies is to provide an extensive knowledge base that will be invaluable for effective habitat management.

These studies will be replicated over three years (91/92, 92/93, 93/94) and thereby quantify natural variation within the study area and identify any impacts resulting from development.

The studies included in this volume have been published in full, hence there is some duplication of information. Material has been presented in this fashion in the belief that interested persons should have the opportunity to review this information in its entirety.

The Introduction and Overview has been prepared by Dr. Mark Pillsworth, Principal Environmental Scientist, a full-time employee of the Port of Brisbane Authority. Acknowledgement is given to Mr Peter Davie (Senior Curator, Crustacea), Queensland Museum for his assistance in this project.



Greg Martin
Chief Executive Officer
Port of Brisbane Authority

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1 INTRODUCTION

Background to the Development proposal

The Port of Brisbane will be subjected to significant development in the next 50 years, in line with its role as a major regional port. It will not only serve the resource rich regions of Queensland and northern New South Wales, but will also expand its role in Australian trade with the Asia - Pacific region. Indications are that it will be a key, and perhaps the principal, trading port for Australia's eastern seaboard. The necessary port development needed to realize this objective will have an obvious local impact and must therefore be carefully managed to minimise environmental effects.

The Port of Brisbane is a significant user of Moreton Bay and an important participant in the economic life of South-east Queensland. Over 3,500 exporters and importers rely on the Port for shipping cargo. A recently completed University of Queensland economic impact statement study (Jensen & Bayne, 1991) showed that $8 billion worth of trade passed through the Port in 1990/1991. This injected $550 million into the regional economy and provided 5900 permanent jobs. An assessment of the Port's current economic impact has been conducted as part of the Port of Brisbane Strategic Development Plan, endorsed by the Queensland Government in January 1993. By 2005, the value of the Port to the regional economy is likely to increase to $871 million, and provide a total of 9540 permanent jobs. Construction projects during this time will mean an additional once-off $640 million in output, and create an additional 2300 person years employment.

A 1990 study by the Applied Population Research Unit, Department of Geographical Sciences, University of Queensland, predicted that for the 15 year period 1986-2001, around 555,000 persons would migrate to Queensland. The greatest number is expected to settle in the south-east corner of the state. In particular, a period of great growth is expected from 1990-2001 in the small area extending from Coolangatta in the south to Noosa in the north and westward to Toowoomba. The population for this area which was 1,600,000 in 1986, should grow to 2,200,000 or possibly more by 2001. Proportionately, this growth is 69% of the State's projected growth in an area presently containing 61% of the State's population.

It is against this backdrop of considerable rural and urban development that the growth of the Port facilities is proposed. The Port will directly impact on a localized area at Fisherman Islands, at the mouth of the Brisbane River.

Environmental Considerations

Moreton Bay is a unique environment on Australia's eastern coastline. Biologically it is remarkable because it marks the transition zone between southern temperate and northern tropical faunas. From a human perspective the sheltered waters behind the large sand islands allow the people of Brisbane many leisure and lifestyle opportunities. The Bay also provides a natural beauty that enhances Brisbane's identity and regional pride. There are many areas where wilderness experiences are still possible and the natural landscapes of the Bay and fringing islands have allowed rich and diverse ecosystems to develop.

Fishing in Moreton Bay is of great economic importance. It is Queensland's major fishing ground, even outranking the Gulf of Carpentaria in terms of fishing activity (Weng, 1990). Property development, leisure industries and mining also generate much wealth for the Moreton region, but these occupations may become less important as they are challenged by a growing community awareness of the need to maintain the Bay's environmental and cultural values.

The future for the Bay will be determined by the open dialogue between participating government, industry and user groups. The quality of their decisions will be dependent on a good understanding of the natural system. The end result must be Environmentally Sustainable Development (ESD) where resources are utilised in such a way that the long term health of the environment can be maintained.

It is proposed that Port expansion will be concentrated in the Fisherman Islands area and extend from the present facilities into Moreton Bay along the existing quay-line. Development of the Port will initially involve construction of bund walls, followed by filling operations behind them, using dredged material. Areas within the reclamation bunds will be altered permanently, however in areas adjacent, there will be the opportunity to restore, rehabilitate or create new wetland, mangrove and seagrass areas.

The Port Area

The Port of Brisbane occupies the greater part of Moreton Bay and extends from about Russell Island in the south to Caloundra in the north and is bounded in the east by Moreton, and North and South Stradbroke Islands (Figure 1).

Study Area

The main area of study is termed the Fisherman Islands and Environs sub-system. This area already has been affected by Port activities, and it is the area upon which future Port expansion will have the greatest impact. It is bounded by the shipping channel which extends from the Coffee Pots to the Boat Passage. It continues upriver bounded by the landward fringe of the mangroves at Lytton, to Oyster Point, Wynnum North, westward to the nearest tip of St. Helena Island and along the foreshore facing the Port, and from the northern point of St. Helena back to the Coffee Pots (Figure 2).

The Fisherman Islands and Environs area is physically dominated by the mouth of the Brisbane River. It is a low lying area of wetlands, mangrove forests, and intertidal flats. Subtidal flats have seagrass meadows, and are intersected by a system of channels to the southeast (<6m depth).

The predominant biotic communities are:

- wetland
- mangrove (Mangal)
- seagrass

Coral communities are present east and south at Mud, St. Helena and Green Islands, however these are not included in the study area.

2 ECOLOGICAL OVERVIEW

Moreton Bay general description

Moreton Bay (27°S, 153°E) is a large embayment on the mid-east coast of Australia. To its north is a large opening (approx. 35.6 km) to the ocean; to the south it narrows funnel-like, to meet the Southport Broadwater. From the Southport Broadwater to Comboyuro Point, the north-western most point of Moreton Island is approximately 105.6 km.

The Bay is formed inside the barrier of three large sand islands (Moreton, and North and South Stradbroke) which protect it from the direct influence of the South Pacific Ocean. In the north, Pumicestone Passage is protected by another sand island, Bribie Island. The Bay has four connections to the ocean:

- The area between Caloundra and Moreton Island (surf bar, referred to as the Caloundra Bar).
- Rous/Rainbow Channels between Moreton and North Stradbroke.
- Jumpinpin (surf bar) between North and South Stradbroke.
- Gold Coast Seaway from Southport to Broadwater.

The opening at Jumpinpin is only small. As recently as 1895, easterly gales caused the breakthrough that resulted in North and South Stradbroke Islands.

Several river systems flow into the Bay eg. Brisbane, Logan, Albert and Pine Rivers, and greatly influence the composition of Bay waters, especially salinity and turbidity. During periods of peak flooding, such as occurred in 1974, the greater part of the Bay will be affected by freshwater runoff. Moreton Bay can be conceptualised as a transition zone where freshwater flow from the Brisbane River catchment (and others) is filtered through a series of sub-units, which interact and form a link with the greater South Pacific Ocean. Tidal flushing of the Bay is the major environmental factor governing the system. However during times of high freshwater runoff the Brisbane River (and others) can become the driving force.

Tidal characteristics / current flow

Milford and Church (1976) found that a uni-dimensional model of circulation and mixing in Moreton Bay was too simplified, and a two (or three) dimensional model is required.

The Bay ranges from approximately 40 metres maximum depth in the north to approx. 6 metres maximum depth in narrow channels in the south. Channels are a significant feature of Moreton Bay as they are critical to the flow regime. Many channels have sharp cross-section topographical gradients, some have widths of hundreds of metres, while others have predetermined batter shapes which are constructed by dredging and maintained as navigable channels.

Modelling of circulation in the Bay has centered on the open areas of the Bay north of Peel Island as 85% of the tidal prism enters from the north (Milford and Church, 1977). According to Milford and Church's model (1976), completely closing the south passage would result in a decrease in tidal amplitude of approximately 15%. Water entering from the south passage therefore has a significant effect only on the southern section of the Bay.

Milford and Church (1976) realised that they were oversimplifying the Moreton Bay system with their preliminary models but pointed out the constraints imposed by insufficient field data. Their models form a solid base from which to derive a more complex model.

FIGURE 1

Brisbane Port Limits

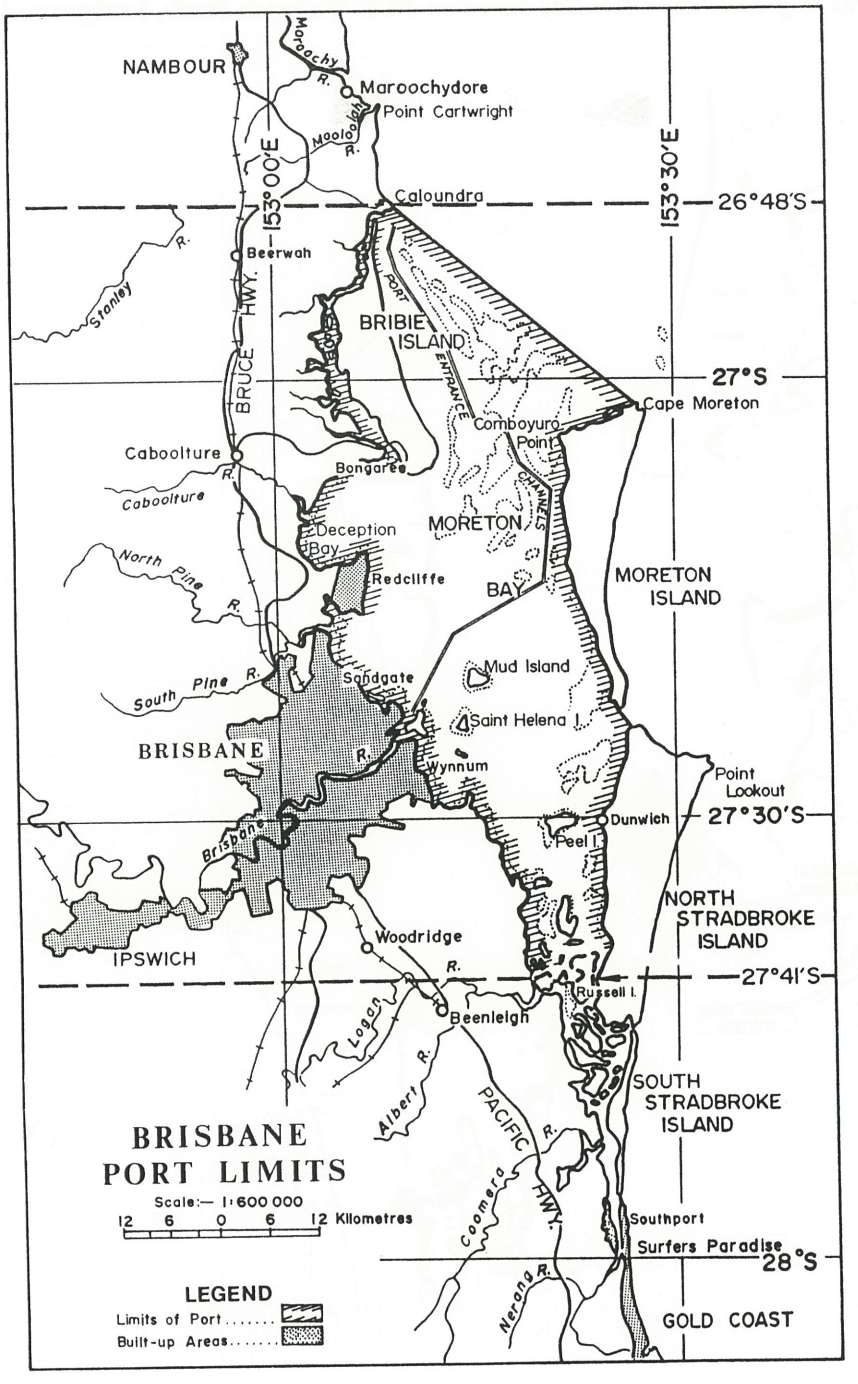
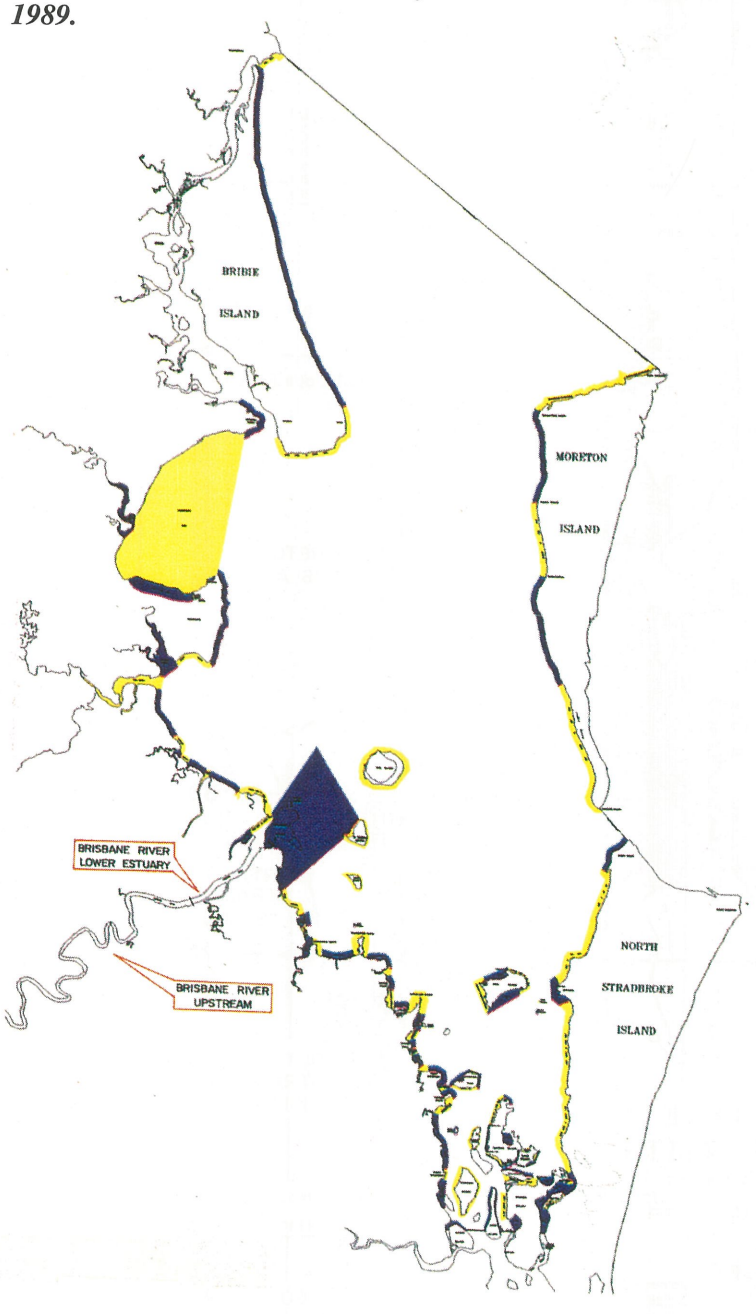


FIGURE 2

Map of sub unit boundaries, Moreton Bay. Other areas are also defined on the foreshores of greater Moreton Bay based on BCC Wetlands Study, background report 1989.



They identified that factors relating to the types of water motion, their interaction, and duration needed to be quantified by future field measurements. These are:

- Tidal fluxes in shallow water (periods of hours to days).
- Natural oscillations produced by winds or tide or occasional other pulses (periods of 0.1 to 2 hours expected in Moreton Bay).
- Small and large eddies (periods of seconds to days, if the latter motions are not destroyed by tides).
- Net drift motions induced by the complete dynamic system. (Traversal of Bay in periods of days to months).

Newell (1971a,b) examined the circulating / mixing mechanisms in the Bay and estimated that 5-6% of the tidal volume is exchanged between the estuarine and ocean systems (Newell, 1971a, 1971b). Milford and Church (1976) hypothesised that there was a clockwise circulation pattern which was the result of a southerly wind stress. Harding (1983) continued the work of Milford and Church (1976,1977) and further refined the modelling by the use of a coarse grid overlay over the Bay to model local effect i.e. a two mile grid.

It is apparent from the above that:

- Water circulation in the Moreton Bay system is complex.
- Results from the investigations done so far are at best preliminary.
- More detailed studies are required before the circulation patterns in the Bay can be fully understood.

Brisbane River Estuary

The definition of an estuary has been the topic of much debate because estuarines are transition zones between fresh and salt water and it is difficult to define precisely where they begin and end.

Davie (1990) defines environmental transitions in the estuary as a complex of interrelated factors which includes not only changes in salinity but also temperature, osmotic pressures, pH, Eh, surface and interfacial tension, pp O2, radiation, turbidity, suspended solids, turbulence, cations, anions and toxic substances. Due to this complex of interrelated factors, no matter how an estuary is defined, the habitat is harsh and consequently relatively species depauperate compared with either the fresh or marine habitats on either side.

The Brisbane River estuary is strongly affected seasonally by rainfall in its catchment.

Stock (1990) notes that the Brisbane River catchment is essentially a dry part of a dry continent. He characterises the catchment by:

- a low average rainfall/runoff ratio
- occasional large volume floods
- occasional severe droughts with zero stream flows
- a pan evaporation equal to the average rainfall

Features above directly determine the physical conditions under which the biota must live. They will clearly vary with season and year.

Boesch (1977) surveyed the Brisbane River, recording both salinities and changes in benthic invertebrate communities, and determined approximate limits for limnetic, brackish and marine habitats. He found the first marked changes in faunal composition at approx. 10-15km from the mouth. Although the salinities were still high (34 p.p.t. most of the year) summer flooding can reduce salinities to approx. 10 p.p.t..

It is presumed that the general location for this marine to brackish coenoclinal change has not varied greatly since this study, and will still be located approximately 10-15km from the Brisbane River mouth. The river can be classified from the Boesch study (1977) as follows:

LOW FLOW CONDITIONS	HIGH FLOW CONDITIONS
marine, up to approx. City Reach	brackish, past river mouth into Moreton Bay
brackish, City Reach to junction with Bremer River approximately	limnetic, City Reach upstream

The upstream limit for brackish water is not significant to this investigation, but what is important is that the management units,

- Fisherman Islands and Environs
- Brisbane River lower estuary
- Greater Moreton Bay

are marine habitats most of the time except for periods of flooding. The brackish water habitat with its species depauperate community (although species abundance can be extremely high) and highly specialised estuarine endemics occurs in management unit 'Brisbane River Upstream'.

This has ramifications for the development of environmental management strategies in that:

- It would be expected that there would be a greater number of species in the marine community at the mouth of the River than would be expected in the brackish water habitat further upstream.
- Marine species are generally less tolerant to changes in their habitat than brackish water endemics .

The importance of this to the system is that at irregular intervals the marine habitat at the mouth of the Brisbane River (Fisherman Islands and Environs) can be greatly modified by flooding. In the case of the 1974 flooding, marine communities at the mouth of the River, and beyond, were largely destroyed by the freshwater conditions which persisted for some time.

Recruitment to recolonise areas at the mouth of the River after major flooding and destruction of marine benthic communities, would come from the greater Moreton Bay.

The time period during which these studies were conducted (1991/1992) was marked by a period of extreme drought, and therefore the marine habitats were stable. Higher salinity conditions could be expected further upstream then usual.

The water mass is not static, and its physical movements are a controlling force for the whole system. The degree of horizontal and vertical mixing of waters originating in the catchment is influenced by wind, tide and the rate of freshwater runoff. As a consequence of this outflow from the River, events occurring in the area of the Fisherman Islands and Environs can directly influence the greater Moreton Bay system by changing conditions at the mouth of the River. This may in turn even influence species outside the Bay and some species which may migrate into the area eg. annual migration of summer whiting *Sillago ciliata* onto sand banks at the mouth of the River.

Owing to the dynamics of the system and movement of species into and around the Bay, it can be concluded that impacts from development can be felt some way off.

3 APPROACH TO THE STUDY

The Port of Brisbane Authority (PBA) has undertaken a base-line resource assessment of the Port area because of the need for future Port development. The large multi-disciplinary study that it is undertaking will provide an extensive knowledge base that will be invaluable for effective habitat management. It can also be expected to provide knowledge which will add to our basic understanding of the functioning of estuarine and shallow, sheltered, coastal environments.

To attempt to understand the total system it is necessary to approach the study using several different perspectives, broadly defined as:

- global (interacting with the eastern seaboard)
- system (Moreton Bay as a unit)
- neighbourhood (sub-units of Moreton Bay)

The neighbourhood sub-units are further divided into habitat units following the system of classification proposed in the study 'Planning for Brisbane Wetlands' (1989) (refer Figure 2). In that study, the greater port area was subdivided into habitat units according to their floral characteristics i.e., sites were described according to the dominant types of vegetation and its structural characteristics. This system of habitat units was adopted as a guideline for PBA studies because conformity to a standard is needed for cross study comparisons, and information can be easily inputted to a map/information data base.

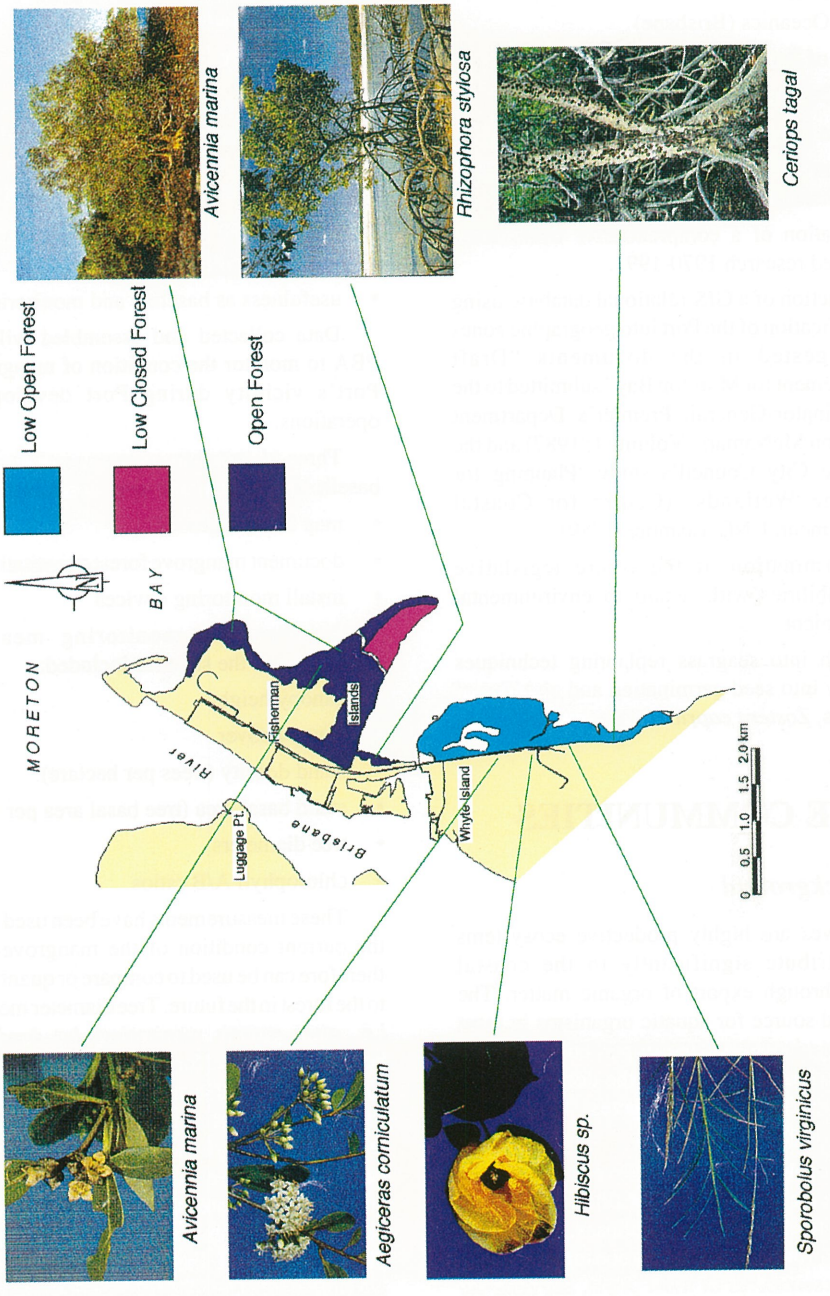
Six major components of the system were chosen for detailed, intensive field study in the period 1991/1992. The choice was largely governed by a consideration of the most likely impacts of the proposed development.

In the period 1991/1992, the baseline studies were performed by the following consultants:

- Mangrove / Wetland habitat
  WBM Oceanics (Brisbane)
- Seagrass habitat
  CSIRO Fisheries (Cleveland)

FIGURE 3

Port of Brisbane Authority: Mangrove Habitat Study - 1991/92



Illustrations from "Mangroves of Australia"
are published courtesy of Tom Turner and Richard Lear

- Sediment profiles / Current movements
  WBM Oceanics (Brisbane)
- Bird habitat
  Dr.P.Driscoll (Mt. Glorious)
- Fish habitat
  WBM Oceanics (Brisbane)
- Effects of Bait-worm digging
  WBM Oceanics (Brisbane)

  (Reports are contained in appendices I-VI)

These studies were complemented by PBA initiatives, including:

- Compilation of a comprehensive database of published research 1970-1991.
- Construction of a GIS-relational database using a classification of the Port into geographic zones as suggested in the documents "Draft Improvement for Moreton Bay" submitted to the Co-Ordinator-General, Premier's Department (Cameron McNamara; Volume 1: 1987) and the Brisbane City Council's study 'Planning for Brisbane Wetlands' (Centre for Coastal Management, UNE, Lismore, 1989).
- A determination of the future legislative responsibilities with regard to environmental management.
- Research into seagrass replanting techniques (initially into seed germination and viability of eel-grass, *Zostera capricornii*).

4 MANGROVE COMMUNITIES

Study Background

Mangroves are highly productive ecosystems which contribute significantly to the coastal ecosystem through export of organic matter. The primary food source for aquatic organisms in most mangrove-dominated estuaries is particulate organic material (detritus) derived from the decomposition of mangrove forest litter (leaves, twigs, and reproductive or fruit material).

During decomposition, mangrove litter becomes a food source for a wide variety of filter, particulate, and deposit feeders such as molluscs, crabs, and polychaete worms. These primary consumers, which include representatives of most phyla, are food for secondary consumers, usually small forage fish species and juveniles of the larger predatory species, that form the third consumer level. In addition, there are important fisheries species which occupy both primary and secondary consumer levels. They feed directly on particulate organic detritus and also upon primary consumers.

Mangroves function as important fish nursery and feeding grounds.

Methodology

Six sites were chosen for survey on Fisherman and Whyte Islands. These sites were selected on the basis that they appeared to be mature stands with high canopy. Parameters were selected to assess:

- conservation value
- present condition
- usefulness as baseline and monitoring sites

Data collected and assembled will allow the PBA to monitor the condition of mangroves in the Port's vicinity during Port development and operations.

Three bi-monthly surveys were completed and baseline measurements were conducted to:

- map the mangroves
- document mangrove forest quantitative structure
- install monitoring devices

Baseline and monitoring measurements undertaken at the six sites included:

- canopy height
- canopy cover
- stand density (trees per hectare)
- stand basal area (tree basal area per hectare)
- tree diameters
- chlorophyll A/B ratios

These measurements have been used to establish the current condition of the mangrove forest and therefore can be used to compare or quantify changes to the forest in the future. Tree diameter measurements i.e., stem growth monitoring, by dendrometer is believed to be novel for mangrove studies in Australia. Changes recorded in stem girth were consistent with the assessment of the forest as being mature and stable. Chlorophyll A/B ratio measurement is also believed to be novel in mangrove studies in Australia and leaf colour determined largely by this ratio will be coupled with data collected from digital photography and therefore should allow remote measurement of the condition in the mangrove forest.

Processing of remote sensing images (LANDSAT) of mangrove areas was also performed in this period and WBM Oceanics liaised with CSIRO and supplied ground truthing data. An image of the area was obtained for the 7th September, 1991 and the passover time of 09.30 corresponded to a tide height of 1.8 metres. The PBA also took aerial photographs of the study area at 14.30.

Concurrent with the capture of Landsat TM and aerial images:

- Ground level recordings of the radiance - reflectance of the mangrove canopy were made using Standard R, G, B filters and a digital F spotmeter.
- Turbidity profiles of the water in the channel off St. Helena along with radiance - reflectance of the water at approximately 1.5m height.

The mangroves were mapped delineating areas of similar colour and toning using the infra-red and green bands from LANDSAT images.

Results

In a regional context, the mangroves of the study area represent approx. 1.7% of the 13900 ha of mangroves in Moreton Bay and the saltmarsh-claypan of the study area represents 0.5% of the 5000 ha that occurs in Moreton Bay (Hyland and Butler, 1988; Dowling, 1986) (Figure 3).

The mangrove study showed that the mangroves at the study sites exhibited:

- Structure and composition typical of similar mangrove communities elsewhere in Moreton Bay.
- An overall appearance which did not indicate on-going adverse impacts.
- Litterfall which averaged 1.8 dry g/m2/day over the 17 weeks of the study. (Extrapolated to an annual figure of 6.6 dry t/ha/yr, it agrees closely with other litterfall studies conducted in Moreton Bay i.e. Davie, (1984)).
- A small stem growth increment over the duration of the study (<0.001%), probably indicating that the mangrove communities at the monitoring sites are mature and are at, or near, climax phase.
- No major structural changes in their communities at the sites over the monitoring period (September, 1991 to February, 1992).

Remote sensing analysis showed that there were 235.1 ha of mangroves in the study area. Five mangrove classes were identified from Landsat TM images. These were:

- a dense/high - canopy class (38.5 ha)
- a dense/mid - canopy class (124.8 ha)
- a dense/low - canopy class (46.2 ha)
- a seedling/mangrove fringe (22.7 ha)
- a class along the edge of the mangroves which was due to both mangroves and mud-flat being in a pixel (2.9 ha)

5 SEAGRASS STUDY

Study outline

The seagrass meadows at Whyte and Fisherman Islands were surveyed to assess:

- conservation value
- seagrass biomass and density variance estimates for sample design optimization
- baseline and monitoring sites

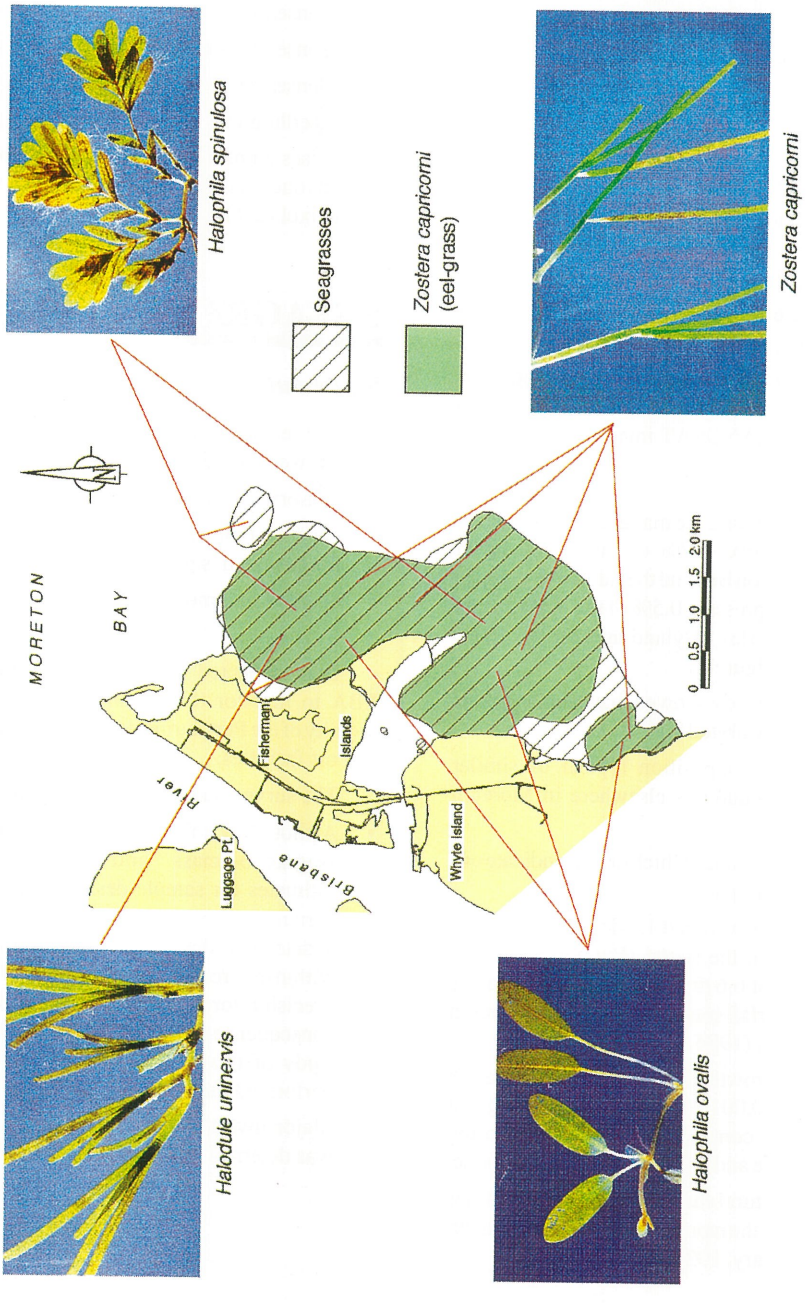
Data collected and assembled will allow the PBA to monitor the condition of seagrass in the vicinity of the Port during development and operation of Port facilities.

The survey had two complementary stages:

- A pilot study; this study was undertaken to obtain seagrass biomass and density variance estimates for sample design optimization. The variance estimates were used via Power Analysis to determine the number of sample sites required within the area for a nominated level of precision. Precision for the study was set at 12% and as a consequence of this, 480 sites were required. A study of this size and precision has not been performed in Australian studies before.
- Major investigation; the intensity of sampling was determined as a result of the pilot study.

FIGURE 4

Port of Brisbane Authority: Seagrass Habitat Study - 1991/92



Cribb AB & JW - Plant Life of Great Barrier Reef & Adjacent Shores - University of Qld Press, St Lucia - 1985

Methodology

The Seagrass survey was completed and baseline measurements were conducted to:

- map the seagrass
- document seagrass meadow quantitative structure
- locate monitoring sites using a satellite ground positioning system

At each of the sample sites, a grab sample of seagrass and sediment was retrieved. Seagrass so obtained was processed by:

- separating into species taxa
- separating above-ground shoots and stems
- separating below-ground rhizomes

For each species the following parameters were measured:

- number of shoots in each sample
- lengths and widths of ten randomly selected shoots
- weight of dried material in sample

From the above, the total leaf area per sample for each species was calculated using the average leaf area per shoot

Results

Pilot study

Results show four seagrass species, *Halophila ovalis, Halophila spinulosa, Zostera capricorni* and *Halodule uninervis* were found in the study area. The seagrass was dense and common on the intertidal banks but rapidly thinned out subtidally (Figure 4).

No seagrass was recorded deeper than 5m in the channel between St. Helena and Fisherman Islands. *Zostera capricorni* and *Halophila ovalis* were the most common species in the study area. Shoot density and leaf area for *Zostera capricorni* showed a fairly uniform distribution throughout the intertidal regions adjacent to the mainland, Fisherman Islands and on the mud-flats off St. Helena Island. However, *Z. capricorni* was four times as dense off St. Helena Island compared to the mainland and Fisherman Islands. *Halophila ovalis* distribution was not as uniform as *Z. capricorni* but it occurred throughout the study area. In contrast, *Halophila spinulosa* and *Halodule uninervis* distributions were very patchy. They were largely restricted to a small area 2000m off the northern end of Fisherman Islands.

Similarly, the leaf area for the four seagrasses followed the same patterns of distribution as the biomass and shoot density values.

The study area was stratified (layered by depth) from a colour photographic mosaic provided by the PBA. Seven strata were identified; six seagrass strata and a subtidal channel area. The six seagrass strata were: intertidal high density seagrass on the mudflats off Fisherman Islands; worming areas on the intertidal mudflats off Fisherman Islands; patchy seagrass areas; very sparse seagrass areas; patchy low density seagrass near Oyster Point; and, high density seagrass near St. Helena Island.

Within the six seagrass strata, *Z. capricorni* dominated in biomass, shoot density and leaf area. This seagrass comprised well over 80% of the biomass, leaf area and shoot density for most strata. The shoot density in the Oyster Point strata was an exception with *H. ovalis* contributing up to 40% of the shoots. The highest average above ground biomass was in the patchy seagrass strata. In contrast, the St. Helena strata was highest for below ground biomass and shoot density.

The stratified mean was 45.8 gm/m2. This gives an estimate of 564 tonnes of seagrass above ground plant material in the study area. The precision of this estimate is low (39%) since the purpose of the pilot study was to obtain seagrass biomass and density variance estimates for future sample design optimisation. However, this method of allocating samples among the strata based on the strata area and variance estimates (Neymann allocation), resulted in improvements of over 10% in the precision obtained compared to a simple random sample.

Landsat processing and aerial photography

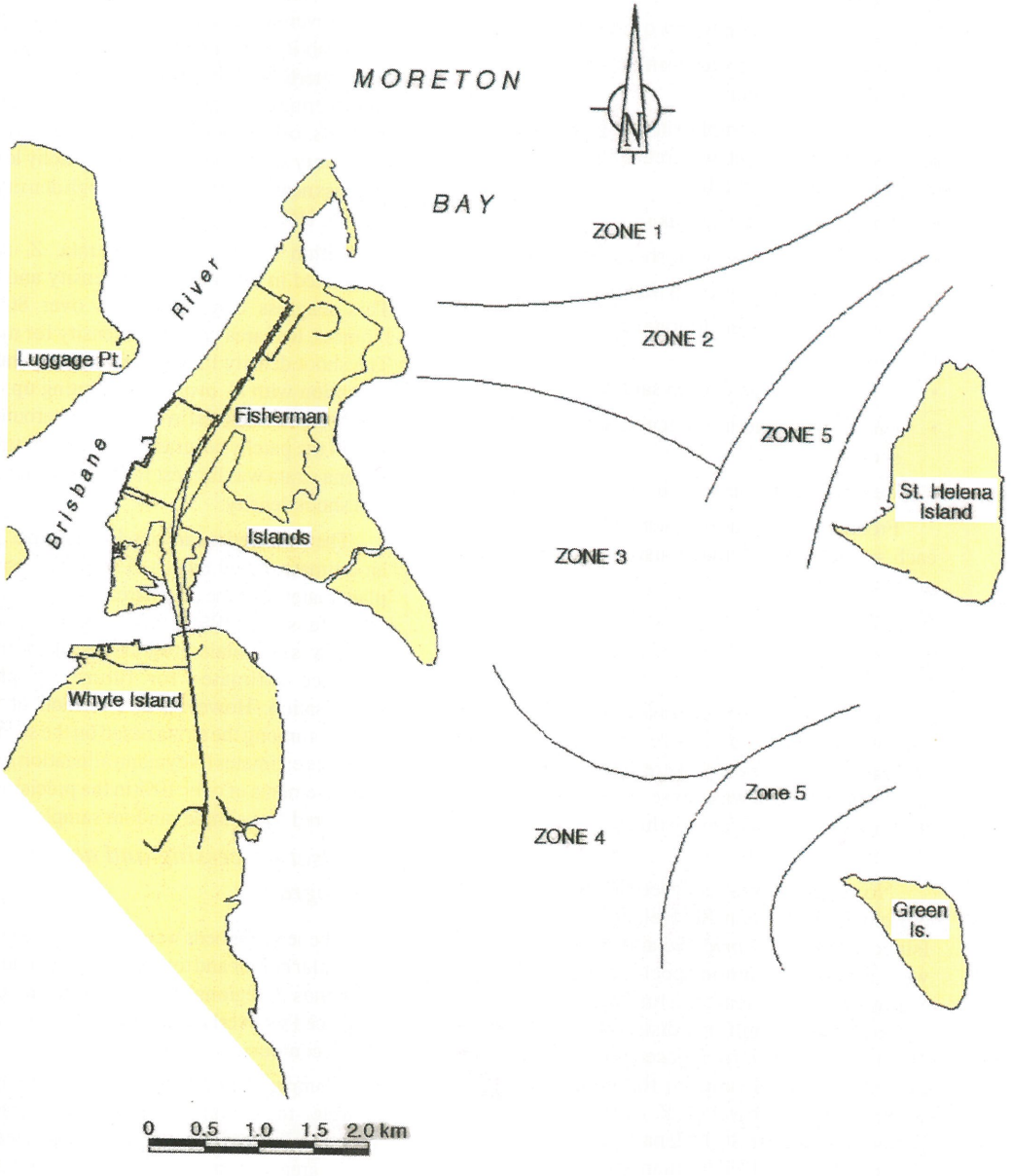
The seagrass beds were mapped delineating areas of similar colour and toning using the blue, green and red bands. A regional perspective of the seagrass was produced by overlaying the rectified image onto the depth contours.

Compared to field studies based on simple random sample, there were large gains in precision (% accuracy of prediction) for most species when the study area was stratified based on depth digitized area photographs or Landsat satellite mapping.

Levels of precision also were found to differ depending on which seagrass species was being mapped, which stratification method was used (aerial photography or Landsat) and what parameter was being recorded eg, above ground biomass.

FIGURE 5

Port of Brisbane Authority: Sedimentation Zone Study - 1991/2



The most accurate predictive relationships were the correlations between:

- below ground biomass *spectral band (Landsat)
- below ground biomass *depth (Aerial photography)
- shoot density *depth (Aerial photography)

There was 1190ha seagrass supporting habitat in the study area. Of the seven strata which were identified, the follwoing areas were included:

- dense seagrass 807.8 ha
- worm digging area 45.4ha
- very patchy seagrass 125.6 ha

The seagrass areas recorded at St Helena Island and Oyster point were 14.9 ha and 63.8 respectively

6 MARINE CURRENTS AND SEDIMENTS

Study outline

The composition and behaviour of ecological communities in nearshore marine areas are strongly related to the nature of the sediments, pattern of sedimentation and scour. Sediment composition is significantly influenced by current patterns induced by wave, tide and wind influences.

The objectives of the current and sediment study were to describe and quantify:

- general current patterns
- current velocities
- the effects of tide and wind on the above

These objectives were to be achieved through the use of computer modelling techniques based on:

- definition of the bathymetry of the area from survey data
- input of tidal and wind boundary forcing data

A two-dimensional model was linked to a one-dimensional model of the Brisbane River to take into account flow to and from the River mouth, and the link via the Boat Passage.

Results

Results from the model show that the study area has five broad zones of distinctly different hydrodynamic character (Figure 5) and these would be expected to display different sedimentation patterns.

They are:

Zone 1

The northern banks directly east from Bishop Island, with relatively low shear stresses but exposed to wave action from east to north directions. Highly variable in the northern banks, with areas of silts, sandy silts and silty sands depending on the degree of exposure to wave action. Some exposed patches may contain relatively clean sand.

Zone 2

A zone of shallow banks with high tidal current related bed shear stresses, extending eastward from the northern part of Fisherman Islands and past the northwestern tip of St. Helena Island. Sand and silty sand on the shallow banks where high bed shear stresses occur.

Zone 3

A large, more or less circular, zone of low bed shear stress, adjacent to the central parts of Fisherman Islands, and significantly sheltered from waves by St. Helena and Green Islands. Silts and sandy silts in the large sheltered zone where low bed shear stresses are identified.

Zone 4

A zone of moderate bed shear stress, towards the southern nearshore area, being the principal flowpath to and from the Boat Passage. Mixed bed sediments and relatively high water turbidity in the southern areas leading to the Boat Passage, with a net movement of sediments towards the Passage and zones of bed shear capable of continually re-suspending this material.

Zone 5

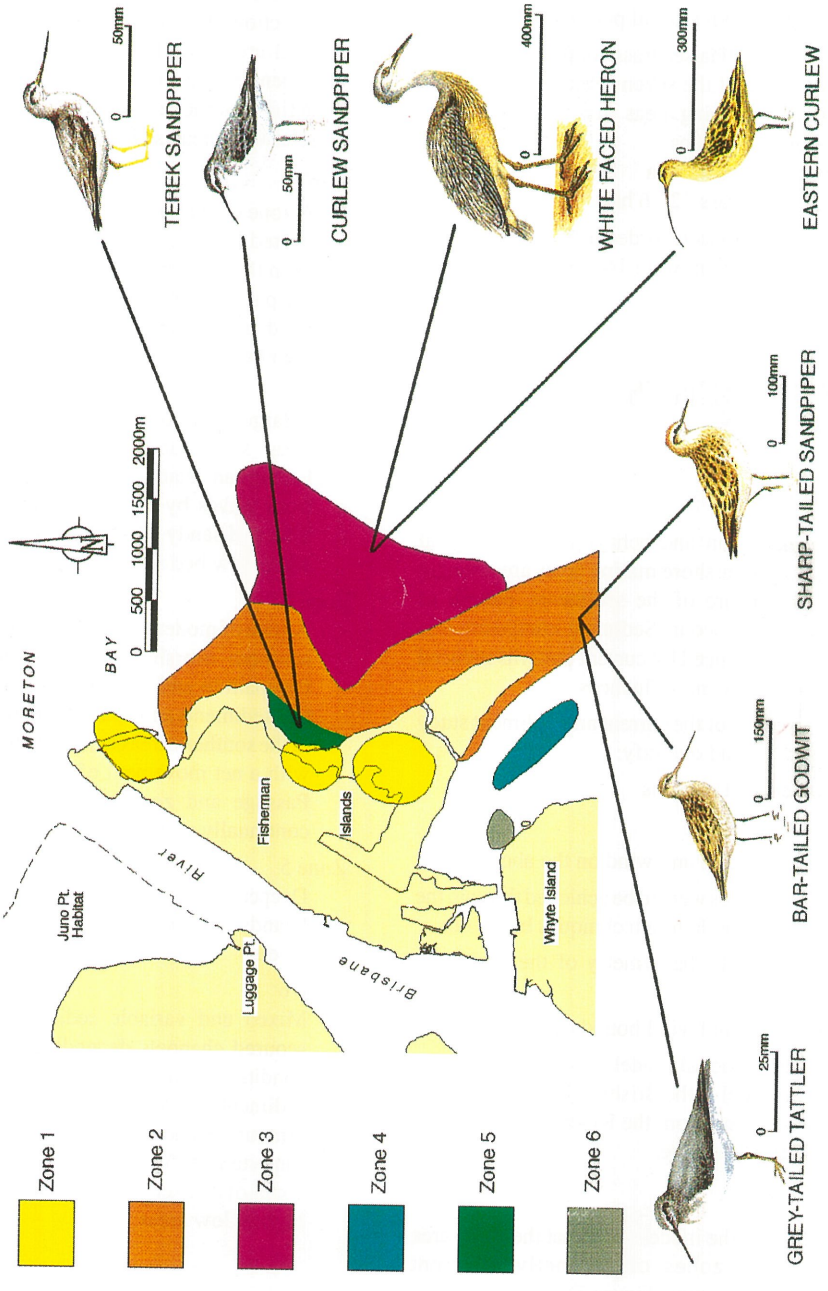
Deeper channels adjacent to St. Helena and Green Islands with moderate to high bed shear stress levels.

Zone 6

Mixed and variable sediments in the deeper scoured channels depending on the tide range conditions, sediment supply and relict sub surface sediments at any given time and place. Bed armouring and/or cohesive properties may be important in fine silt areas. There may also be zones of coarser sands or exposed bedrock in the higher flow areas.

FIGURE 6

Port of Brisbane Authority: Bird Habitat Study - 1991/92



Illustrations from "What Bird is That?" by Neville Cayley, Published courtesy of Angus & Robertson Publishers

7 BIRD COMMUNITIES

Study Outline

The objectives of this study were to determine the distribution, relative density and movement patterns of birds around Fisherman Islands and where appropriate relate these findings to other areas of Moreton Bay. The focus of the study is on birds using the littoral zone (intertidal mudflats) which is still largely intact i.e., not impacted by Port development. Less detailed consideration is given to forest (mangrove) birds and those that mainly occur in open grassland which has been artificially created on Fisherman Islands.

Because of the dramatic seasonal changes that occur in the bird communities around Fisherman Islands, three periods of field work were undertaken; a winter sampling in July, a spring sampling in October and a summer sampling in January. The fieldwork was most intensive during spring which is the time of highest bird numbers because of the southward through-movement of migratory waders. The tide has an overriding influence on the activity of birds that feed on intertidal mudflats. Local distribution was assessed during both high and low tides, and consideration was given to the positioning of high tide roosts with respect to low tide feeding areas.

Particular emphasis is placed on the importance of migratory waders for three reasons:

- As a group they are becoming increasingly affected by environmental constraints throughout their migratory range, which can extend from the sub-Arctic to southern parts of Australia.
- They rely upon feeding and breeding areas in a number of countries, and their requirements have been the focus of inter-government discussion. A large proportion of the migratory waders that occur in Moreton Bay are subject to the RAMSAR convention, an international migratory bird agreement.
- Moreton Bay is arguably the most important feeding area for migratory waders along the coastline of eastern Australia, evidenced by the large numbers of birds which aggregate in the area during the southern migration period.

Sampling methods

Three habitats were systematically sampled: mangrove forest along transects; exposed intertidal areas; and high tide roost sites. All other field work involved random observations to record the number and location of birds seen, and whether they were feeding, flying or roosting. A large body of incidental sightings was accrued at all stages of the tide and mapped.

Results

Over the sampling period, 84 bird species were recorded. About 10% are uncommon around Moreton Bay, 30% could be considered moderately common, and the remaining 60% common to very common for at least part of the year.

Food categories

The diets of the Moreton Bay species can be broken into the following food categories:

- small vertebrates (20%)
- seeds (25%)
- other plant products (including nectar, fruit or soft shoots) (20%)
- fish (25%)
- terrestrial invertebrates (45%)
- aquatic invertebrates (55%)

These food categories are not mutually exclusive, and do not necessarily apply to the actual foods consumed around Fisherman Islands, however, they can be assumed to be similar. Species can also be assigned to one or more of three broad habitat categories that occur on Fisherman Islands:

- 61% are coastal and will utilise intertidal mudflats and/or open water
- 32% utilise mangroves
- 10% may be found in open areas of grass and reeds

(Note that there is habitat utilization overlap for categories)

Zonation

Figure (6) shows a broad zonation for major bird activities or species composition as revealed by field observation and analysis by clustering techniques. Zone descriptions are as follows:

Zone 1

The three major high water roost sites. The roost at Bishop Island is used by species which forage mainly on the exposed intertidal mud-flats around Fisherman Islands, but also, notably, at Juno Point, where there are extensive feeding areas for a different mix of species.

Zone 2

Areas characterized by high species diversity. The intertidal mud-flats represent the primary feeding area for waders. A soft muddy surface layer has a relatively firm sandier sub-surface. The area is dominated by three species (Grey-tailed Tattler, Bar-tailed Godwit and Sharp-tailed Sandpiper) which comprise 73% of the total abundance. Note that seagrass areas within the zone range from dense seagrass (adjacent to the Boat Passage, westward) to very sparse/absent at the easterly extent (refer CSIRO seagrass study). *Zostera capricorni* is the dominant species of seagrass over the area and the sediment type is described (WBM Oceanics study, currents and sediments) as an area of low bed shear stress with significant shelter from waves, afforded by St. Helena and Green Islands.

Zone 3

Characterized by larger waders, notably the Eastern Curlew and White Faced Heron, which can exploit the deeper seagrass meadow. The area is similar in seagrass composition, sediment type and hydrology to zone 2.

Zone 4

East of the Boat Passage. It has a species mix derived from those present in zones 1 & 2 with species found at sites to the south of Wynnum foreshores. This is described (WBM Oceanics) as an area of moderate bed shear stress being the principal flow path to and from the boat passage. *Zostera capricorni* is the dominant species of seagrass.

Zone 5

The zone is characterized by Terek & Curlew Sandpipers. The sediment is particularly muddy and lacks seagrass and the birds here prefer to feed on the invertebrate infauna characteristic of soft mud.

Zone 6

A second area east of the Boat Passage. An important staging area for various species when moving on and off their high water roosts. Not just a feeding area (similar to zone 4).

This study shows that the area is of local and regional significance to birdlife. The proximity of habitat protection, and port and industrial zoning on Fisherman Islands, raises special management issues. There is either direct overlap of important bird habitat zones or little buffering between areas. Areas utilized by birds, in particular roost sites, cater for significant numbers of birds, and at least as many as any site on the foreshores of Moreton Bay. It is also noteworthy that the species of wader common on the feeding grounds at Fisherman Islands are not necessarily common in other parts of Moreton Bay.

In particular, Marsh Sandpipers and Black-tailed Godwits are generally uncommon in Moreton Bay but were regularly recorded on or around Fisherman Islands. Furthermore, the high density of Sharp-tailed Sandpiper at Fisherman Islands is unmatched elsewhere in the Bay.

Preservation of areas of intertidal mudflats and mangrove forest at Fisherman Islands would be of considerable benefit to local resident bird populations, and to migratory species which use the site opportunistically in transit along the eastern seaboard. The site has certain unique values not found elsewhere in Moreton Bay.

8 FISH STOCKS

Study outline

This fish stock study was undertaken to provide information on commercial fishing operations and the fisheries importance of aquatic habitats present in the Fisherman Islands region.

Information Base

This study has been compiled from information provided by several sources including:

- Queensland Fish Management Authority (QFMA)
- Queensland Department of Primary Industries (DPI, Fisheries)
- Queensland Commercial Fisherman's Organization (QCFO)
- Several commercial fisherman who regularly operate adjacent to Fisherman Islands. Some of the information was supplied in confidence by commercial fisherman and is consequently not included in the published report (WBM Oceanics, Fish Habitat Study; Appendix V).

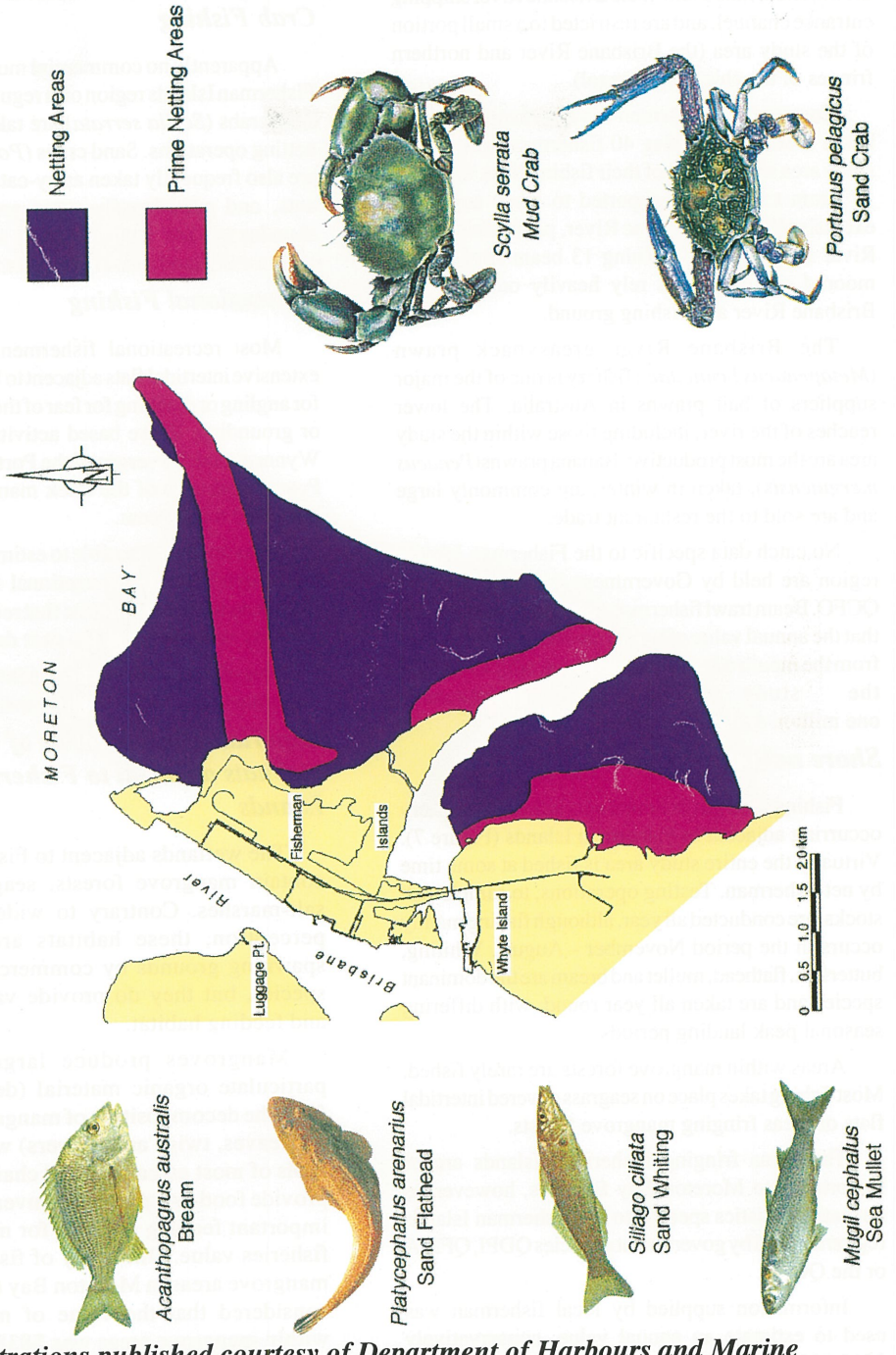
Commercial Fishing Operations

Three main types of commercial operations excluding bait worm digging occur in the study area. These are:

- beam trawling
- mesh (gill) netting
- tunnel netting
- shore netting

FIGURE 7

Port of Brisbane Authority: Fish Habitat Study - 1991/92



Illustrations published courtesy of Department of Harbours and Marine Queensland Government

Beam Trawl

Beam trawl operations cannot legally occur on the intertidal flats south of the Brisbane River shipping entrance channel, and are restricted to a small portion of the study area (the Brisbane River and northern fringes of the shipping channel).

Commercial fishermen advised that approx. 30 beam trawlers involving 40 fisherman work in the study area at least 50% of their fishing time. Of these, 17 beam trawlers are reported to moor and work exclusively in the Brisbane River, particularly at the River mouth. The remaining 13 beam trawlers are moored elsewhere but rely heavily on the lower Brisbane River as a fishing ground.

The Brisbane River greasyback prawn (*Metapenaeus bennettae*) fishery is one of the major suppliers of bait prawns in Australia. The lower reaches of the river, including those within the study area are the most productive. Banana prawns(*Penaeus merguiensis*), taken in winter, are commonly large and are sold to the restaurant trade.

No catch data specific to the Fisherman Islands region are held by Government Authorities or the QCFO. Beam trawl fisherman conservatively estimate that the annual value of beam trawled prawn landings from the mouth of the Brisbane River, which includes the study area, is approaching one million dollars per year.

Shore netting

Fishing with gill or tunnel nets is the main fishery occurring adjacent to Fisherman Islands (Figure 7). Virtually the entire study area is fished at some time by net fisherman. Testing operations, to sample fish stocks, are conducted all year, although fishing mainly occurs in the period November - August. Whiting, butterfish, flathead, mullet and bream are the dominant species and are taken all year round, with differing seasonal peak landing periods.

Areas within mangrove forests are rarely fished. Most fishing takes place on seagrass covered intertidal flats or areas fringing mangrove forests.

The areas fringing Fisherman Islands are of importance to Moreton Bay fisheries, however no net catch statistics specific to the Fisherman Islands region are held by government agencies QDPI, QFMA or the QCFO.

Information supplied by local fisherman was used to estimate an annual value, conservatively $560,000 a year. This represents 10% of the gross annual value of finfish caught in Moreton Bay. By weight, the study area produces 100-150 tonnes of fish per year, which also relates to approx. 10% of the QFMA estimates of 1300 - 1400 tonnes of fish landed annually in Moreton Bay.

Crab Fishing

Apparently no commercial mud crabbers use the Fisherman Islands region on a regular basis, although mud crabs (*Scylla serrata)* are taken as by-catch in netting operations. Sand crabs *(Portunus pelagicus*) are also frequently taken as by-catch in mesh/tunnel nets, and occasionally traps are set when crab abundances are high. Reports indicate that one commercial sand crabber frequently fishes this area.

Recreational Fishing

Most recreational fishermen do not use the extensive intertidal flats adjacent to Fisherman Islands for angling or crabbing for fear of their boats stranding or grounding. Shore based activities are limited to Wynnum and the verges of the Port Drive at the Boat Passage because of the thick mangrove fringe and restricted road access.

It has not been possible to estimate the size of the total catch taken by recreational fishermen. Other studies do however estimate that recreational fishing intensity will double in the next decade.

This will result in greater utilization of areas near Fisherman Islands for angling and bait collection.

Importance to Fisheries of Wetland Habitats adjacent to Fisherman Islands

The wetlands adjacent to Fisherman Islands contain mangrove forests, seagrass beds and salt-marshes. Contrary to widely held public perception, these habitats are not used as spawning grounds by commercially important species, but they do provide valuable nursery and feeding habitat.

Mangroves produce large amounts of particulate organic material (detritus) derived from the decomposition of mangrove forest litter (ie. leaves, twigs and flowers) which forms the basis of most estuarine food chains. Mangroves provide food and shelter for juvenile fish and are important feeding grounds for many species of fisheries value. One study of fish utilization of mangrove areas in Moreton Bay (Morton, 1990) considered that the value of marketable fish within mangrove areas was $8380 per hectare.

Research by QDPI on seagrass beds adjacento Fisherman Islands indicates that seagrass beds are of

FIGURE 8

Port of Brisbane Authority: Baitworm Habitat Study - 1991/92

substantial importance for fish and prawns. Seagrass beds also provide habitat for worms which form the basis of a major baitworm fishery in the study area.

9 THE BAITWORM INDUSTRY

Study outline

Some intertidal areas adjacent to Fisherman Islands are utilized by commercial baitworm diggers. The baitworm fishery provides a major bait supply for local anglers targeting estuarine fish such as bream, whiting and flathead.

The objectives of the study were to:

- Map the major worm collecting areas in the region near Fisherman Islands.
- Describe the characteristics of the baitworm fishery operating near Fisherman Islands.
- Comment on the impact (short and long term) of present worm digging operations on seagrass beds and other areas of ecological importance.
- Assess the sustainability of existing collecting operations in the Fisherman Islands region.

Usage

Information supplied by QDPI indicates that 70 commercial baitworm diggers (mudworm only) operate in Moreton Bay, although the number varies annually from 60 - 80. Discussions with commercial fishermen indicate that 30 - 40 fishermen regularly work the area adjacent to Fisherman Islands which is considered to be the most heavily utilized area in Moreton Bay. On some occasions many unlicensed commercial operators are present in the area.

Commercial fishermen report that relatively few amateur fishermen dig in their areas presumably because access is restricted (by boat only). Most amateur operations occur in more landward areas near Wynnum where access is easier.

Digging generally occurs during the day although some diggers are equipped to work during the night (lights etc.,) if the demand for bait is high. Fishermen generally only dig in seagrass areas to the low water spring tide mark. Although mudworms occur in unvegetated areas, worm abundance is greatest in seagrass areas and hence almost all digging occurs in such areas.

Results

The main digging areas at Fisherman Islands cover approx. 180ha (refer figure 8). This area was determined on the basis of the regions in which seagrass has been disturbed by digging activities (Figure 8).

Enquiries at several bait shops indicated that retail prices of worms in 1991 ranged from $0.50 to $1.75 per worm depending upon size. Some retail outlets sell worms on a weight basis.

No data on the total catch value of the mudworm fishery in Moreton Bay are available from QDPI. Discussions with baitworm diggers in association with the present study, suggest that the Fisherman Islands region produces approx. $500,000; however, using the detailed study of Forbes (1984) the catch would be valued at considerably more than this.

Recommendation

All digging should be controlled by DPI and the destructive impact on the seagrass must be monitored. All worm diggers should have their past digging areas checked periodically so as to ensure that they carefully remove and replace seagrass during digging efforts. (Past studies show that failure to replace seagrass sods has led to erosion and little, if any, seagrass growth).

The present system where bait collectors are able to dig areas on an unrestricted basis inhibits efficient use of the baitworm grounds and should be reviewed.

10 SYNTHESIS AND PRIORITIES FOR ONGOING STUDIES

Baseline studies

In this first volume of Baseline Studies, it was intended that the major environmental elements be included. If there were other elements deserving of more detailed study then it was anticipated that these would be identified during this first study period. It is intended that the baseline studies are to be replicated over an initial three year period (1991-1994) and thereby quantify natural variation within the study area and identify any impacts resultant from development. As the studies progress, it will be possible to input environmental considerations into engineering processes at the time of construction.

Strategic planning

During this initial period there has been the emergence of two significant strategic plans:

- Key Port Brisbane: Strategic Plan to 2005 and Beyond (Endorsed by Cabinet 27th January, 1993).
- Moreton Bay Strategic Plan (Moreton Bay Marine Park gazetted 19th February, 1993) (Figure 9).

Concurrently, an inter-agency working group determining Brisbane River and total catchment management has been established (Brisbane River Management Group).

It is essential that the management associated with the above have a management link with common goals which mimic the characteristics of the system at hand. For example, as stated in Section 2, there is an interaction and a link from the Brisbane River Catchment to the greater South Pacific Ocean. The management groups must recognize that environmental management decisions will impact from the river catchment area 'downstream' to Moreton Bay, while economic, cultural and recreational decisions in relation to Moreton Bay will largely impact 'upstream' on the management of the river catchment area.

Research

With consideration of the management interaction suggested above, it will be necessary to coordinate all studies from the various groups and thereby share resources to optimize the research effort needed. In the future, it is likely that PBA studies will be conducted in a three tier administrative structure.

The tiers will be:

(1) The PBA will coordinate the baseline studies and interact with the other groups and agencies.

(2) Consultants will perform the baseline studies according to their brief, and with the prescribed resources agreed upon in contracts.

(3) The PBA will oversee relevant university post-graduate research investigations into specific topics directly related to the Port.

Within this three tier management structure there will be the opportunity for levels (2) and (3), to interact directly and thereby enhance each other's research effort by the sharing of common resources and intellectual property.

Results from this research will be published in subsequent volumes to this baseline study report and in relevant journals.

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APPENDIX I

FISHERMAN ISLANDS
TIDAL WETLANDS STUDY

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EXECUTIVE SUMMARY

Fisherman and Whyte Islands have been developed as a major port facility at the Brisbane River mouth by the Port of Brisbane Authority (PBA). The PBA foresees the need to expand port capacity which will involve disturbance of intertidal and subtidal lands of the Fisherman Islands, some of which are vegetated by mangroves.

This report describes the results of a study, commissioned by the PBA, to collect baseline data on mangrove communities in the Fisherman Islands region and initiate monitoring programs.

Of the tidal wetlands in the study area (Fisherman Islands, Whyte Island and the Wynnum foreshore) - mangroves, seagrass and saltmarsh - mangroves are the most conspicuous.

Saltmarsh vegetation collectively covers only a few hectares in the study area and is probably of much lesser importance to fisheries than mangroves or seagrasses. Saltmarsh vegetation is associated with unvegetated intertidal areas, referred to as claypan, which combined with saltmarsh, occur over less than 25 ha of the study area.

Mangrove areas cover approximately 240 ha. Mangrove communities of Moreton Bay are highly productive and structurally complex. They provide large amounts of plant litter, an important primary food source for aquatic organisms of mangrove-dominated estuaries. Mangroves are also important nursery and feeding grounds for many fishes and crustaceans, most of which are of direct importance to commercial and recreational fisheries.

Seagrass beds, ranging in cover from high density to sparse, occur in intertidal and subtidal areas covering approximately 1200 ha in the Fisherman Islands region. Seagrass beds provide large amounts of leaf litter (the basis of important food chains), and are important feeding areas for dugong, turtles, some fishes and juvenile prawns. Natural disturbances can cause wide variations over time in the extent and distribution of seagrass beds whilst mangrove forests tend to be more temporally stable.

In a regional context, the mangroves of the study area on Fisherman Islands represent 1.7% of the 13900 ha of mangroves in Moreton Bay. The saltmarsh-claypan of the study area represents 0.5% of the 5000 ha that occurs in Moreton Bay.

The mangrove study has gathered data on the structure and productivity of mangrove communities at six sites in the study area during September 1991 to February 1992. This data will enable detailed comparisons to be drawn between mangrove communities prior, during and following reclamation works. Key findings of the baseline studies are:

- The mangroves at the monitoring sites were typical in structure and composition to mangrove communities elsewhere in Moreton Bay.
- Mangroves are not subject to on-going adverse impacts.
- Litterfall averaged 1.8 dry g/m2/day over the 17 weeks of the study. Extrapolated to an annual figure of 6.6 dry t/ha/yr, it agrees closely with other litterfall studies conducted in Moreton Bay.
- Stem growth over the duration of the study was very small, probably indicating that the mangrove communities at the monitoring sites are mature and are at, or near, a climax phase.
- No major structural changes in the mangrove communities at the sites were observed over the monitoring period (September 1991 to February 1992), nor were they expected although changes may occur over a longer term.

Further monitoring is necessary to reveal seasonal patterns in litterfall and stem growth rates and provide data appropriate to quantifying any long term impacts to mangrove communities adjacent to Fisherman Islands resulting from reclamation operations.

Litterfall monitoring continued over the next 6-8 months would provide data encompassing the full range of seasonal variation in productivity. Litterfall collection should be made preferably at intervals of no more than two months; longer than this and trapped litter begins to decompose and result in litterfall production being underestimated.

Stem increment/decrement readings need only be collected every four months. These readings should also be continued for at least one year to be able to arrive at an actual annual stem girth increment figure.

The first 12 months of monitoring would provide the minimum necessary for a baseline data set. Further monitoring should then continue during and following reclamation, to assess any impacts upon mangrove productivity. The frequency of future monitoring could be assessed on the basis of the results from the baseline study and proposed reclamation schedules.

1.0 INTRODUCTION

The Port of Brisbane Authority (PBA) has developed Fisherman and Whyte Islands as a major Port facility at the mouth of the Brisbane River. Tidal wetlands (saltmarsh, mangroves and seagrass) occur on and adjacent to the islands.

The PBA has identified a long term need to expand the capacity of the Port to accommodate a future expansion in port usage. The draft Moreton Bay Strategic Plan, designed to ensure appropriate land use within Moreton Bay, identifies lands adjacent to Fisherman Islands for Port related activities.

Further expansion of Port related facilities on the southern side of the mouth of the Brisbane River, proposed by the PBA, will require disturbance of intertidal and subtidal lands near the Fisherman Islands, some of which support mangroves.

WBM Oceanics was commissioned by the PBA to undertake studies of tidal wetlands occurring on and adjacent to Whyte and Fisherman Islands and the Wynnum foreshores. The study area is shown diagrammatically in Figure 1.1, in recent aerial photography (1991) in Figure 1.2 and in historical aerial photography (1958) in Figure 1.3.

The studies were to:

- describe the ecological value of wetlands adjacent to Fisherman Islands.
- document the existing distribution and structure of mangroves in the vicinity of the Port and;
- to initiate a program of monitoring mangrove areas.

The results of the study will provide the PBA with background information for port management and development strategies. Section 9.0 provides a glossary of terms used in this report.

2.0 ECOLOGICAL VALUE OF WETLANDS

The term tidal wetland is used in the present study to refer to plant communities influenced by tidal action. It includes subtidal areas to an Australian Height Datum (AHD) depth of 6 metres.

Estuarine wetlands, including mangroves, are among the most productive natural ecosystems in the world providing:

- nursery and feeding grounds for commercially important fish and other estuarine fauna.
- breeding, roosting and feeding areas for local and migratory birds.
- nutrient sinks, regulating nutrient flow into the estuary and nearshore region.
- contaminant traps and sediment filters (Hutchings and Saenger 1987).

2.1 Saltmarshes

Almost all available literature on Australian saltmarsh is descriptive, with information on its vegetation, either as species lists or as factors producing zonation patterns (Clark and Hannon 1967).

The dominant vegetation of saltmarshes in the Moreton Region is samphire bushes (eg. *Sarcocornia quinqueflora, Suaeda australis*) and marine couches (*Sporobolus virginicus*; Durrington 1974, 1977). Approximately 15% of the high tides inundate this habitat annually. The most comprehensive study on saltmarshes in the Moreton Region was by McLeod (1969). That study provided a general description of mangrove and saltmarsh vegetation in the Region, described the algae present, and gave a global literature review of the macroscopic algae in saltmarshes and mangroves.

Only one study (Morton et. al. 1988) has examined the fisheries value of Australian saltmarshes and most available information relates to the North America region. Australian and American saltmarshes are markedly different in structure and species composition and comparisons between them are spurious at best.

Studies by Morton et al. (1988) at Coomera Island (southern Moreton Bay) concluded that:

- relatively few fish utilise saltmarsh, as aquatic habitat is limited to isolated pools filled by rainwater and large spring tides.
- the abundance of fish fluctuates widely on a seasonal basis with most fish occurring in summer months when pool water levels are high.
- relatively few species important to commercial fisheries use the upper littoral saltmarsh habitat.

FIGURE 1.1

Study Area

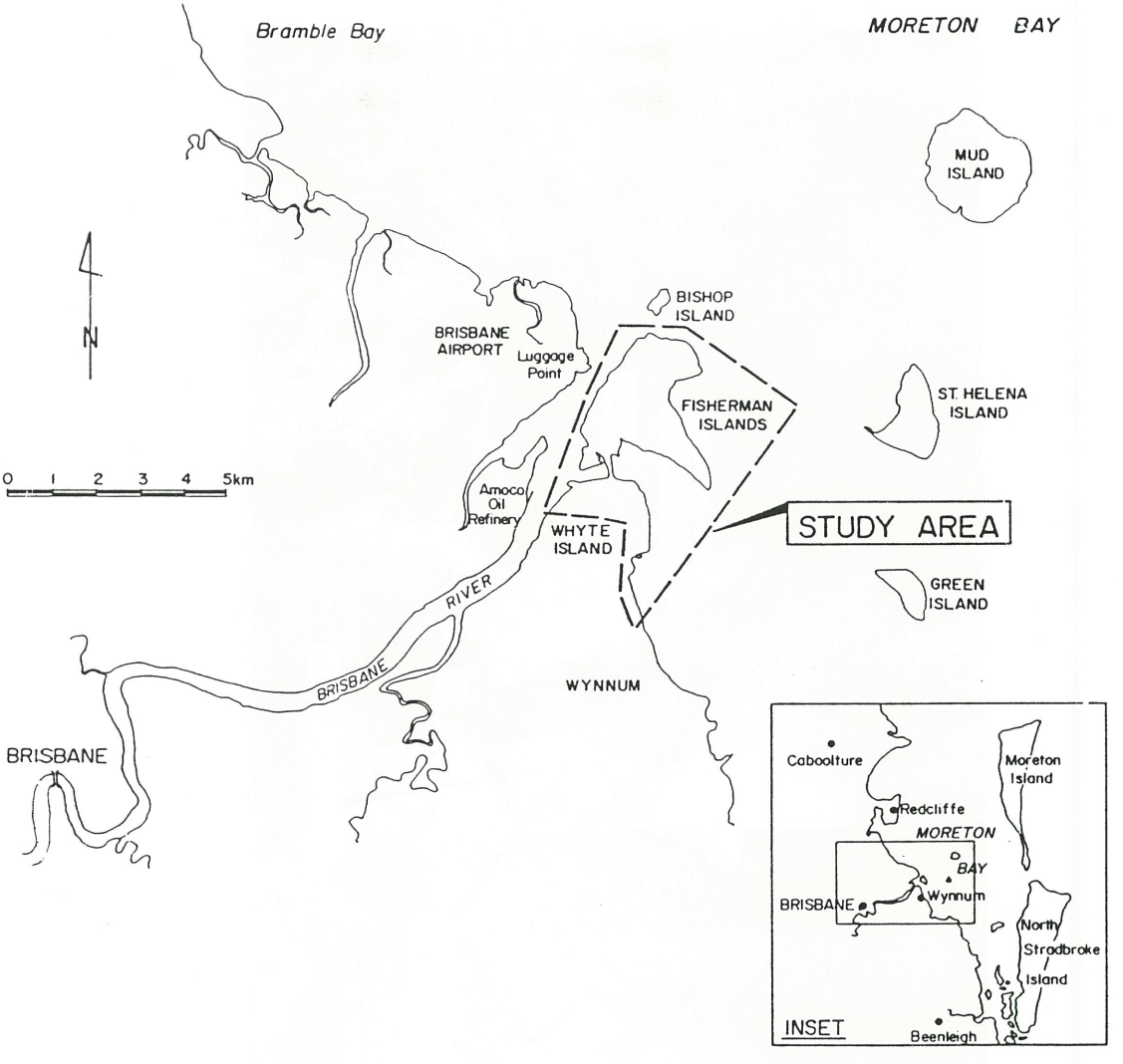


FIGURE 1.2

1991 Aerial Photography of Study Area

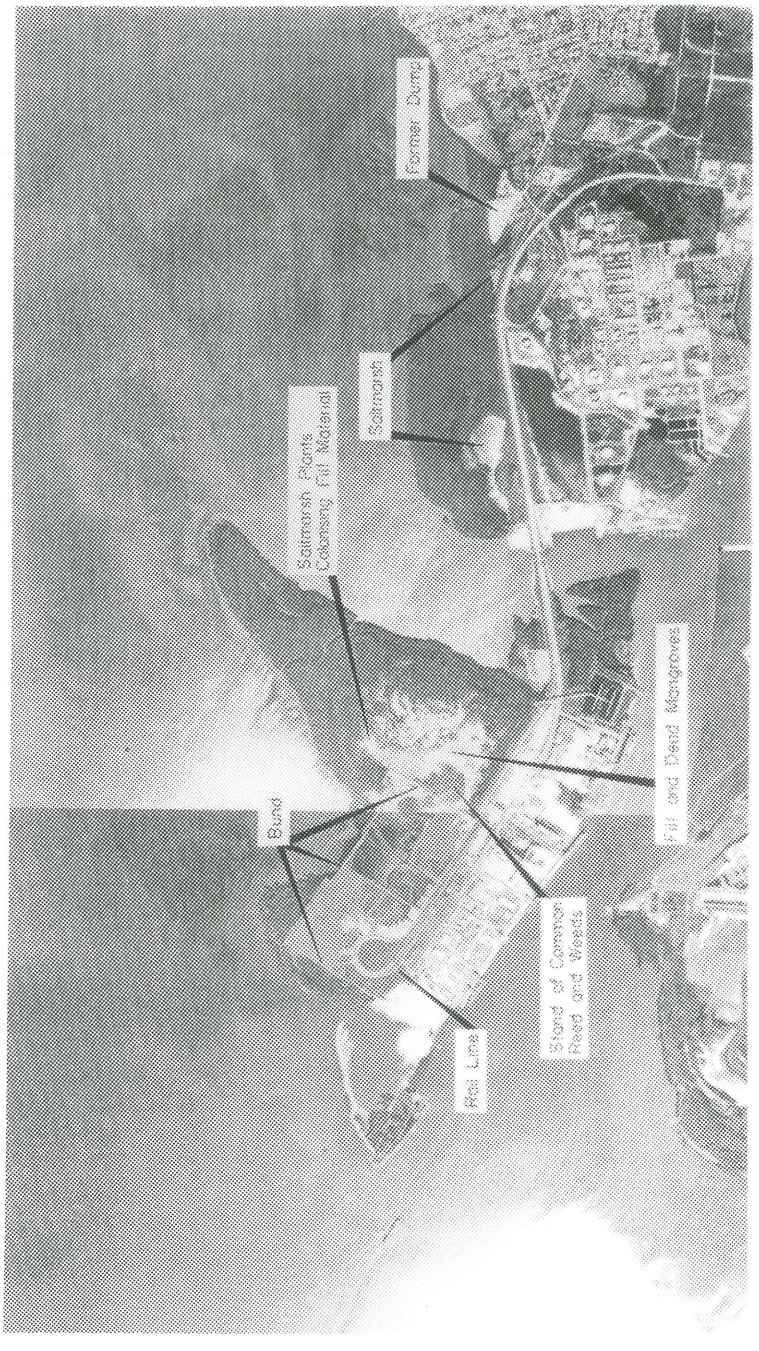
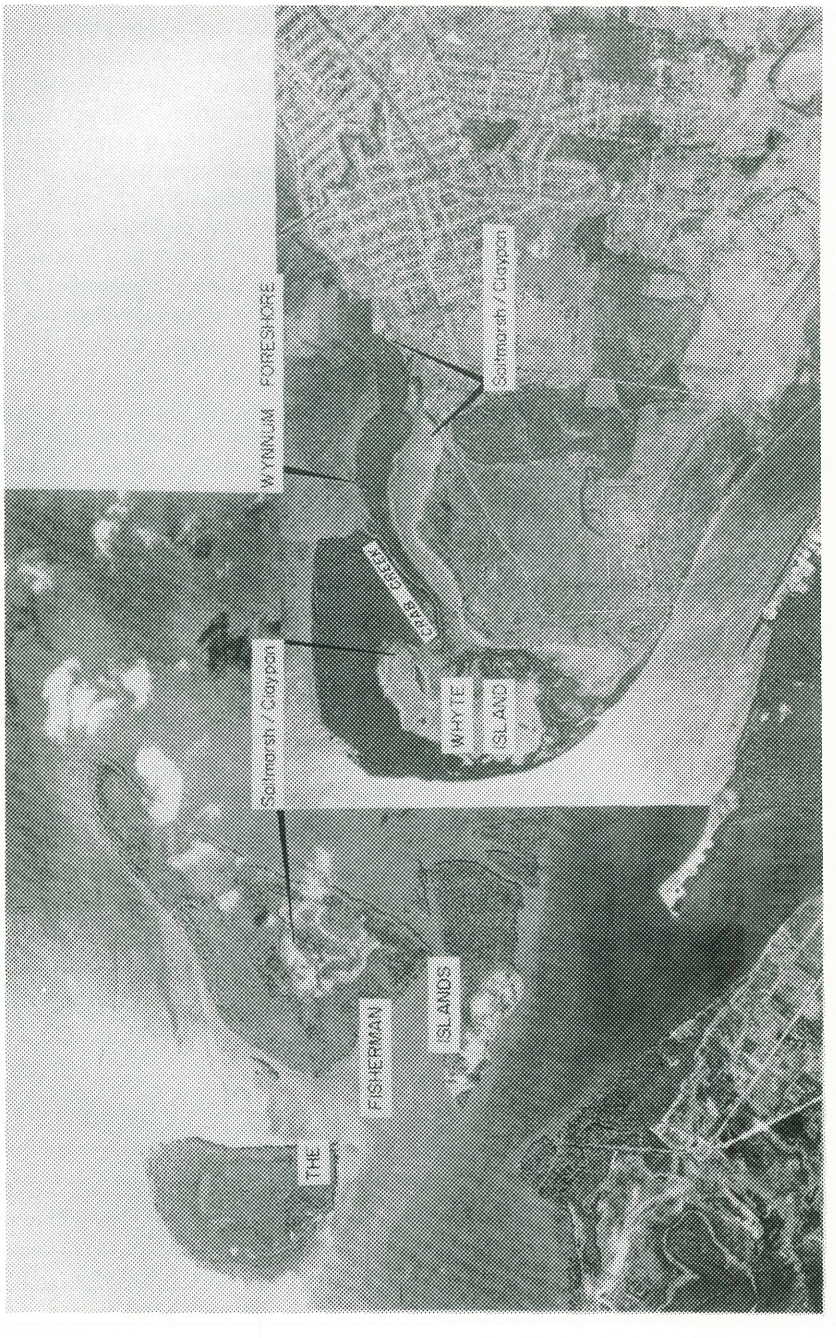


FIGURE 1.3

1958 Aerial Photography of Study Area



Tidal inlets to saltmarshes, which are often lined with mangroves, provide habitat for juvenile fish (Morton et. al. 1987). The diversity of fish assemblages utilising such inlets is low compared to those occurring in lower littoral mangrove areas. Tidal inlets serve as feeding areas for certain species (some of which are of direct fisheries value). However, it is unlikely that any of these species rely on specific areas. Although the value of a single saltmarsh area for maintenance of fish populations is perhaps not critical, intertidal lands in Moreton Bay contain large areas (approximately 5000 ha, Hyland and Butler 1988) of saltmarsh and associated tidal inlets. When considered in total, these inlets constitute a major habitat for estuarine fishes and provide rich feeding grounds for certain types of fishes.

2.2 Mangroves

Mangroves are the most conspicuous component of tidal wetlands in the Fisherman Islands region and occur from the mean tide level to extreme high water spring level. Seven mangrove species (Table 2.1) occur in Moreton Bay (Hyland and Butler, 1988), five of which were observed during the present field surveys on Fisherman and Whyte Islands and the adjacent Wynnum foreshores.

Hutchings and Saenger (1987) noted that in terms of the number of species and structural complexity of forests, the Moreton Region has one of the most highly developed mangrove areas along the east coast of Australia.

Mangroves are highly productive ecosystems which contribute significantly to the coastal ecosystem through export of organic matter. The primary food source for aquatic organisms in most mangrove dominated estuaries, such as Moreton Bay, is particulate organic material (detritus) derived from the decomposition of mangrove forest litter (leaves, twigs, and reproductive or fruit material). Average mangrove plant litterfall (the most commonly measured component of net primary production) from Fisherman Islands and the Wynnum foreshores over summer months is 1.8 dry g/m2/day (see Section 5.0).

During decomposition, mangrove litter becomes a food source for a wide variety of filter, particulate, and deposit feeders such as molluscs, crabs and polychaete worms. These primary consumers, which include representatives of most phyla, are food for secondary consumers, usually small forage fish species and juveniles of the larger predatory species, that form the third consumer level (Odum and Heald,

TABLE 2.1

MANGROVE AND SEAGRASS SPECIES WHICH OCCUR WITHIN THE MORETON REGION

SCIENTIFIC NAME	COMMON NAME
MANGROVES	
Avicennia marina (Forskal) Vierh. var. *australasica* (Walp.)*	Grey Mangrove
Aegiceras corniculatum (L.) Blanco*	River or Black Mangrove
Ceriops tagal var. *australis* C.T. White*	Yellow-leaved Spurred Mangrove
Rhizophora stylosa Griff.*	Spotted-leaved Red Mangrove
Bruguiera gymnorhiza (L.) Lam*	Large-fruited Orange Mangrove
Exocoecaria agallocha L.	Milky (blind-your-eye) Mangrove
Lumnitzera racemosa Wild.	White-flowered Black Mangrove
SEAGRASSES	
Zostera capricorni Aschers.*	Eel Grass
Halodule uninervis (Fork.) Aschers, in Boisser*	A Sea grass
Halophila ovalis (R.Br.) J.D. Hook*	Sea-wrack
Halophila spinulosa (R. Br. Aschers*	Spiny sea-wrack
Cymodocea serrulata (R.Br.) Aschers and Magnus	A sea grass
Syringodium isoetifolium (Aschers). Dandy	A sea grass

*Recorded in Fisherman Islands study area

1972). In addition, there are important fisheries species which occupy both primary and secondary consumer levels. They feed directly on particulate organic detritus and also upon primary consumers.

Mangroves function as important fish nursery and feeding grounds. Numerous studies have noted that fishes (particularly juveniles) are more abundant in mangrove dominated areas than in their nearshore habitats (Robertson and Duke 1987, Morton 1990). Possible explanations for this increase in fish abundance near mangroves include high availability of foods (Beumer 1978, Blaber 1980, Morton 1990) and a high degree of structural heterogeneity of habitat in the form of prop roots, pneumatophores and tree stems (Robertson and Duke 1987). Many of the fishes present near mangrove areas of subtropical Queensland are of direct fisheries value (WBM Oceanics 1991).

Morton (1990) examined fish communities, using foreshore mangrove stands at Lota Creek (10 km south of Fisherman Islands). He noted that:

- 46% of the species, 75% of the number of fishes and 94% of the biomass taken during the study were of direct importance to regional fisheries.
- Standing crop estimates for fish occurring within the mangroves were amongst the highest recorded for estuarine areas in Australia, whilst those for adjacent waters were comparable to those of other estuarine studies.
- A conservative estimate of the value of mangroves to fisheries was $8380/ha/yr. This was based upon the monetary value of fish caught during the study and does not take into account the numerous commercially important juveniles captured or non-commercial values (recreation, education).

Some prawn species, especially Banana prawns, also rely heavily upon mangrove areas as nursery grounds (see Dall 1985 for review, Staples et al. 1985, Robertson and Duke 1987). Banana prawns (*Penaeus merguiensis*) are taken by beam trawlers operating near the mouth of the Brisbane River but are a relatively minor component of the Moreton Bay fisheries (WBM Oceanics 1991). Staples et. al. (1985) concluded that Banana prawns are almost exclusively found along the mudbanks immediately adjacent to the mangrove fringe. Prawns and similar macrobenthos within mangroves are also important food sources for many fish species (Blaber 1980, Morton 1990).

Few mammals, amphibians or reptiles inhabit subtropical mangroves exclusively. Mangroves generally provide an extension of their range or a bridging habitat between terrestrial habitats. Mangroves provide roosting (and to a less extent, feeding) sites for fruit bats and many species of estuarine birds.

Mangroves also stabilise foreshores, minimising erosion (Bird 1971, Bird and Barson 1977).

2.3 Seagrasses

Seagrasses are marine angiosperms occurring in shallow coastal tropical and subtropical seas. Unlike seaweeds, seagrasses have a true root or rhizome system which grows into the top few centimetres of substrate to derive nutrients. Seagrasses are amongst the most productive of all coastal ecosystems.

In Moreton Bay, most seagrasses grow on mudflats or mudbanks exposed at low tide. Seagrasses generally grow in mixed species communities. Six species of seagrasses (Table 2.1) are found in Moreton Bay occurring from the mid-intertidal zone down to 1-2m below mean low water. The dominant species *Zostera capricorni*, *Halodule uninervis* and *Halophila ovalis* are usually found in intertidal areas, although in clear waters may extend into subtidal regions. All three species are widely distributed along the Queensland coast and are tolerant of a wide range of environmental conditions. *Halophila spinulosa, Cymodocea serrulata,* and *Syringodium isoetifolium* are all tropical species, occur below spring low tide levels, and are poorly represented within Moreton Bay.

Young and Kirkman (1975) and Kirkman (1975, 1976) have described the seagrass communities of Moreton Bay, while Poiner (1984) used aerial photographs to examine the stability of seagrass beds over a 25 year period. Hyland et. al. (1989) provided recent maps of the location and species distribution of seagrasses in the Moreton Region. Most seagrass communities in Moreton Bay occur south and west of the Little Sandhills on Moreton Island, to Dunwich on North Stradbroke Island and encompassing the Moreton and Amity Banks and the foreshore of North Stradbroke Island between Amity and Dunwich. These banks cover approximately 10,000 ha and form about 70% of the seagrass communities in Moreton Bay.

Studies by CSIRO (Cleveland) for the PBA have mapped and described the seagrass areas adjacent to

Fisherman Islands. High density seagrass covers 810ha of intertidal mudflats, while patching to very sparse seagrass occurs over another 420 ha.

Seagrass beds are important feeding areas for a variety of organisms. Dugong, turtles, and some fishes (garfish) feed directly on seagrass whilst most other animals feed upon epiphytes, detritus, microfauna and the benthos associated with seagrass areas. Harlin (1980) reported that seagrass provides an extensive surface area for large numbers of epiphytes which are grazed by amphipods and gastropods (Orth and Van Montfrans 1984). These animals are eaten by higher order animals. Very few studies have been conducted on the fishes associated with seagrass beds in Queensland. Studies in New South Wales have shown that seagrass beds support a large variety of fishes many of which are important to fisheries. Small epibenthic crustaceans were noted as a main part of the diet of juvenile fish in seagrass (Pollard 1984).

Young (1978) made a detailed study of juvenile prawn habitats in Moreton Bay and concluded that seagrasses provide an important settlement area for the postlarval stage of several species of penaeid prawns. The postlarval stage follows the plankton stage and adopts a bottom dwelling (or demersal) lifestyle. Seagrass beds are considered valuable prawn nursery grounds, especially for the Tiger prawn, *Penaeus esculentus* (Young 1978, Staples et. al. 1985, Coles and Lee Long 1985) and Endeavour prawns, *Metapenaeus endeavouri*, and *M. ensis* (Coles et. al. 1987). Post larval and juvenile stages are found almost exclusively in seagrass beds. Within seagrass beds, Tiger prawns (*Penaeus esculentus*) feed on polychaetes, gastropods, algae and seagrass (*Zostera capricorni*) seedcases (Wassenberg and Hill 1987). It is probable that if larval Tiger or Endeavour prawns do not settle in an area of seagrass they will be unlikely to survive and will be lost to the fishery.

Seagrasses provide shelter for fish and prawns, however the degree of shelter apparently varies between different seagrass beds. Seagrass leaf shape, bed density, species type and bed elevation (intertidal vs subtidal) have an important bearing on the amount of shelter afforded.

Seagrass beds are known to vary substantially in extent over time. Natural events, such as storms and cyclones, atypical tidal conditions, floods and sediment movements can have a marked influence on seagrass distribution. For example, extreme flooding in Moreton Bay in 1974 led to a substantial loss of seagrass both in western regions of the Bay and in the Southport Broadwater. Following the flood, the seagrass beds above low water spring tides in the Fisherman Islands and Wynnum areas expanded from an estimated 524 ha in 1974 to 1024ha in 1980 (Forbes 1984).

Large natural fluctuations in seagrass distribution complicate identification of man-induced impacts that may result from reclamation, dredging, pesticides, industrial effluents or sewage.

3.0 MANGROVE AREAS ADJACENT TO FISHERMAN AND WHYTE ISLANDS AND THE WYNNUM FORESHORES

Mangroves within the study area (defined in Figure 3.1) were mapped on the basis of 1991 aerial photography (Lands Department, Sunmap Photography QC 4951; Run 12, Photo 117, Run 11 Photo 186) and detailed field surveys which involved inspection of most landward fringes and all seaward fringes. Areas of saltmarsh and claypan were also inspected during field surveys and mapped where possible. Areas of saltmarsh have not been mapped separately from claypan because there are few areas larger than 2000 m2 (total saltmarsh area is estimated at < 3.0 ha). As a result, this study has placed emphasis on mangrove areas.

The present studies estimate that 240 ha of mangroves occur on Fisherman Islands and 131 ha occur on Whyte Island/Wynnum foreshores. Saltmarsh-claypan covers 11 ha of Whyte Island and the Wynnum foreshores and less than 10 ha on the Fisherman Islands.

Areas of saltmarsh-claypan on the Fisherman Islands were not mapped due to the difficulty in distinguishing claypans naturally occurring from those resulting from filling (reclamation) operations (see Section 3.2) although naturally occurring claypans probably cover < 10 ha.

3.1 Historical Changes

The mangroves within the study area have been subjected to varying degrees of disturbance. Filling works have occurred landward of all mangroves in the study area, replacing the original vegetation and altering natural drainage patterns.

FIGURE 3.1

Mangrove Vegetation, Fisherman Island 1991

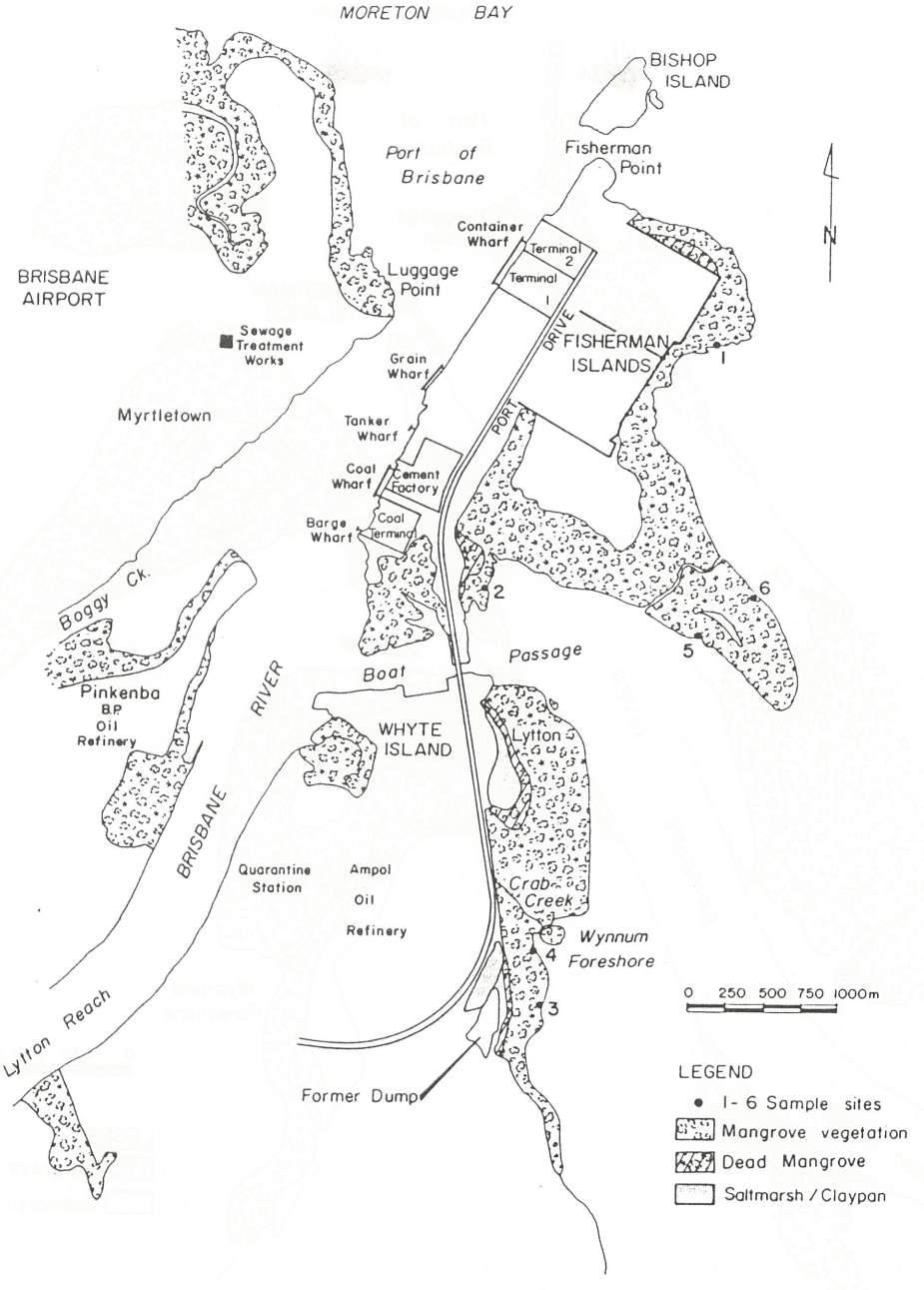
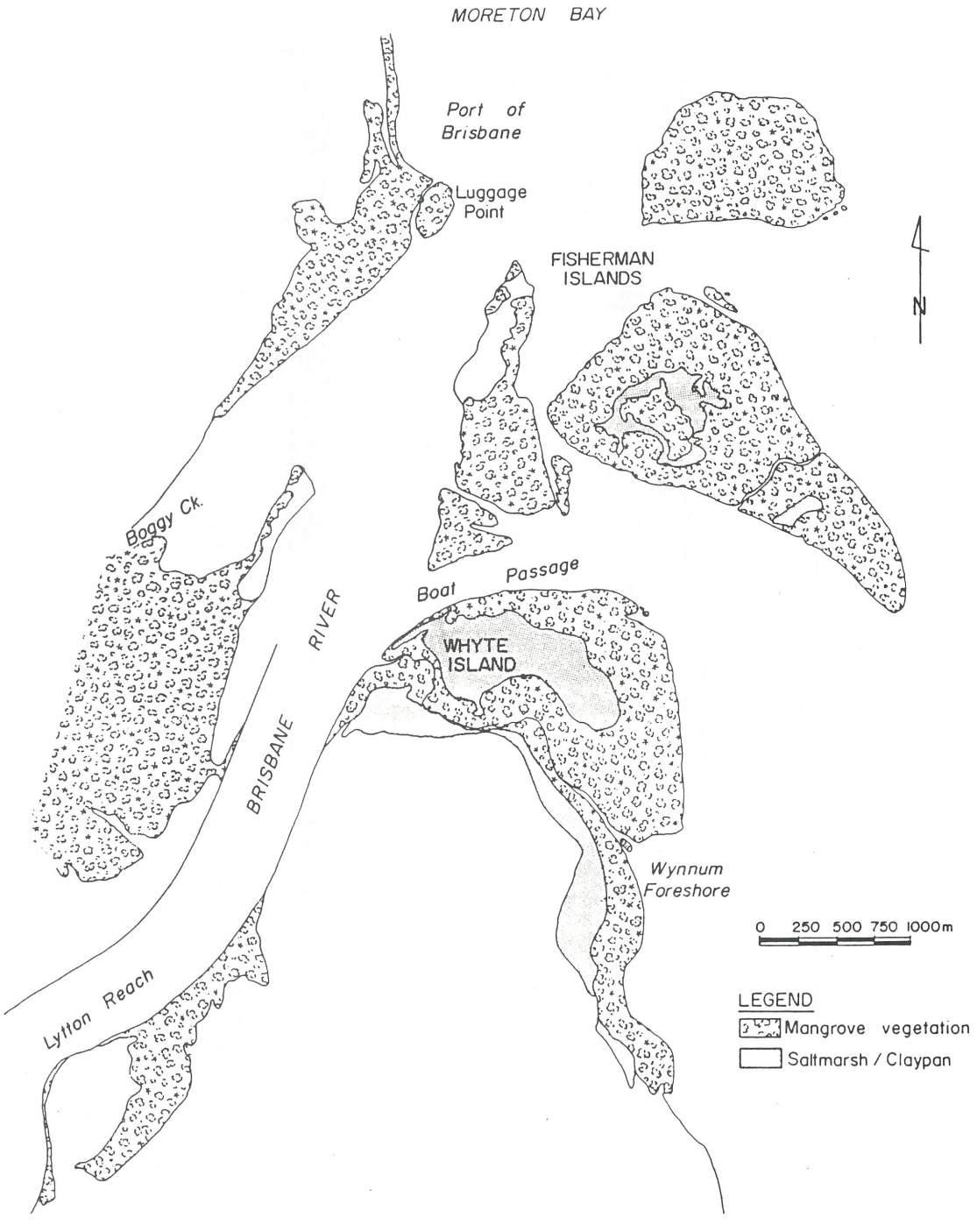


FIGURE 3.2

Mangrove Vegetation in Study Area, 1958



Fisherman Islands

Reclamation works have amalgamated what used to be several islands, collectively known as the Fisherman Islands, virtually into a single island (compare Figures 3.1 and 3.2 and Figures 1.2 and 1.3). This has lead to a reduction in mangrove area from 342 ha in 1958 to 240 ha in 1991, and a reduction in saltmarsh-claypan from 19 ha in 1958 (Figure 3.2) to less than 10 ha in 1991.

The mangroves fringing the Fisherman Islands are in an apparently healthy condition although some landward portions are degraded as a result of adjacent reclamation works. In many areas, filling of bunded areas has not been completed and areas of standing dead mangroves remain. The bunded areas are isolated from tidal influence and are of negligible ecological value.

Some mangroves adjacent (external) to bunds have died (Figure 3.1) apparently because their pneumatophores (air breathing roots) have been buried by sediment runoff from the bunds. Sediment runoff appears to have occurred within a short time of bunds being constructed, prior to bund material stabilising. Mangroves seedlings are becoming established amongst dead trees. The adverse effects of sediment runoff decrease with increasing distance from the bund wall; most mangroves more than 50 m away from the bunds appear healthy and not affected.

Overall, mangroves fringing Fisherman Islands are subject to no apparent ongoing adverse impacts.

Whyte Island and Wynnum Foreshores

Reclamation works on Whyte Island ceased approximately five years ago.

Since 1958 the area of mangroves of Whyte Island and the Wynnum foreshores has declined from 190 ha to 131 ha in 1991. In the same period, saltmarsh- claypan has declined from 102 ha to 11 ha (compare Figures 3.1 and 3.2). Adverse effects of bund wall runoff to mangroves are less conspicuous than on Fisherman Islands because regrowth of mangroves has occurred in the affected areas. Bund walls are older and hence more stable and less prone to stormwater erosion than recently bunded areas at Fisherman Islands.

Secondary treated sewage effluent discharges via an open concrete drain into Crab Creek, north of Wynnum foreshore monitoring sites 3 and 4 (Figure 3.1). A dirt access track along the drain has been used by people to dump rubbish into the creek and surrounding mangroves, including old car bodies and mattresses. Large rocks have since been placed across the track to curb such activities. Sewage discharges presumably contain elevated nutrient levels and may be partly responsible for extensive algal growth in Wynnum foreshore mangrove communities near the mouth of Crab Creek. Green filamentous algae occurs on substrates, pneumatophores and tree trunks. Such algal growth is not typically observed in mangrove forests in the Moreton Region.

The extent of beneficial and/or detrimental effects to mangroves of sewage input are unknown. Mangroves have the capacity to assimilate high levels of nutrients, particularly those contained in sewage (Nedwell 1974).

The Wynnum rubbish tip is located on the landward fringes of the Wynnum foreshore mangroves (Figure 3.1). Although the tip is now disused, leachates from the tip appear to be entering the mangrove communities. Mangroves bordering the tip are subjected to leachates which have "oily" characteristics as evident by the sheen on substrates at low tide. The influence of leachates upon mangrove communities and associated fauna is uncertain given the unknown composition of leachates. The tip is in an industrial area and it is possible that some industrial wastes have been dumped.

Litter occurs throughout the mangroves adjacent to the tip. Additionally, indiscriminate dumping of rubbish has occurred in mangrove areas fringing the tip. Rubbish dumping reduces the aesthetic appeal of the area near the tip.

Overall, the mangroves within the study area fringing Whyte Island and those adjacent to the mouth of Crab Creek along the Wynnum foreshores are subject to ongoing adverse influences from both the Wynnum rubbish tip and the sewage outfall from Crab Creek.

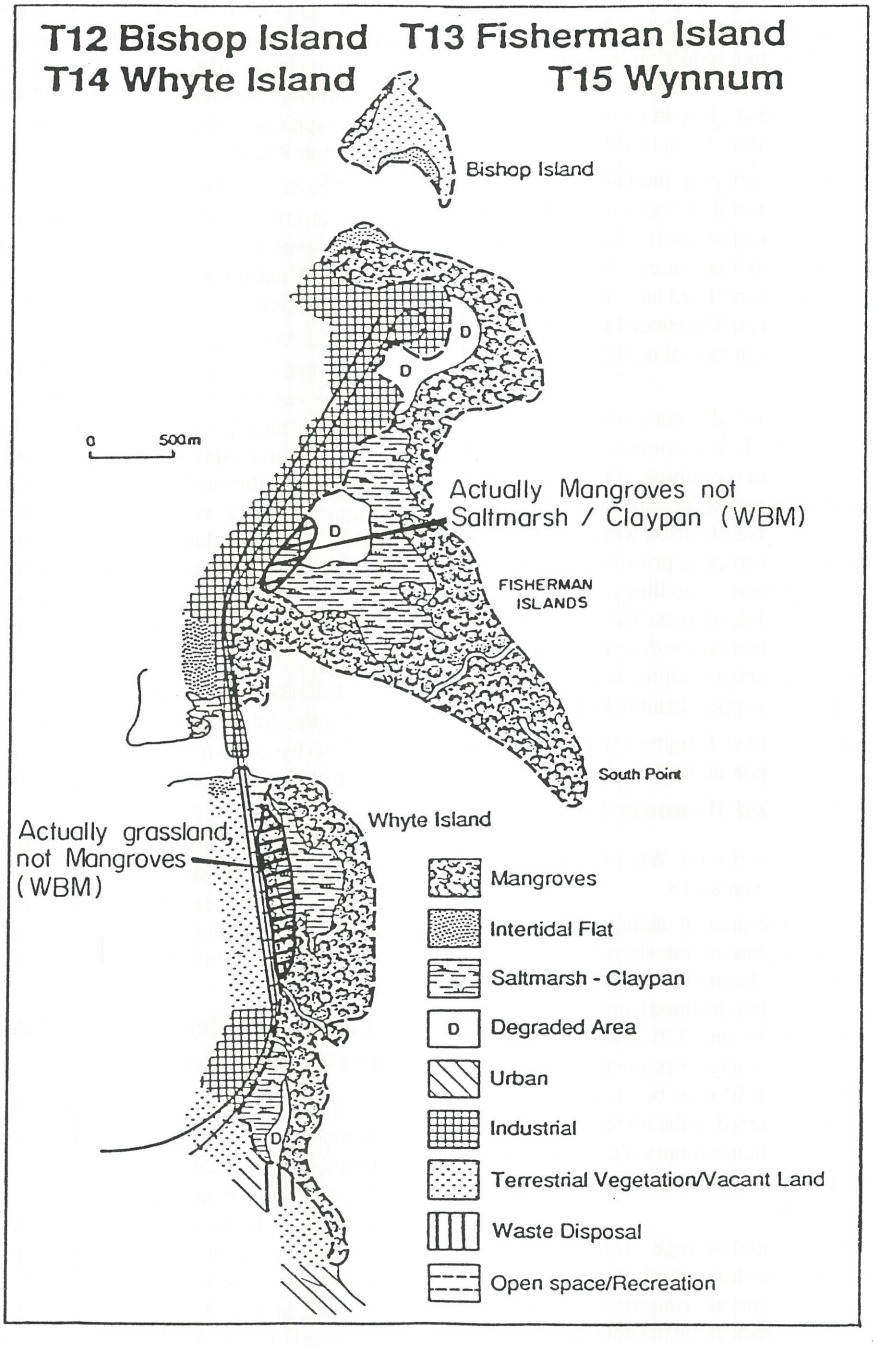
3.2 Wetland Regional Significance

Previous Studies

The most recent wetland study of the Fisherman Islands area (prior to the present study) was conducted for the Brisbane City Council in 1989 (CCM 1989). The vegetation maps produced (Figure 3.3) indicated that the Fisherman Islands supported 65.8 ha of saltmarsh-claypan and 250.5 ha of mangroves. Whyte Island was reported to contain 21 ha of saltpan-claypan and 67.3 of mangrove. Wynnum North (referred to as the Wynnum foreshore in this study) contained 26.7 ha of mangroves. The CCM (1989)

FIGURE 3.3

Vegetation mapped by C.C.M. (1989)



report did not describe methods used to map various wetland types, the degree of reliance upon aerial photography or the extent of ground surveys although it notes that "little opportunity was available for detailed field investigations".

Hyland and Butler (1988) also mapped (Figure 3.4) wetlands near the mouth of the Brisbane River using 1984 and 1986 aerial photographs and vegetation maps produced by Dowling (1986). They concluded that the Fisherman and Whyte Island region supported 445.2 ha of mangroves and 109 ha of saltmarsh-claypan although the boundaries of the region they considered were not clearly identified in their report. Based on the scale of their vegetation map however (Figure 3.4), the area of saltmarsh-claypan is closer to 18 ha on the Fisherman Islands and 24 ha in the Whyte Island/Wynnum foreshore region.

Comparisons to the Present Study

Saltmarsh-claypan

As noted previously, the area of claypan within the study area has not been mapped in the present study because of difficulties in distinguishing naturally unvegetated saline flats from those resulting from filling operations. A conservative estimate of natural claypan area would be < 20 ha. Although saltmarsh areas have not been mapped, it is estimated that the total area of saltmarsh within the study area is < 3.0 ha with no individual areas > 0.2 ha.

The discrepancy between the present and previous studies apparently results from a combination of:

- the studies being conducted at different times. Reclamation of saltmarsh-claypan has occurred since 1986 in relation to the Hyland and Butler (1988) study, and since 1988, in relation to the CCM (1989) study.
- misclassification of habitat types. Many of the saltmarsh-claypan areas shown by Hyland and Butler (1988) and CCM (1989) are reclaimed lands (see Plate 3.1). For example, much of the saltmarsh-claypan mapped in the CCM (1989) report was subtidal lands that separated the Fisherman Islands and was reclaimed in the early 1970's (compare Figures 1.2 and 3.1 with Figures 1.3 and 3.2). Similarly, areas on both Fisherman Islands and Whyte Island classified by previous studies as saltmarsh-claypan are reclaimed lands. Dead mangrove stems amongst these areas attests to the original vegetation of these areas (Plate 3.2).

Some of the reclaimed lands are presently being colonised by saltmarsh vegetation (*Suaeda australis, Sesuvium portulacastrum, Sarcocornia quinqueflora*) although generally not covering continuous areas of > 2000 m2 (Plate 3.2). Other species growing on reclaimed land are opportunistic and weed species and include *Phragmites australis* (Common Reed), *Fimbristylis polytrichoides* (Fringerush), *Cyperus polystachyos* (Bunchy Sedge), *Chloris gayana* (Rhodes Grass), *Rynchelytrum repens* (Red Natal Grass), *Cenchrus echinatus* (Mossman River Burr), *Sesbania cannabina* (Sesbania Pea), *Crotalaria zanzibarica* (Cursara Pea) and *Aster subulatus* (Wild Aster).

Mangroves

The area of mangroves recorded in the present study (371 ha) is comparable to that recorded by the CCM (1989) study (344.5 ha).

However, there is a difference of 20.5 ha in the mangrove area estimated for the Fisherman Islands (240 ha this study c.f. 250.5 ha CCM 1989). Differences in estimates can arise through different methods of measurement (planimeter versus grid paper) and/or operator error. Mistakes can also be made in aerial photo interpretation, which appears to have occurred in the CCM study (1989), where an area of grassland has been mapped as mangroves on Whyte Island and an area of mangroves on the Fisherman Islands being mapped as saltmarsh-claypan (Figure 3.3).

There is a considerable discrepancy between the estimate of mangrove area made in this study (371 ha) and that from Hyland and Butler's (1988) study (445.2 ha). The difference (74.2 ha) is likely to result from; mangrove removal (eg. on Whyte Island) since the 1986 maps used by Hyland and Butler (1988), misclassification of habitat types (eg. Bishop Island is shown on Figure 3.4 as mostly mangroves although it is actually covered in terrestrial vegetation) and differing study area boundaries.

Overview

The present study provides an accurate assessment of mangrove areas near Fisherman and Whyte Islands. In contrast to previous studies, the assessment has been undertaken using a combination of aerial photography and detailed ground surveys.

The area of mangroves in the total study area (371 ha) represents 2.7% of the 13900 ha mangrove resource of Moreton Bay, from the southern tip of south Stradbroke Island to Caloundra (Hyland and Butler 1988).

FIGURE 3.4

Tidal Wetland mapped by Hyland and Butler (1988)

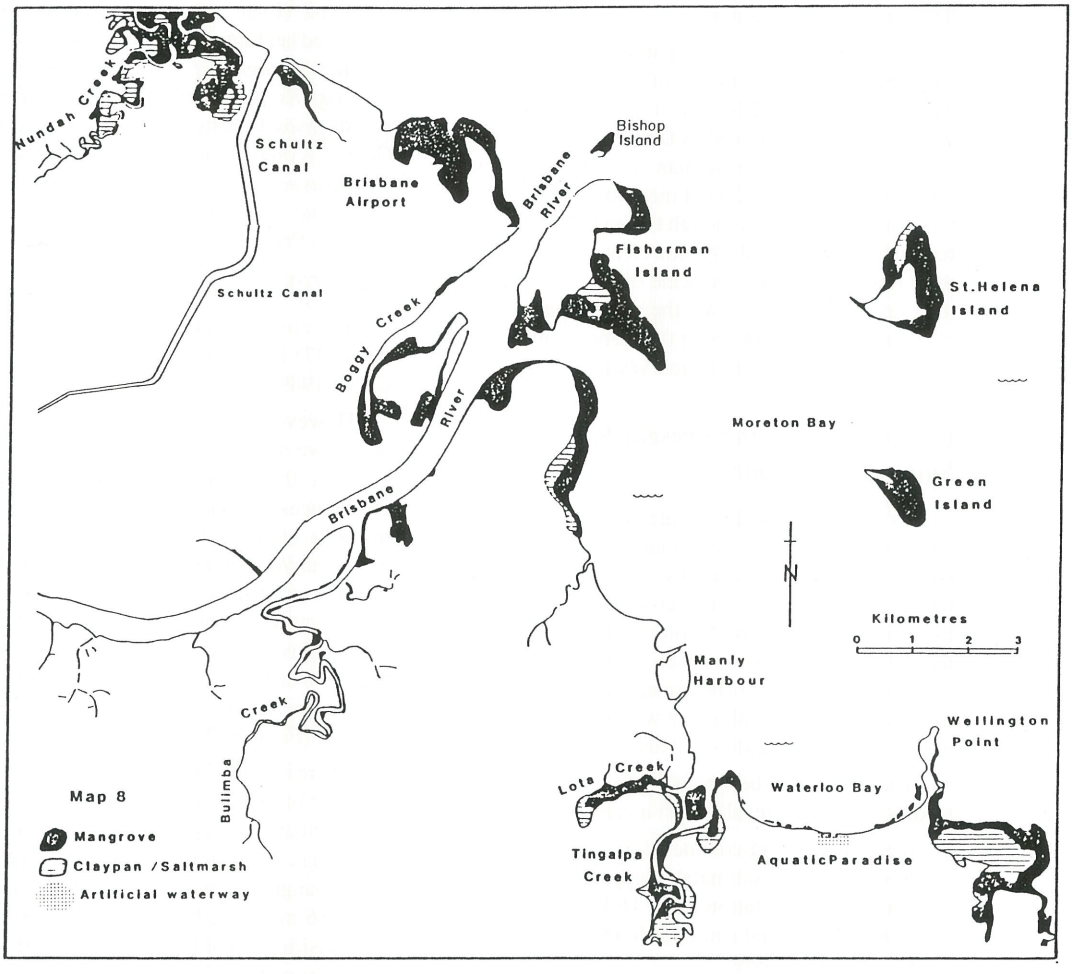


PLATE 3.1

Large seedling population on mudflats seaward of site 4, 13th September 1991

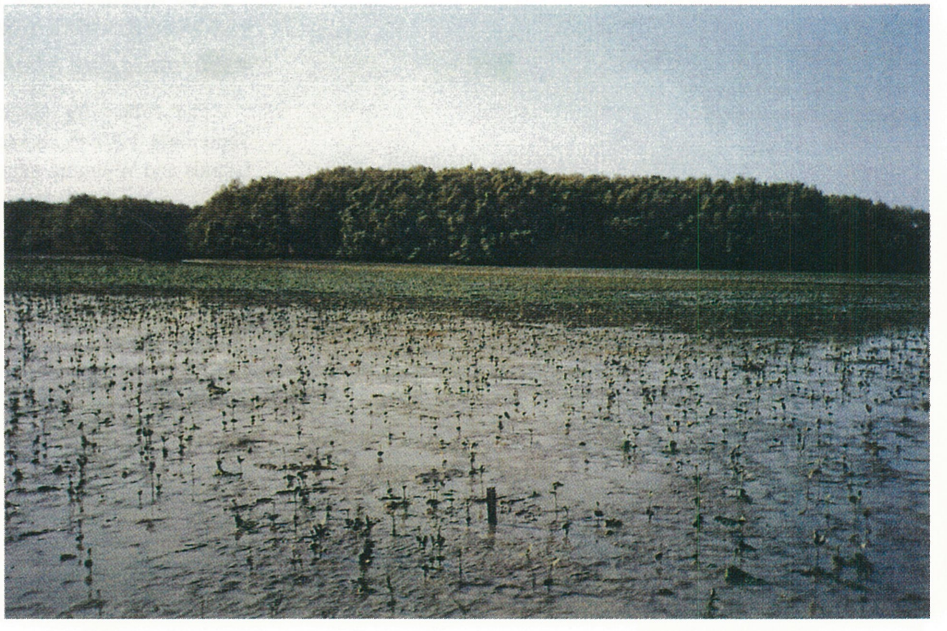
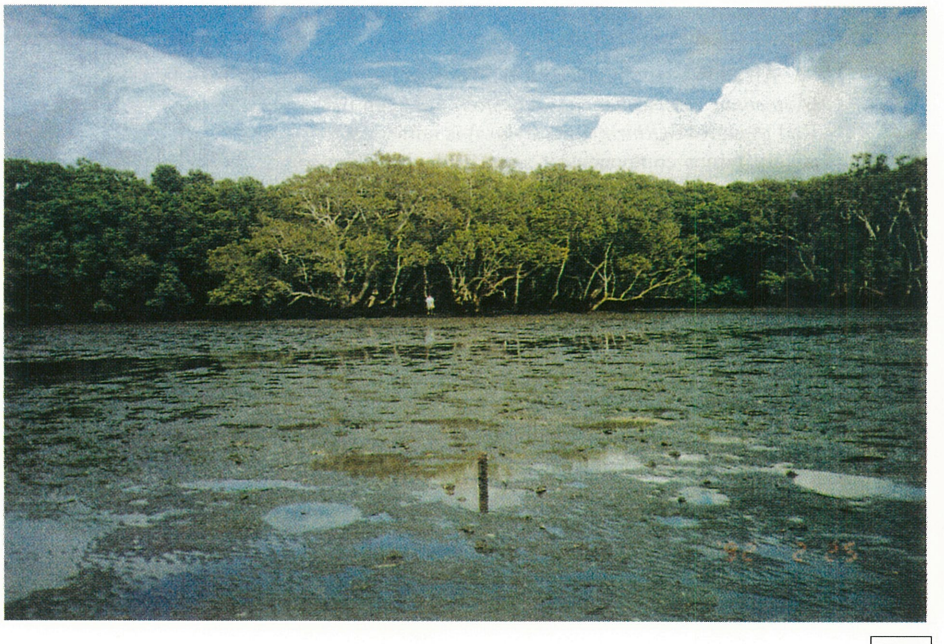


PLATE 3.2

High mortality in same seedling population by 25th February 1992



The structure of the mangrove forests in the study area varies from low shrubland to forest, and is typical of mangrove communities occurring at the mouths of rivers along western Moreton Bay.

4.0 MONITORING PROGRAMME

The present monitoring program was implemented to provide quantitative baseline data on mangrove communities adjacent to the Fisherman Islands prior to any future reclamation works for the PBA. Quantitative ecological data will allow objective assessment of any impacts to the mangroves resulting from proposed reclamation works.

Selection of monitoring sites, and monitoring parameters, was undertaken in consultation with PBA environmental personnel. Monitoring studies commenced in September 1991. A variety of mangrove community structure parameters were measured. Some parameters were remeasured (as detailed below) in December 1991 and February 1992. Future measurements are proposed to occur on a regular basis to provide baseline data prior to reclamation works.

4.1 Monitoring Sites

Six sites were identified by the PBA for the mangrove study; sites 1 and 6 in the eastern Fisherman Islands region, sites 2 and 5 fringing the Boat Passage and sites 3 and 4 on the Wynnum foreshores near Whyte Island (Figure 3.1).

All sites are dominated by the Grey Mangrove (*Avicennia marina var. australasica*) although the Red Mangrove (*Rhizophora stylosa*) is numerically a very minor component at some sites. No other mangrove species were observed at any of the sites although other species occur landward.

Each of the six sites is immediately landward of the fringing mangrove community. These communities were selected for study because:

- they were considered to be in areas most appropriate to monitor effects of altered current patterns/water sediment loads.
- the stature of their component trees and their open structure allowed efficient measurement.
- their position slightly landward from the water's edge afforded some protection from human interference with measuring equipment.
- the mangrove communities at the six sites appeared to be unaffected by sediment runoff from landward reclamation works that have occurred for port development.

The structure of the mangrove community at each site is described in Section 5.0.

4.2 Monitoring Methods

The following variables were measured in September 1991 to characterise the six Fisherman Islands and Wynnum mangrove monitoring sites:

(i) Projective foliage cover
(ii) Canopy height
(iii) Stand density
(iv) Stand basal area

Plant litterfall traps were installed at sites 1, 4, 5 and 6 in September 1991 and litter data collected in December 1991 and February 1992. Stem girth increment/decrement monitoring dendrometers were installed in October 1991 and measurements taken in February 1992.

A brief explanation of each of the variables measured is provided below.

Projective Foliage Cover

Projective foliage cover (PFC) estimates the horizontal cover of a site by the overstorey canopy and provides a measure of a plant community's potential productivity (Specht 1981). PFC was determined at each site from 100 random point quadrat sitings within the mangrove community and expressed as a percentage.

Canopy Height

The canopy height of the overstorey, or tallest stratum of a plant community, combined with PFC, provide an approximation of the major biomass of a stand and are the basis for the widely used vegetation classification scheme of Specht (1970), (Appendix A, Table 1).

Canopy height was indirectly determined by heighting ten "typical" trees in the overstorey canopy at each site with a Suunto Clinometer.

Stand Density, Stand Basal Area and Stem Girth Distribution

Stand density (number of tree stems per hectare, s/ha) and stand basal area (stem sectional area at breast height per hectare, m2/ha) were determined by the point-centred quarter sampling method (Cottam and Curtis 1956). For this study, trees were defined

as mangrove plants over 10 cm in diameter at breast height, breast height being 1.3 m above ground level (Carron 1968). The choice of a 10cm diameter was arbitrary, however plants smaller than this were usually not tree-like in stature.

The tree stem measurements made for the estimation of stand basal area also allowed the derivation of stem girth distributions for the mangrove communities at each site. A stem girth distribution shows, by means of a table and/or diagram, the allocation of trees within the community across size classes.

Litterfall

Primary production, from wetland plant communities, is the basis of the estuarine ecosystem (Hutchings and Saenger 1987). Net primary production, gross production less production lost in the respiration of plants, is not available for Australian mangroves (Hutchings and Saenger 1987). Instead, components of net primary production which are easier to measure are used to compare the relative productivity of different plant communities.

Litter production is a component of net primary production commonly measured in mangrove studies because it is more easily obtained than estimates from gas exchange systems or micro-climatology measurements (Boto 1983).

Plant litterfall monitoring was conducted at sites 1,4,5 and 6. On the 13th September 1991, fourteen randomly located litter catchers were suspended from canopy branches at each site to keep them clear of high tides.

Each litter catcher comprised a metal ring 50 cm in diameter (0.2m2 catching area) around which an inverted cone of 50% shade-cloth was constructed. Fourteen catchers per site was considered sufficient to provide an acceptable level of data reliability, given the relatively uniform overstorey canopies of the mangrove communities at each site, and results from a previous mangrove litterfall study at nearby Mud Island (Davie 1984).

The first litter collection was made on 4th December 1991 and the second on 7th February 1992. After collection, the plant litter was sorted into leaf, wood and fruit material (including all stages from bud to fully developed propagule), oven dried at 80oC, then weighed (± 0.01 g).

Stem Girth Increment/Decrement

Stem girth increment/decrement studies were initiated on 25th October 1991 at all six sites when dendrometers were installed. Dendrometers comprised a length of 30mm wide brass shim wrapped around the tree at breast height and held in tension by a spring. A vernier scale inscribed on the band allowed changes in tree girth (to a precision of 0.025mm) to be recorded. A detailed description of the construction and use of these dendrometers is provided by Liming (1957).

Ten trees at each site were permanently fitted with dendrometers. The dendrometers were read only at the end of the study (February 1992), to avoid the considerable short term variations that occur in stem growth (Carron 1968) and focus on long term trends.

Photographic Record

In addition to these quantitative measures, a photographic record of the mangrove community at each site was made by taking a photo facing each major cardinal point - north, south, east and west - from a reference point marked with a 2.4 m star picket. These photographs will allow gross structural changes in the communities to be monitored.

Statistical Analysis

Mangrove litterfall was compared between sites within monitoring periods using a one-way ANOVA in conjunction with Duncan's Multiple Range test (Walpole, 1974). A t-test was used to compare sites between monitoring periods.

Statistical analysis was carried out using the computer software SPSSPC.

5.0 RESULTS

The structural features of the mangroves at each site are summarised in Table 5.1, and described in detail below.

Projective Foliage Cover (%)

Projective Foliage Cover (PFC) ranged from 62% to 72%. All but site 5 had a PFC of less than 70%, the cut-off point between vegetation communities classed as open (<70%) and those classed as closed (> 70%; Appendix A, Table 1). The

mangrove community at site 5 (PFC 72%), was only marginally above this cut-off point.

Canopy Heights

Canopy height at sites 3, 4 and 5 was up to 10 m and between 10 and 13 m at sites 1, 2 and 6 (Table 5.1). Vegetation communities classed as low are < 10 m (Appendix A, Table 1).

Stand Density, Stand Basal Area and Stem Girth Distribution

Stand densities (number of stems per hectare) of the mangrove communities at the six sites fell into two groups. Sites 3, 4 and 5 were similar with stand densities of 830, 876 and 893 s/ha respectively (Table 5.1). Stand densities at sites 1, 2 and 6 however, were much lower, at 334, 462 and 380 s/ha respectively (Table 5.1).

TABLE 5.1

STRUCTURAL FEATURES OF FISHERMAN ISLANDS AND WYNNUM FORESHORES MANGROVE MONITORING SITES

	SITE		
	1	**2**	**3**
Vegetation Structural form (after Specht 1970)	Open Forest	Open Forest	Low Open Forest
Dominant species	*Avicennia marina*	*Avicennia marina*	*Avicennia marina*
Projective foliage cover (%)	62	67	62
Canopy height (m)	10-13	10-13	8-10
Stand density (stems per ha)	334	462	830
Stand basal area (m^2/ha)	24.0	23.1	24.1
Stem girth (cm)*	87.0±4.4 (n=72)	73.5±3.5 (n=68)	56.9±2.5 (n=60)
General description	Large tall trees, predominantly single stemmed and widely spaced	Tall, median diameter trees single or double stemmed.	Small crooked-stemmed trees closely spaced
	4	**5**	**6**
Vegetation Structural form (after Specht 1970)	Low open forest	Low closed forest	Open forest
Dominant species	*Avicennia marina*	*Avicennia marina*	*Avicennia marina*
Projective foliage cover (%)	62	72	61
Canopy height (m)	8-10	8-10	10-13
Stand density (stems per ha)	876	893	380
Stand basal area (m^2/ha)	28.9	24.1	24.3
Stem girth (cm)*	59.7±3.1 (n=60)	55.9±2.2 (n=60)	86.1± 3.5 (n=60)
General description	Small diameter low spreading trees, crooked stems closely spaced.	Small trees, crooked stems, community of closely spaced trees.	Large tall trees well spaced predominantly single stemmed.

* mean ± standard error

TABLE 5.2

TOTAL AND COMPONENT LITTERFALL VALUES (MEAN± STANDARD ERROR) FISHERMAN ISLANDS AND WYNNUM FORESHORES (g/m^2/day)

Site (Structural Form)*	Collection**	COMPONENT Total	Leaf	Wood	Fruit
1 (*Avicennia marina* open forest)	1	1.10±0.11	1.00±0.11	0.10±0.015	0.00±0.00
	2	1.95±0.32	1.40±0.15	0.52±0.28	0.03±0.01
4 (*A. marina* low open forest)	1	1.64±0.14	1.43±0.12	0.20±0.04	0.01±0.00
	2	2.68±0.33	2.01±0.12	0.63±0.24	0.04±0.01
5 (*A. marina* low closed forest)	1	1.71±0.17	1.51±0.15	0.18±0.03	0.01±0.01
	2	2.29±0.20	1.54±0.12	0.67±0.12	0.08±0.01
6 (*A. marina* open forest)	1	1.25±0.10	1.14±0.09	0.09±0.02	0.01±0.01
	2	1.76±0.12	1.51±0.08	0.21±0.04	0.04±0.02

**After Specht (1970)*

***Collection 1 4th Decemmber 1991 (initiated 13 September 1991)*
Collection 2 7th February 1992

Stand basal area (stem sectional area at breast height per hectare) did not divide the sites into similar groupings as for stand density. All stand basal areas were around 23 to 24 m2/ha (Table 5.1) except at site 4 (28.9 m2/ha).

Average stem girths of the mangrove communities at each site are shown in Table 5.1 and stem girth distributions displayed in Figure 5.1. The size class intervals in Figure 5.1 span 10 cm up to and including the value indicated for each class, hence the first size class spans from 0.30 m - 0.39m (inclusive). The final size class however, includes all trees equal to or greater than one metre in girth, to allow the representation (and comparison) of all sites on one page.

At sites 3, 4 and 5 the number of trees declined from the smaller to the larger size classes (Figure 5.1). Sites 1 and 6 showed the opposite trend with the number of trees increasing from the smaller to the larger size classes. Site 2 had a fairly even distribution of trees across all size classes but still with a large number of trees in the final size class (± 1.0 m girth), compared to sites 3, 4 and 5.

Litterfall

Total

Total litterfall, averaged over the 14 litter-catchers at each of the four sites (1, 4, 5 and 6) for the first collection (December 1991), ranged from 1.1 g/m2/day (site 1) to 1.7 g/m2/day (site 5; Figure 5.2, Table 5.2). Within-site standard errors ranged from 8 to 10% of the mean.

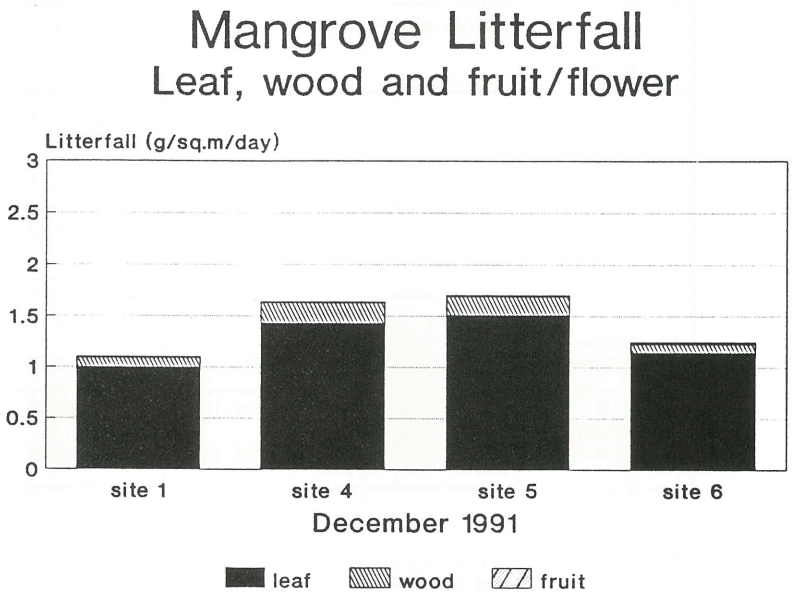
Total litterfall for the second collection (February 1992), ranged from 1.8g/m2/day (site 6) to 2.7 g/m2/day (site 4; Figure 5.2, Table 5.2). Within-site standard errors for the February collection were over 10% of the mean for sites 1 and 4, due mainly to a large and highly variable wood component in the litterfall.

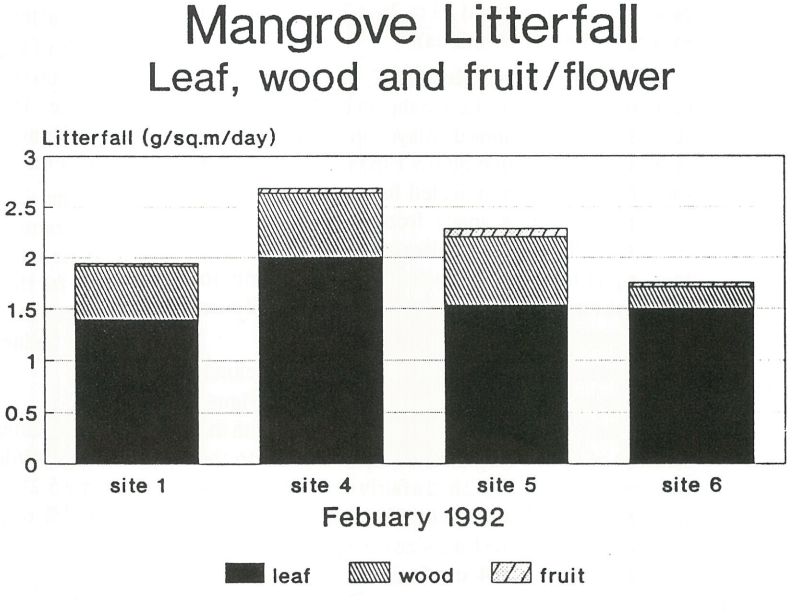
Leaf

Leaf litterfall ranged from 1.0 g/m2/day (site 5) to 1.5g/m2/day (site 1) for the December collection (Table 5.2). Within-site standard errors ranged from 8 to 11% of the mean

FIGURE 5.1

Mangrove Litterfall for December and February Collection





For the February 1992 collection, leaf litterfall rates ranged from 1.4 (site 1) to 2.0 g/m2/day (site 4). Within-site standard errors for the February collection ranged from 5 to 11% of the mean.

Wood

Wood litterfall values ranged from 0.1 (site 1 and 6) to 0.2 g/m2/day (site 4 and 5) for the December collection, to 0.2 (site 6) to 0.7 g/m2/day (site 4) for the February collection. Within-site variability in wood litterfall was high, standard errors ranging from 15 to 22% of the mean at the first collection, and 19 to 54% of the mean at the second collection.

Fruit

Fruit litterfall made only a minor contribution to total litterfall over both collections. In the December collection it ranged from 0.00 to 0.01 g/m2/day and in the February collection, from 0.03 to 0.08 g/m2/day.

Comparisons between sites

For the December 1991 collection, total litterfall at sites 4 and 5 was significantly greater than at sites 1 and 6 ($p < 0.05$, Duncan's multiple range test). Leaf litterfall was also greater at sites 4 and 5 than at site 1 ($p < 0.05$) but only site 5 had a significantly greater ($p < 0.05$) leaf litterfall than site 6.

For the February collection site 4 had a significantly ($p < 0.05$) greater total litterfall than site 1 and 6, and a significantly greater leaf litterfall than all other sites.

Differences in wood litterfall and fruit litterfall were considered too variable within-site for meaningful comparisons to be made between sites.

Comparisons between collections

Total litterfall increased significantly ($p < 0.05$, t-test) from the December 1991 to the February 1992 collection at all sites. Leaf litterfall also increased significantly ($p < 0.05$) from the December to the February collection at all sites except site 5, where it remained relatively constant (Figure 5.2; Table 5.2).

However, the percentage contribution of the leaf component to total litterfall declined markedly from the December collection (87-91%) to the February collection (67-86%). Conversely, the contribution of the wood component to total litterfall, increased from December (7-12%) to February (12-29%) (Figure 5.2).

No statistical analysis was made of the differences between collections for the wood component, because of its high within-site standard error (15 to 22% of the mean for December and 19 to 54% of the mean for February).

Fruit litterfall also showed a small increase in its contribution to total litterfall, from 0 to 1% in December to 2 to 4% in February. No statistical analysis of the difference in fruit litterfall between collections was conducted because of its high within-site variability.

Stem Girth Increment/Decrement

Stem increment/decrement measured as change in girth at breast height (1.3 m above ground level) varied from -4.10 mm to 1.80 mm (Table 5.3) over the 60 trees during the approximately 15 week monitoring period (25/10/91 to 7/2/92).

Girth increment/decrement for the sites ranged from -4.10mm to 1.80 mm. The greatest increment (1.80 mm) was measured at sites 1 and 5, while the greatest decrement (-4.10 mm) was measured at site 6.

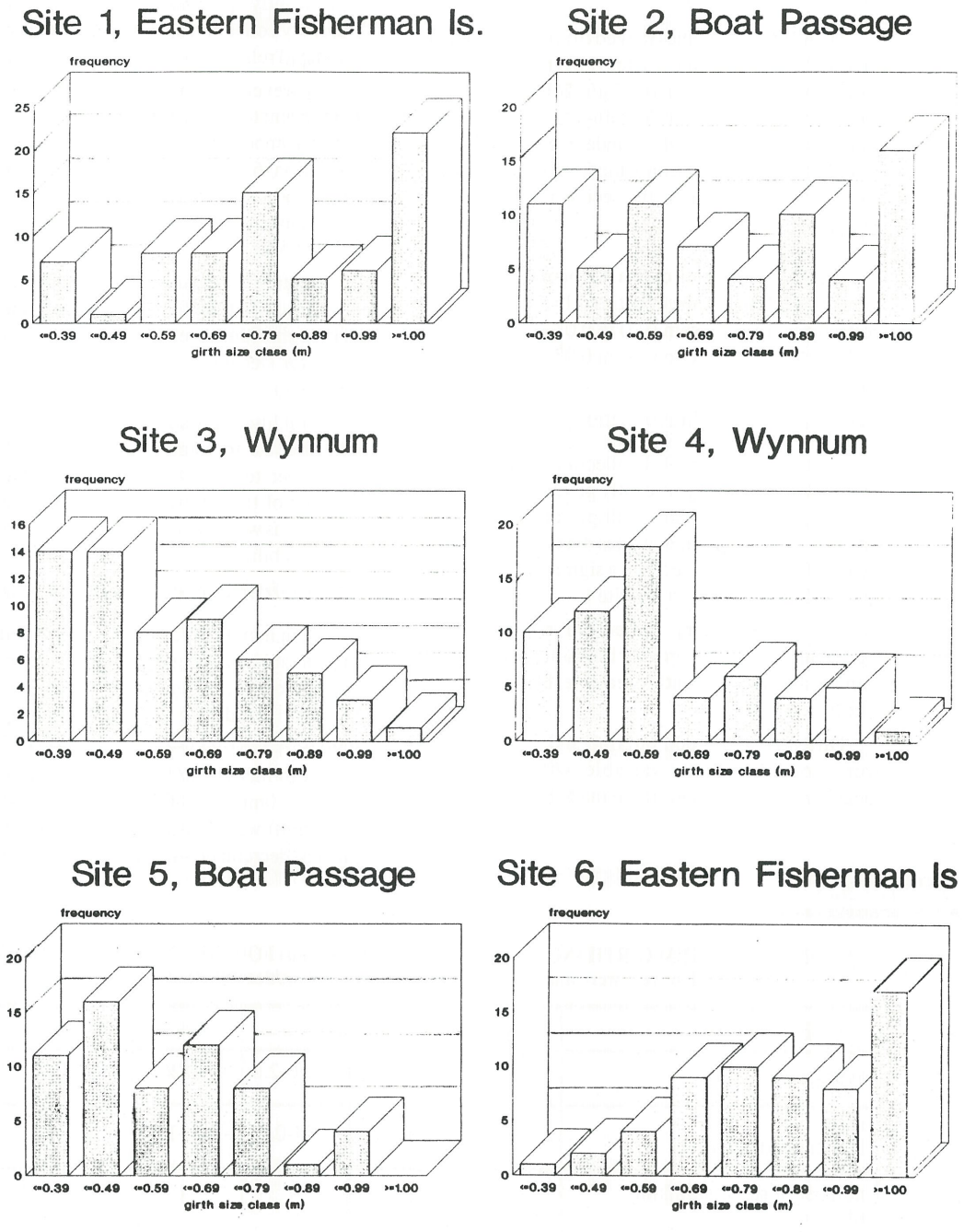
TABLE 5.3

SUMMARY OF STEM GIRTH INCREMENT/DECREMENT (mm) FOR THE PERIOD 25/10/91 TO 7/02/92
Ten trees were monitored for stem girth increment/decrement at each site.

SITE	1	2	3	4	5	6
average girth	753±54.6	754±48.2	636±32.6	600±26.8	773±55.7	952±62.7
range in increment/decrement	-0.76-1.80	-2.54 - 0.51	-2.54-0.51	-1.00-1.30	-2.3-1.80	-4.10-0.00
number of stems shrinking (decrement)	4	2	3	3	3	7
number of stems - no change	3	5	4	5	2	3

FIGURE 5.2

Stem Girth Distribution



Twenty-two trees showed no change in girth during the monitoring period over all sites. Twenty-two trees decreased in girth over the monitoring period and the remaining 16 trees increased in girth. At any one site, the greatest number of trees increasing in girth was 5 (site 5) while the greatest number decreasing in girth was 7 (site 6).

Photographic Record

The photographic record did not reveal any gross changes in the structure of the mangrove communities at the monitoring sites. Large changes were not expected, given the short duration of the study (September 1991 to February 1992). However a marked changed was noted on the mudflats immediately seaward of site 4, (Plates 5.1 and 5.2) where a very large seedling population present in September 1991 (developed to about the second leaf-pair stage) experienced a mortality rate of greater than 90% by February 1992.

6.0 DISCUSSION

The importance of mangroves in the estuarine food chain and their presumed role in land preservation are both connected with mangrove community structure (Rodriguez 1987) and have been the focus of much mangrove research.

The response of mangrove forests to stress (climatic and man-induced) can be identified with quantitative data (Odum et. al. 1982) such as that collected in the present study. Hence the importance of this baseline quantitative data on the mangroves of the Fisherman Islands and Wynnum foreshores.

Projective Foliage Cover and Canopy Height

Projective foliage cover and canopy heights recorded in this study are comparable to the results from other studies of mangrove communities in Moreton Bay (Durrington 1974, Dowling 1986). These two measures are almost standard in Australian studies for characterising plant community structure. Large changes over the medium to long-term in the values of these two variables would not be anticipated unless a drastic change in the local environment occurred such as large alterations of tidal regime.

Stand Density

The stand densities in the low closed to open forest mangrove communities of this study (334-892 s/ha) are comparable to similar mangrove communities in other parts of Moreton Bay. Dowling (1986) recorded stand densities ranging from 120 to 2900 s/ha for *Avicennia marina* low open forest and open forest at various locations in Moreton Bay. Durrington (1974) recorded densities of 100 to 800s/ha for *Avicennia marina* low open forest and open forest along Serpentine Creek, Moreton Bay. Much lower stand densities of 99 and 103s/ha were recorded by Davie (1984) in low closed *Avicennia marina* forests on Mud Island in Moreton Bay. This variation is not surprising though, considering the wide range in mangrove stand structure in Moreton Bay (Dowling 1986).

Basal Area

Basal area (m2/ha) is a structural variable less commonly measured in Australian mangrove studies, probably because of the irregular stem form of plants in many mangrove communities (Davie 1984).

On Mud Island, Moreton Bay, the basal area of a seaward low closed mangrove forest was 16 m2/ha (Davie 1984), compared to the 24.1 m2/ha for the low closed *Avicennia marina* forest at site 5 (Boat Passage) in this study. The basal area of other mangrove communities investigated in this study (low closed forest - low open forest - open forest) ranged from 23.1 to 28.9 m2/ha.

In riverine *Avicennia marina* vegetation along Strangers Creek, Sydney, basal areas of 43 and 44 m2/ha were recorded (Briggs 1977), perhaps indicating a much more productive environment than that of Fisherman Islands and the Wynnum foreshores.

Differences in basal area estimates may be partly due to the choice of criteria for defining which plants will be measured and not all mangrove studies clarify what is included in the basal area estimates, limiting the reliability of comparisons between studies.

Stem Girth Distribution

The stem girth distribution of the mangrove communities at sites 3,4 and 5 (many small trees and few large trees) is typical of uneven-aged forest stands (Carron 1968). The opposite trend at sites 1 and 6 may indicate that the mangrove communities at these sites are very mature and possibly over-mature or senescent. The large number of big trees (±1.0 m girth) at sites 1 and 6 may limit incoming solar radiation, nutrients and root space sufficiently to prevent the establishment and development of smaller mangroves. Some mortalities may occur over the next 10 to 20 years amongst the larger trees

PLATE 5.1

Unvegetated filled areas. Fisherman Islands



PLATE 5.2

Saltmarsh colonising partially filled mangrove area, southern Fisherman Islands.



at sites 1 and 6 and would probably be followed, possibly with a 5 to 10 year lag, by an increase in the population of smaller, younger trees.

Litterfall

The increase in total litterfall from the first collection (December 1991) to the second collection (February 1992) in this study was accounted for largely by an increase in the wood component. This may have been due to an increase in rain and storm activity leading up to the second litterfall collection, dislodging dead wood in the mangrove canopies. Prior to the first litterfall collection there were just 16 rain days over the months of September, October and November 1991, whereas there were 20 rain days in December 1991 and January 1992, prior to the second litterfall collection (Bureau of Meteorology).

Litterfall collection in this study has only occurred on two occasions and will need to continue over a longer period to detect seasonal litterfall patterns. A 17 month litterfall study in a low closed forest on Mud Island in Moreton Bay found that litterfall peaked in September 1979 and August 1980 (late winter/early spring) while minimums occurred in November 1979 and March 1980 (late spring, early autumn) (Davie 1984).

Longer term litterfall collections are considered necessary to determine whether the present trend of sites 4 and 5 producing more litterfall than sites 1 and 6 continues. It may relate to features of the physical environment at sites 4 and 5; such as a higher nutrient input. This could be tested by conducting nutrient analyses of the receiving waters, the soils and the foliage at the various sites. The nutrient characteristics of the soil-water covering the roots of mangroves is thought to be a significant growth-limiting factor (Davie 1984).

The extrapolated average litterfall of 6.6 dry t/ha/yr for this study is comparable to the estimate of 6.42 t/ha/yr (Davie 1984) for low closed *Avicennia marina* forest on Mud Island, Moreton Bay. It is also comparable to data from studies elsewhere in the world in mangrove forests at similar latitudes (see Hutchings and Saenger 1987 and Table 6.1).

TABLE 6.1

LITTERFALL VALUES FOR MANGROVE FORESTS IN AUSTRALIA AND FLORIDA (USA)

Location	Forest Type	Leaf Litter (t/ha/yr)	Total Litter (t/ha/yr)	Study Period	Reference
Moreton Bay, Brisbane	*Avicennia marina* low closed forest to open forest	5.3 (extrapolated from 21 weeks)	6.6 (extrapolated from 21 weeks)	13th Sep1991 to 7th Feb 1992	This Study
Middle Harbour, Sydney	*Avicennia marina* Low closed forest	*4.6*	5.8	Mar 1977 to Apr 1978	Goulter and Allaway (1979)
Moreton Bay, Brisbane	*Avicennia marina* low closed forest	--	6.42	Aug 1979 to Dec 1980	Davie (1984)
Moreton Bay, Brisbane	*Avicennia marina* low open shrubland	--	1.94	Jan 1980 to Dec 1980	Davie (1984)
Missionary Bay, Hinchinbrook Island North Queensland	mixed species	--	3.7-28.1	*1*975 to 1978	Bunt (1982)
Missionary Bay, Hinchinbrook Island North Queensland	*Avicennia sp.* forest	*6.6*	9.5	1975 to 1976	Duke et al (1981)
Florida	*Aviennia germinans* forest	--	3.7-5.6		Lugo et al. (1980) cited by Odum et al. (1982)

A review of litterfall studies from mangrove communities around the world (Hutchings and Saenger 1987) reveals a wide range, from 0.8 dry t/ha/yr in a temperate/subtropical *Rhizophora mangle/Laguncularia racemosa/Avicennia nitida* forest in Southern Florida (25°N) to 28.1 dry t/ha/yr in a mixed species tropical mangrove forest in North Queensland, Hinchinbrook Island (18°S). Litter production is typically higher in tropical than in temperate mangroves, although there is considerable variation within a given mangrove community (Hutchings and Saenger 1987).

Human interference with the litterfall catchers has been confined to just one catcher out of the total of 56 in the period from 13th September 1991 to 7th February 1992, so continued measurements are feasible.

The litterfall collections for this study will provide valuable quantitative data on the productivity of the Fisherman Islands and Wynnum foreshore mangroves.

Stem Girth Increment/Decrement

Measurement of mangrove stem girth increment/decrement by dendrometers in the present study appears to be novel for Australian mangrove studies. The irregular stem form of individual mangroves in many mangrove communities in Australia would often rule out such measurements.

The small increments in stem girth noted in this study may be because monitoring has only been conducted over a short period at a time of year when mangrove productivity is typically low (Davie 1984).

The decrement in girth noted on 22 of the 60 stems measured may be due to actual stem shrinkage, faulty installation of the dendrometers, or a combination of both. Shrinkage is a common phenomenon in tree stems (Bormann and Kozlowski 1962) that has been attributed to low rainfalls in the week preceding recordings. For the months August 1991 to January 1992, preceding and during this study, there was a rainfall deficit of 184.4 mm compared to the long term average (Bureau of Meteorology). Differences in each tree's genotype governing its response to a water deficit may account for the variation in tree growth rates. The possibility that shrinkages were due to faulty installation of the dendrometers is considered unlikely.

Continued recording of stem increment/decrement with the dendrometers as an adjunct to productivity measured by the litterfall catchers would be worthwhile. The readings taken from the dendrometers may indicate that the mangroves of the monitoring sites do not experience rapid stem growth, so measurements will become of more value as they are recorded over longer periods.

Photographic Record

The photographic record did not reveal any gross structural changes at the mangrove sites over the study's duration. Photos taken on the mudflats seaward of site 4 however, proved very useful in monitoring changes in exposed seedling populations. Future study could monitor this mudflat area and investigate what may have caused the large seedling mortalities observed. Possible causes are grazing by crabs and/or fish, a root pathogen or a severe storm event dislodging seedlings.

7.0 RECOMMENDATIONS FOR FUTURE MONITORING

The present study has provided important baseline data in regard to mangrove communities. However studies have:

- been conducted over a period (late spring to early autumn) typically associated with minimal litterfall (see Davie 1984) and therefore are likely to underestimate annual net primary production.
- been conducted over 5 months and do not provide data sufficient to reveal seasonal patterns. The absence of seasonal data severely limits the value of the study in describing baseline conditions and hence quantifying any long term impacts to mangrove communities adjacent to Fisherman Islands resulting from reclamation operations.

It is therefore recommended that litterfall monitoring should be continued for at least another 6-8 months to include the full range of seasonal variation in productivity. Litterfall collection should be made preferably at intervals of no more than two months; longer than this and trapped litter begins to decompose and results in litterfall production being underestimated.

Similarly further stem increment/decrement readings need to be taken to provide seasonal data. Readings need only be collected every four months. These readings should also be continued for at least 12 months to be able to arrive at an actual annual stem girth increment value.

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9.0 GLOSSARY OF TERMS

Claypan: unvegetated high tidal flats, generally landward of mangroves.

Diameter at breast height (dbh): standing trees are almost universally measured at a fixed height above ground level referred to as breast height which in Australia is set at 1.3 m (Carron 1968)

Estuarine: of, or pertaining to an estuary.

Intertidal: land between high and low tides.

Mangroves: the term is used here interchangeably to refer to an individual species of plant or to a stand or forest of plants belonging to many species (after Hutchings and Saenger, 1987); a community (or a plant thereof) arising from an estuarine or tidal mudflat.

Saltmarsh: high tidal flats landward of mangroves vegetated by saltcouch grass and samphire bushes.

Seagrass: marine flowering plant growing on intertidal to subtidal flats.

Subtidal: below the level of lowest astronomical tides.

Wetlands: plant habitats subject to tidal action including subtidal areas to an Australian Height Datum (AHD) depth of 6 m; encompassing saltmarsh/saltpan, mangroves and seagrass communities.

APPENDUM A

Table 1 Structural forms of vegetation 8in Australia(Modified from Specht 1970)

LIFE FORM AND HEIGHT OF TALLEST STRATUM	PROJECTIVE FOLIAGE COVER OF TALLEST STRATUM			
	Dense (70-100%)	Mid Dense (30-70%)	Sparse (10-30%)	Very Sparse (< 10%)
Trees*>30m	Tall closed-forest	Tall open-forest	Tall Woodland	Tall open-woodland
Trees* 10-30m	Closed-forest	Open-forest	Woodland	Open-woodland
Trees* 5-10m	Low closed-forest	Low open-forest	Low woodland	Low open-woodland
Shrubs* 2-8m	Closed-scrub	Open-scrub	Tall shrubland	Tall open-shrubland
Shrubs*0-2m	Closed-heath	Open-heath	Low shrubland	Low open-shrubland
Hummock grasses 0-2m	-	-	Hummock grassland	Open-hummockgrassland
Herbs (inc. moss, ferns,	Closed-herbland	Herbland	Open herbland	-
hemicroptophytes,	Closed tussock grassland	Tussock grassland	Open-tussock grassland	-
geophytes, therophytes	Closed-grassland	Grassland	Open-grassland	-
hydrophytes, helophytes)	Closed Herbfield	Herbfield	Open-herbfield	-
	Closed sedgeland	Sedgeland	Open-sedgeland	-
	Closed fernland	Fernland	Open-fernland	-
	Closed-mossland	Mossland	Open-mossland	-

* A tree is defined as a woody plant more than 5m tall, usually with a single stem. A shrub is a woody plant less than 8m tall, frequently with many stems arising at or near the base (slightly modified from Beadle and Costin, Proc. Linn. Soc. N.S.W. 77, 1952, 61)

APPENDIX II

CSIRO MARINE LABORATORIES REPORT SEAGRASS BEDS AND MANGROVE FORESTS OF FISHERMAN ISLANDS, MORETON BAY, QUEENSLAND

Final Report to the Port of Brisbane Authority

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June 1992

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EXECUTIVE SUMMARY

- Mangrove forests and seagrass beds were mapped at Fisherman Islands, Moreton Bay. There was 2.35 km^2 of mangroves in the study area. Five mangrove classes were identified: a dense high-canopy-height class (0.385 km^2); a dense mid-canopy-height class (1.248 km^2); a seedling/ mangrove fringe (0.227 km^2) and a small area (0.029 km^2) comprised of a mixture of mangroves and intertidal mudflat along the seaward edge of the mangroves.
- The seagrass beds in the study area were identified from photo-interpretation of digitised aerial photographs. There was 11.90 km^2 of seagrass supporting habitat in the study area. Seven strata were identified: dense seagrass (8.078 km^2); worm digging area (0.454 km^2); patchy seagrass (1.737 km^2); very patchy seagrass (1.256 km^2); St. Helena Island seagrass bed (0.149 km^2); Oyster Point seagrass bed (0.638 km^2) and a channel strata which included all areas where the bottom structure was not discernible from the aerial photograph (26.00 km^2).
- Four seagrass species were sampled in the study area, *Zostera capricorni*, *Halophila ovalis*, *Halophila spinulosa* and *Halodule uninervis*. The dominant seagrass, in terms of biomass, was *Z. capricorni*.
- The total seagrass biomass in the study area was estimated at 4,460 t, with 17% precision where precision is the closeness of repeated measurements of the same quantity. The dense seagrass strata had high seagrass biomass (196 $g.m^{-2}$; 16% precision). The worm digging and patchy seagrass areas had moderate seagrass biomass (123$g.m^{-2}$; 30% precision and 128$g.m^{-2}$; 40%). The very patchy seagrass strata had low seagrass biomass (46 $g.m^{-2}$; 49% precision). The biomass at St. Helena Island was as high as the dense seagrass strata on Fisherman Islands (158 $g.m^{-2}$; 48% precision). Seagrass biomass was highest at Oyster Point (370 $g.m^{-2}$; 74% precision). The lowest biomass was found in the channel strata (31 $g.m^{-2}$; 57% precision). The relatively high overall precision (17%) was due to the high precision (16%) of the biomass estimate for the dense seagrass strata, which comprised one third of the study area.
- Stratification substantially improved the precision (from 31% to 17%) of the estimate of total seagrass biomass compared to simple random sampling .
- The precision of the estimate of total seagrass biomass was similar, regardless of stratification technique (digitised aerial photographs, Landsat satellite mapping and depth).
- The cost of digitising existing aerial photographs and digitising depth data from nautical charts was much lower compared to the costs of obtaining and processing Landsat-TM satellite data.
- Acceptable seagrass biomass estimates can be obtained for sample processing and field sampling costs of around $14,000 (1992 dollars) for 20% precision and $20,000 for 15% precision. The cost for precisions better than 15% increases dramatically to $28,000 for 10% and $56,000 for 5%.
- The use of networked image processing, Computer Aided Drawing (CAD), and Geographic Information System (GIS) software substantially improved productivity and accuracy in the study. It also provided a permanent, geo-coded digital database which forms the basis for future mangrove and seagrass monitoring at Fisherman Islands.

INTRODUCTION

Geographic Information Systems (GIS) provide managers with a tool for storing, manipulating and displaying spatial data to assist in the rational management of environmental resources. Knowing where the resources are, and in what quantities, is a prerequisite to informed and objective management.

Fisherman Islands form part of the Port of Brisbane and are managed by the Port of Brisbane Authority (PBA). The environmental resources of Fisherman Islands include mangroves and seagrass beds, both of which have been shown to be important nurseries and habitat for prawns and fish. Monitoring these resources is expensive, and it is important to compare techniques to establish the most cost-effective procedure.

The aim of the study was to compare, contrast and assess the relative merits and disadvantages of three techniques — scanned aerial photography, digitised aerial photography and Landsat-TM imagery. Comparisons were made on cost, complexity of the mapping exercise and precisions of seagrass biomass estimates obtained from stratification using the three mapping techniques. GIS software (SPANS) was used in conjunction with image processing (micro BRIAN) and CAD software (Auto CAD) to increase the productivity and accuracy, and to provide a permanent, geo-coded digital database of the mapping results.

A further objective of the project was to provide cost and precision estimates for an annual seagrass biomass monitoring program for the Fisherman Islands area.

Eleven tasks were identified to fulfil the project specifications:

- digitising the study area in Auto CAD for input into the SPANS GIS system;
- mapping the mangroves using image processing of Landsat TM satellite data;
- stratifying the study area by photo-interpretation of digitised aerial photographs;
- undertaking a pilot study to determine seagrass-biomass estimates from photo-interpretation of the digitised aerial photograph. Sample sizes for the pilot study were obtained from seagrass variance estimates from previous work by CSIRO at Victoria Point;
- stratifying the study area based on a classified Landsat TM satellite image;
- stratifying the study area using scanned aerial photographs;
- stratifying the study area by depth;
- field sampling to quantify seagrass biomass, shoot density and leaf area (allocation of samples to strata using seagrass biomass variance estimates obtained from the pilot-study);
- analysis of the relative merits and disadvantages of digitised aerial photographs, Landsat satellite mapping and scanned aerial photographs. The four techniques were compared on the basis of cost and complexity of implementing as well as the precision of the estimate of seagrass biomass;
- transfer of the GIS database to the PBA GIS.

METHODS

Landsat satellite image

A Landsat TM image of the area was obtained for 7 September, 1991. The passover time was 09:30, which corresponded to a 1.8 m tide.

Aerial photograph

Aerial photographs of the study area were taken at low tide (14:30) on 7 September, 1991 (the same day as the Landsat TM image) at 3,000 m using a Hasselblad camera with a polarising filter.

Geographic Information System

A digital map of the Fisherman Islands provided in DXF format by the PBA was input into CSIRO's SPANS GIS system. However, the map did not cover the entire study area, so the area south of Oyster Point and north to Serpentine Creek was digitised from 1:25,000 nautical and topographic charts of the area (Chart — Lower Brisbane River and Approaches 1:25,000, Qld Dept Transport, 1986; Chart — Wellington Point to the Blue Hole, 1:25,000, 1985, Department of Harbours and Marine, Qld; Wynnum Topographic Map 1:25,000, 1984; Bishop Island Topographic Map, 1:25,000, 1971). Green Island, St. Helena Island and Mud Island were also digitised and incorporated into the map of the study area (Chart — Lower Brisbane River and Approaches 1:25,000, Qld Dept Transport, 1986; Chart — Wellington Point to the Blue Hole, 1:25,000, 1985, Department of Harbours and Marine, Qld; Wynnum; Moreton Bay Southport-Caloundra, 1:100,00, Qld Dept Transport, 1990) (Fig. 1). Depth data from nautical charts of the study area were also digitised with Auto CAD software, input into SPANS and contoured (Fig. 2). The contouring algorithm was based on interpolation of a triangulated-irregular-network.

The study area was stratified by photo-interpretation of a digitised, colour aerial photograph provided by the PBA (Fig. 3). Seven strata were identified; six seagrass strata and a subtidal channel area. The subtidal channel area was defined as all areas in the aerial photograph where bottom structure was not discernible in the photograph. The six seagrass strata were classified as intertidal high-density seagrass beds on the mudflats off Fisherman Islands, worming areas within the high-density seagrass beds, patchy seagrass areas,very patchy seagrass areas, patchy seagrass near Oyster Point, and high-density intertidal seagrass along the west side of St. Helena Island.

The aerial extent of the study area, the channel strata and the seven seagrass strata were calculated in SPANS. The total area was 41.0 km^2 of which 25.9 km^2 was subtidal channel. The most extensive seagrass strata was the intertidal high density seagrass areas on the mudflats off Fisherman Islands (8.1 km^2) which covered most of the 14.5 km^2 of intertidal mudflats.

The patchy seagrass and very patchy seagrass strata were similar in size (1.737 and 1.256 km^2 respectively). The worm digging area (0.454 km^2) was about the same size as the patchy seagrass area near Oyster Point (0.638 km^2). The smallest strata was the high-density seagrass bed along the western side of St. Helena Island (0.149 km^2). Intertidal areas (14.5 km^2) covered about 30% of the study area.

MANGROVES

The mangroves were mapped from the Landsat TM image using unsupervised classification of a ratio of band 4 (near infrared) to band 3 (green), band 4 and band 3 (Fig. 4). The image was rectified and re-sampled from the original 30 x 30 m pixel size to 25 x 25 m pixels.

SEAGRASS

Study area stratified by Landsat TM satellite data

The study area was mapped into 20 classes using unsupervised classification of bands 1, 2 and 3 (blue, green and red light) (Fig. 5). The 20 classes were reduced to nine by examining a dendrogram based on euclidean distances between average spectral values for the 20 classes. The image was rectified and re-sampled from the original 30 x 30 m pixel size to 25 x 25 m pixels. The spatial pattern of Landsat classes closely paralleled depth contours, and areas deeper than 3.5 m were removed from the Landsat map in SPANS because seagrass was known not to occur deeper than 3.5 m. The area was categorised into areas that potentially could support seagrass and mangroves (Fig. 5).

Study area stratification using scanned aerial photograph

The aerial photograph of the study area was scanned in simple image format (SIF) and imported into micro BRIAN (Fig. 6). The spatial resolution of the scanned aerial photograph was in the order of 1-2 m. However, the aerial photo-montage of the study area could not be used for mapping purposes because sun flare across frames made the montage useless for scanning. Variations in brightness and colour within many photographs were non-linear and could not be corrected for (Fig. 6). To overcome this problem, the photo-montage was digitised and input into SPANS.

Field sample design-pilot study

A pilot study was undertaken to obtain seagrass biomass and density variance estimates for the strata obtained by photo-interpretation of the digitised aerial photograph . To optimise sample design (Appendix 1). Anarea 60 x 60 m was chosen to be the primary sample unit because the 30 m accuracy of the GPS position fixing equipment indicated that the probability of correctly locating a 60 x 60 m sample unit in the field was greater than 95%. A complete listing of all potential sample units for each strata was generated using SPANS. Seventy-eight sample sites were randomly selected from this list. Sample sites were allocated to the six seagrass strata and the channel strata in proportion to their aerial extent and estimated above-ground seagrass biomass variance estimates (Fig. 7). Above-ground seagrass biomass variance was estimated from ongoing CSIRO studies of the seagrass of Victoria Point Twenty-seven samples were allocated to the dense seagrass, 8 to the worm digging area, 8 to the patchy seagrass, 8 to the very sparse seagrass, 8 to the St. Helena seagrass, 6 to the Oyster Pt. seagrass and 5 samples to the channel strata.

Pilot study field work

Sites were located in the field using a JRC-GPS receiver. At each site, a sample of the bottom was taken using a 0.085 m^2 hand-operated seagrass grab. The sample was washed in the field using a lug-basket (10 mm holes) to remove the sediment from the seagrass rhizomes. Seagrass samples were transferred to plastic bags and stored on ice. All seagrass samples were returned to CSIRO Marine laboratories, Cleveland for processing.

Sample processing

Seagrasses were separated into species taxa *Zostera capricorni*, *Halophila ovalis*, *Halophila spinulosa* and *Halodule uninervis*. For each species, the above-ground shoots and stems were separated from the below-ground rhizomes. The number of shoots/species in each sample were counted and for each species, the lengths and widths of ten randomly-selected shoots were measured. The above and below-ground components were dried at 60°C for 8 hours and weighed to the nearest 0.1 g. The leaf area was calculated for each species by multiplying the number of shoots in a sample by the average leaf area per shoot.

Pilot study results–optimal allocation of samples to strata

Variance estimates from the pilot study indicated that, for a sample size of 314, with Neymann allocation of samples to strata, a precision of around 15% would be obtained for seagrass biomass (Appendix 2). Because of the small sample size used in the pilot study, and hence, unreliable variance estimates, an additional 84 samples were allocated to the strata. Furthermore, at ten sites, 10 samples were taken to give a total sample size of 492. The study area was sampled again, using the same methods as the pilot-study.

RESULTS

Mangroves

There were 2.35 km^2 of mangroves in the study area. Five mangrove classes were identified; a dense/high-canopy class (0.385 km^2); a dense/mid-canopy class (1.248 km^2); a dense/low-canopy area (0.462 km^2); a seedling/mangrove fringe class (0.227 km^2) and a thin strip of mixels (mixed pixels) along the seaward edge of the mangrove forest due to mixed mangrove and mudflat pixel reflectance values (0.029 km^2). Mangroves classes were ground-truthed by Mark Pillsworth, Principal Environmental Scientist with the PBA.

Seagrass species distribution and shoot density

Four seagrass species, *Zostera capricorni*, *Halophila ovalis* , *H. spinulosa* and *Halodule uninervis* were recorded in the study area (Fig. 8 a to d). The seagrass was dense on the intertidal banks but density and cover declined rapidly with increasing water depth. *Zostera capricorni* and *Halophila ovalis* were the dominant species (Fig. 12).

Z. capricorni showed a fairly uniform distribution throughout the intertidal regions adjacent the mainland, Fisherman Islands and on the mudflats off St Helena Island. Highest values for *Z. capricorni* occurred off Oyster Point where densities of up to 136,100 shoots m^{-2} were recorded (Table 1).

Halophila ovalis also occurred extensively throughout the study area and values as high as 2,000 shoots m^{-2} were recorded. In contrast, *H. spinulosa* showed a very clumped distribution, with most of this seagrass restricted to an area 2,000 m off the mangroves on Fisherman Islands. Densities of 75,500 shoots m^{-2} were recorded. There was a large degree of overlap between *H. spinulosa* and *Halodule uninervis* distribution

Moreover, neither seagrass was sampled closer than 800 m to the shore. *H. uninervis* shoot densities were the lowest of all the seagrasses with a maximum density of 4,100 shoots m^{-2}.

Seagrass morphometrics

The average number of leaves per shoot was 2.09 for *Halodule uninervis* and 2.64 for *Zostera capricorni.* The average shoot length was 68 and 135 mm for *H. uninervis* and *Z. capricorni* respectively. The averages for *H. spinulosa* were 54 mm for the shoot length and 25 mm for the shoot width. The average leaf length and width for *H. ovalis* was 17 and 8 mm respectively. The standard errors of all estimates were less than 0.01.

Seagrass above and below-ground biomass

The patterns of distribution of the above and below-ground biomass for all seagrasses were similar to the distribution patterns for shoot density (Fig. 9 a to d and 10 a to d). Above-ground biomass was highest for *Z. capricorni* with a maximum 2.5$kg.m^{-2}$ recorded on the intertidal mudflats off Oyster Point and off Fisherman Islands. The maximum below-ground biomass was similar to the above-ground biomass (2.8 $kg.m^{-2}$). There was no significant difference between the above and below-ground biomass ($P>0.01$). The next largest biomasses recorded were for *H. spinulosa* at 0.2 $kg.m^{-2}$. There was no significant difference between above and below-ground biomass for this seagrass either ($P>0.01$). The maximum above-ground biomass for *H. uninervis* and *H. ovalis* was similar at 0.03 and 0.048 $kg.m^{-2}$ respectively. However, the ratio of above to below-ground biomass differed for these two species. The below-ground biomass for *H. uninervis* was significantly greater than the above-ground biomass ($P<0.01$), whereas there was no significant difference for *H. ovalis* ($P>0.01$).

The estimate of total biomass in the study area was highest for *Zostera capricorni* with an estimated 1,876 t of above-ground and 2,212 t below-ground material (Table 2). The estimated above and below-ground biomass of *H. ovalis* was 125 t and 127 t. For *H. uninervis,* it was 14.7 t and 27.7 t, and 50 and 29 t for *H. spinulosa* (Table 2).

Seagrass leaf area

The leaf area for the four seagrasses followed the same distribution patterns as biomass and shoot density (Fig. 11 a-d). The highest leaf areas were recorded for *Z. capricorni* with 0.24 m^{-2} leaf m^{-2} (Table 1). The next largest was *H. ovalis* at 0.15 m^{-2} leaf m^{-2}. *Halophila spinulosa* (0.064 m^{-2} leaf $m^{-2)}$ and *H. uninervis* (0.03 m^{-2} leaf m^{-2}) had relatively low leaf areas compared to the other two species.

Area covered by seagrass

The area covered by seagrass can be calculated from the results of random point sampling. It will overestimate seagrass cover since areas were sampled, not points, but the bias is minimal because the grab area was small (0.085 m^{-2}) relative to the study area size. Seagrass cover for each species and all strata was calculated as the proportion of sites in a strata where seagrass was sampled (Table 3). *Zostera capricorni* seagrass cover ranged from less than 1% in the channel strata to 82% in the St. Helena strata. *Halophila ovalis* cover ranged from less than 1% in the channel strata to 64% in the worm digging area. *H. spinulosa* cover was 23% in the dense seagrass strata and was largely absent from the remaining strata. *Halodule uninervis* was absent from all strata except the dense seagrass strata (8%), the worm digging area (7%) and channel (<1%).

Stratification

There were large gains in precision for most species when the study area was stratified based on depth, digitised aerial photographs or Landsat satellite mapping, compared to precisions expected if a simple random sample was used (Table 4). Precisions ranged from 15% for *Zostera capricorni* below-ground biomass stratified by depth or Landsat mapping, to 65% for *Halophila ovalis* shoot density from a random sample. With the exception of the random sample, which was always less precise than stratified estimates, the precisions varied depending on species and stratification method. Therefore, the best stratification method depended on the target species. For *Zostera capricorni*, the dominant seagrass in the study area, the highest precisions for above-ground biomass were obtained when stratification was based on digitised aerial photographs or Landsat satellite mapping. For below-ground biomass, the most precise estimates were obtained using either Landsat satellite data or depth and, for shoot density, the most reliable estimates were obtained when stratified by depth.

DISCUSSION

The aims of the study were to map and classify the seagrass and mangrove communities of the Fisherman Islands area using satellite imagery and aerial photography, and to compare and contrast the results. Three techniques (Landsat, digitised aerial photograph, and scanned aerial photograph) were compared for mapping and stratifying the study area.

There were 2.35 km^2 of mangroves in the study area. Five mangrove classes were identified: a dense high-canopy-height class (0.385 km^2); a dense mid-canopy-height class (1.248 km^2); a seedling/ mangrove fringe (0.227 km^2) and a small area (0.029 km^2) comprised of a mixture of mangroves and intertidal mudflat along the seaward edge of the mangroves.

There were 11.90 km^2 of seagrass supporting habitat in the study area. Four seagrass species were sampled in the study area, *Zostera capricorni*, *Halophila ovalis*, *H. spinulosa* and *Halodule uninervis*. The dominant seagrass, in terms of biomass, was *Z. capricorni*. The total seagrass biomass in the study area was estimated at 4,461.4 t, with 17% precision.

Stratification was an appropriate method for estimating seagrass biomass. It substantially improved the precision (from 31% to 17%) of the estimate of total seagrass biomass compared to simple random sampling However, the precisions were relatively unaffected by stratification method because of the significant correlation between seagrass biomass and depth. All three stratification methods resulted in strata which mirrored depth contours (Table 3).

The cost of digitising an aerial photograph was less than purchasing, image processing and rectifying Landsat satellite data, principally because of the small study area size. The cost of taking and scanning aerial photographs, for input into an image processing software system, was about the same as Landsat mapping.

It was not possible to stratify the study area using the scanned aerial photograph because sun flare across frames made the montage impossible to scan. However, image processing of a scanned colour aerial photograph could be an effective way of monitoring in small-scale studies because of the high resolution and colour contrast between features in the image. If the objective of the study included targeting small (>1 m) spatial objects, a scanned aerial photo is ideal because the image may be blocked up until the pixel reflectance variance reaches a maximum which corresponds to one half to three quarters the object size. This spatial resolution gives maximum discrimination between objects. For example, if the purpose of the study was to monitor changes in seagrass cover, due to the activities of worm diggers in the study area, then the optimal pixel size would be around 5 m. A possible monitoring strategy for such a study would be to compare variance estimates of a sequence of blocked scanned images as an indirect method of measuring changes due to worm digging. Image processing of scanned aerial photography provides one technique for such a study. Digitising the photo at this resolution would not be cost-effective and would suffer from digitising inaccuracies.

The precision of the estimate of total seagrass biomass was similar, regardless of stratification technique (digitised aerial photographs, Landsat satellite mapping and depth). However, the cost of digitising existing aerial photographs and digitising depth data from nautical charts was much lower compared to the costs of obtaining and processing Landsat-TM satellite data.

The use of networked image processing, Computer Aided Drawing (CAD), and GIS software substantially improved productivity and accuracy in the study. It also provided a permanent, geo-coded digital database which forms the basis for future mangrove and seagrass monitoring at Fisherman Islands.

Acceptable seagrass biomass estimates can be obtained for sample processing and field sampling costs of around $14,000 (1992 dollars) for 20% precision and $20,000 for 15% precision. The cost for precisions better than 15% increases dramatically to $28,000 for 10% and $56,000 for 5%. The optimal sample strategy for monitoring seagrass on Fisherman Islands intertidal area, based on these results, is to stratify the area based on depth (0 to 3.5 m at 0.5 m intervals - 7 strata) and use field sampling to estimate seagrass biomass. An acceptable 15% precision can be obtained for around $20,000. This sample design would permit reliable (80%) detection of changes in mean seagrass biomass of 15-18% with 95% confidence.

APPENDUM 1

Equations used for variance estimates

Terms

N_h total number of sampling units in stratum h

n_h number of samples in stratum h

y_{hi} value obtained from ith unit

$W_h = \frac{N_h}{N_h}$ stratum weight

$f_h = \frac{n_h}{N_h}$ sampling fraction in the stratum

$\bar{y} = \frac{\sum_{i=1}^{n_h} yh.i}{nh}$ stratum mean

$\bar{y}st = \sum_{h=1}^{L} Wh\bar{y}h$ stratified mean

$sh2 =$ sample estimate of stratum variance

$v(\bar{y}_{st}) = \sum_{h=1}^{L} \left(\frac{W^2_h s^2_h}{n_h} \right) - \sum_{h=1}^{L} \left(\frac{W^2_h s^2_h}{N} \right) =$

estimated strata variance

Estimation of sample size for fixed variance $v(\bar{y}st)$

where $n_o = \frac{N}{v(\bar{y}_{st})} \sum_{h=1}^{L} Nhsh2$

and $n = \frac{n_o}{\left(1 + \frac{n_o}{N}\right)}$

To compare the variance of a stratified sample with a random sample the following equation was used

$^{v}ran = \frac{N-n}{n(N-1)} \left(\frac{(n-1)}{n} s^2 + v(\bar{y}_{st}) \right) =$ estimated variance of the mean of a simple random sample from the same population where s^2 = estimated sample variation, N = total number of sampling units, n = number of samples.

APPENDUM 2

Pilot Study Strata Variance Estimates

Seagrass Above-Ground Biomass ($g.m^{-2}$)

Stratum	nh	$\bar{y}h$	sh2	Wh	Nh	Area (km2)
1. Dense seagrass	27	50.34	1,265	0.656	2,244	8.078
2. Worming Areas	8	30.27	695	0.037	126	0.045
3. Patchy seagrass	8	68.46	14,055	0.141	483	1.737
4. Very patchy seagrass	8	4.72	178	0.101	349	1.256
5. St. Helena seagrass	8	59.33	1,741	0.012	41	0.149
6. Oyster Pt. seagrass	6	15.99	590	0.052	177	0.638
7. Channel	5	0	0	0.680	7,226	26.000

Stratified mean $\bar{y}st = 45.41\ g.m^{-2}$
Standard error = 17.4
Precision = 39% of the mean

Neymann allocation of samples to strata

Neymann allocation was used to minimise variance for fixed sample size of 314 to give expected precision of 14% of the mean. The actual number of samples taken was 388.

Strata	Neymann n_h	Actual n_h		
1. Dense seagrass	164	1	8	2
2. Worming Area	7	1		4
3. Patchy seagrass	117	1	0	6
4. Very patchy seagrass	9	1		8
5. St. Helena seagrass	4	1		1
6. Oyster Point seagrass	4	1		1
7. Channel	0	46		

TABLE 1

Mean and variances of above-ground biomass, below-ground biomass and shoot density of *Z. capricorni, H. ovalis, H. uninervis* and *H. spinulosa* for the seven strata (see Appendix 2) calculated using stratification by: (a) Digitised aerial photographs, (b) Landsat-TM satellite map, and (c) Depth.

Table 1 (a) — Digitised aerial photographs

Z. capricorni

Strata	*Above ground biomass* ȳh	s^2_h	*Below ground biomass* ȳh	s^2_h	*Shoot density* ȳh	s^2_h
1	86.49	73,439	91.00	39,311	2,104	122,002,508
2	53.02	5,079	55.34	3,444	1,911	5,969,359
3	58.70	42,589	61.85	80,385	1,487	95,341,269
4	20.47	2,093	24.48	2,719	442	793,267
5	57.67	1,674	99.71	27,213	5,652	70,071,630
6	118.82	93,695	245.09	355,529	13,761	1,350,025,848
7	7.91	793	13.86	2,571	261	653,317

H. ovalis

Strata	*Above ground biomass* ȳh	s^2_h	*Below ground biomass* ȳh	s^2_h	*Shoot density* ȳh	s^2_h
1	5.817	394.864	5.405	244 34	1114.7	23,391,277
2	4.926	65.556	7.358	180.46	1384.9	8,616,548
3	3.557	206.421	3.551	74.48	2620.8	125,233,221
4	0.281	0.739	0.237	.56	9.3	80,786
5	0.219	0.274	0.118	0.05	0.9	36,565
6	3.201	19.544	3.076	21.90	1623.9	8,491,847
7	0.916	2.894	1.225	25.40	60.5	317,689

H. uninervis

Strata	*Above ground biomass* ȳh	s^2_h	*Below ground biomass* ȳh	s^2_h	*Shoot density* ȳh	s^2_h
1	0.77	16.29	1.60	70.22	58.82	128,640.4
2	0.63	5.56	1.22	20.78	57.87	48,442.9
3	0.00	0.00	0.00	0.00	0.00	0.0
4	0.00	0.00	0.00	0.00	0.00	0.0
5	0.00	0.00	0.00	0.00	0.00	0.0
6	0.00	0.00	0.00	0.00	0.00	0.0
7	0.10	0.49	0.14	0.91	12.48	7,174.2

H. spinulosa

Strata	Above ground biomass ȳh	Above ground biomass s^2_h	Below ground biomass ȳh	Below ground biomass s^2_h	Shoot density ȳh	Shoot density s^2_h
1	3.33	78.73	1.68	19.03	115.9	103499.7
2	0.00	0.00	0.00	0.00	0.0	0.0
3	0.00	0.00	0.00	0.00	0.0	0.0
4	0.00	0.00	0.00	0.00	0.0	0.0
5	0.00	0.00	0.00	0.00	0.0	0.0
6	0.00	0.00	0.00	0.00	0.0	0.0
7	0.35	2.10	0.33	1.59	20.8	6596.6

Table 1 (b) — Landsat Satellite Map

Z. capricorni

Strata	Above ground biomass ȳh	Above ground biomass s^2_h	Below ground biomass ȳh	Below ground biomass s^2_h	Shoot density ȳh	Shoot density s^2_h
1	10.5	833.0	14.3	1,558	260	563,239
2	80.7	77,228.5	83.9	67,943	2,583	194,096,437
3	2.3	24.9	8.4	523	147	132,671
4	30.9	9,800.1	87.5	113,395	2,639	123,204,345
5	101.1	5,339.7	121.0	12,427	2,128	77,875,422
6	23.0	1,111.8	32.4	3,045	660	906,188
7	13.5	917.5	44.2	11,214	1,020	9,711,436

H. ovalis

Strata	Above ground biomass ȳh	Above ground biomass s^2_h	Below ground biomass ȳh	Below ground biomass s^2_h	Shoot density ȳh	Shoot density s^2_h
1	0.83	8.42	1.12	17.36	143.7	215,922
2	5.13	310.95	4.89	205.82	1,455.8	37,269,867
3	10.20	125.06	10.99	144.85	1,245.7	1,505,080
4	0.35	2.40	0.33	1.72	76.6	62,838
5	2.55	89.25	3.52	168.59	1,979.0	77,525,643
6	0.41	1.35	0.40	1.08	160.3	158,553
7	4.75	553.25	3.54	299.43	2,887.6	202,933,271

H. uninervis

Strata	Above ground biomass ȳh	Above ground biomass s^2_h	Below ground biomass ȳh	Below ground biomass s^2_h	Shoot density ȳh	Shoot density s^2_h
1	0.29	1.43	0.40	2.63	35.90	20,625.8
2	0.57	12.34	1.19	53.21	3.52	97,202.9
3	0.11	0.10	0.37	1.12	21.42	3,672.7
4	0.00	0.00	0.00	0.00	0.00	0.0
5	0.20	1.81	0.39	6.76	19.19	15,770.4
6	0.00	0.00	0.00	0.00	0.00	0.0
7	0.00	0.00	0.00	0.00	0.00	0.0

H. spinulosa

Strata	Above ground biomass ȳh	Above ground biomass s^2_h	Below ground biomass ȳh	Below ground biomass s^2_h	Shoot density ȳh	Shoot density s^2_h
1	0.00	0.00	0.00	0.00	0.00	0.0
2	2.41	59.57	1.20	14.04	82.86	74993.6
3	4.06	63.75	1.99	13.53	214.16	189096.9
4	0.00	0.00	0.00	0.00	0.00	0.0
5	0.01	0.00	0.00	0.00	0.54	12.8
6	0.00	0.00	0.00	0.00	0.00	0.0
7	0.00	0.00	0.00	0.00	0.00	0.0

Table 1 (c) — Stratified by depth

Z. capricorni

Strata	Above ground biomass ȳh	Above ground biomass s^2_h	Below ground biomass ȳh	Below ground biomass s^2_h	Shoot density ȳh	Shoot density s^2_h
1	82.99	47073.8	107.1	110999	4057	372807120
2	79.85	64667.2	95.4	29624	1241	7541423
3	86.24	90425.3	83.3	57258	1913	29204805
4	6.37	697.2	13.5	3636	1568	85504257
5	2.25	41.1	8.0	650	148	199939
6	0.00	0.0	0.0	0	0	0
7	7.32	592.5	10.0	1108	181	399057

H. ovalis

	Above	Below

Strata	*ground biomass* ȳh	s^2_h	*ground biomass* ȳh	s^2_h	*Shoot density* ȳh	s^2_h
1	2.46	139.72	2.35	95.8	1,493	55,265,785
2	6.19	620.59	5.21	366.0	425	43,716,802
3	4.44	70.15	5.54	122.8	1,571	58,448,659
4	6.86	114.02	6.81	138.6	1,820	50,396,349
5	1.22	7.61	2.20	26.2	122	74,021
6	0.00	0.00	0.00	0.0	0	0
7	0.58	5.89	0.79	12.0	103	151,370

H. uninervis

Strata	*Above ground biomass* ȳh	s^2_h	*Below ground biomass* ȳh	s^2_h	*Shoot density* ȳh	s^2_h
1	0.067	0.59	0.12	2.2	6.2	5137
2	0.559	13.33	1.09	58.2	51.5	165755
3	1.165	22.23	2.52	94.3	74.8	79727
4	0.000	0.00	0.00	0.0	0.0	0
5	0.000	0.00	0.00	0.0	0.0	0
6	0.000	0.00	0.00	0.0	0.0	0
7	0.208	0.99	0.28	1.8	24.9	14348

H. spinulosa

Strata	*Above ground biomass* ȳh	s^2_h	*Below ground biomass* ȳh	s^2_h	*Shoot density* ȳh	s^2_h
1	0.004	0.00	0.00	0.00	0.17	4.1
2	1.481	36.54	0.59	6.41	60.76	67322.8
3	4.094	99.77	2.06	23.48	122.24	95105.8
4	4.119	91.60	2.33	25.98	154.56	133160.7
5	1.383	7.36	1.80	15.25	75.88	19578.5
6	0.000	0.00	0.00	0.00	0.00	0.0
7	0.000	0.00	0.00	0.00	0.00	0.0

TABLE 2

Stratified mean estimates $\bar{y}h_{st}$, variance of the mean $v(\bar{y}_{st})$, upper (U95) and lower (L95) 95% confidence limits and estimated tonnes of seagrass in the study area and their 95% confidence limits for the study area stratified by A - digitised aerial photograph, L - Landsat satellite map and D - depth.

Z. capricorni

Above-ground biomass

Strata	$\bar{y}h_{st}$	$v(\bar{y}_{st})$	U95	L95	tonnes	U95	L95
A	29.69	26.61	39.80	19.58	1136	1522	749
L	48.92	70.44	65.37	32.47	1876	2507	1245
D	34.19	42.27	46.94	21.45	1298	1782	814

Below-ground biomass

Strata	$\bar{y}h_{st}$	$v(\bar{y}_{st})$	U95	L95	tonnes	U95	L95
A	37.50	41.04	50.05	24.94	1434	1914	954
L	57.68	79.60	75.16	40.19	2212	2883	1541
D	40.33	36.48	52.17	28.49	1531	1980	108

Shoot density

Strata	$\bar{y}h_{st}$	$v(\bar{y}_{st})$	U95	L95
A	965	54893	1424	506
L	1599	179438	2429	769
D	1071	57811	1542	599

H. ovalis

Above-ground biomass

Strata	$\bar{y}h_{st}$	$v(\bar{y}_{st})$	U95	L95	tonnes	U95	L95
A	2.13	0.2217	3.05	1.21	82	117	46
L	3.26	0.3523	4.42	2.10	125	170	81
D	2.70	0.1843	3.54	1.86	103	135	71

Below-ground biomass

Strata	$\bar{y}h_{st}$	$v(\bar{y}_{st})$	U95	L95	tonnes	U95	L95
A	2.28	0.31	3.38	1.18	87	129	45
L	3.31	0.34	4.46	2.17	127	171	83
D	2.89	0.22	3.82	1.96	110	145	75

Shoot density

Strata	$\bar{y}h_{st}$	$v(\bar{y}_{st})$	U95	L95
A	509	10545	710	308
L	942	41182	1341	545
D	790	40679	1186	395

H. uninervis

Above-ground biomass

Strata	$\bar{y}h_{st}$	$v(\bar{y}_{st})$	U95	L95	tonnes	U95	L95
A	0.241	0.009	0.42	0.06	9.2	16.2	2.2
L	0.384	0.022	0.67	0.10	14.7	25.7	3.7
D	0.323	0.015	0.57	0.09	12.4	21.6	3.3

Below-ground biomass

Strata	$\bar{y}h_{st}$	$v(\bar{y}_{st})$	U95	L95	tonnes	U95	L95
A	0.45	0.025	0.76	0.14	17.2	29.0	5.3
L	0.72	0.065	1.22	0.22	27.7	46.8	8.6
D	0.63	0.048	1.06	0.20	23.8	40.1	7.5

Shoot density

Strata	$\bar{y}h_{st}$	$v(\bar{y}_{st})$	U95	L95
A	21.6	101.08	41.3	1.91
L	34.4	243.62	65.0	3.82
D	27.8	143.61	51.28	4.31

H. spinulosa

Above-ground biomass

Strata	$\bar{y}h_{st}$	$v(\bar{y}_{st})$	U95	L95	tonnes	U95	L95
A	0.94	0.039	1.33	0.56	36.0	50.7	21.
L	1.24	0.057	1.71	0.77	47.4	65.4	29.4
D	1.32	0.062	1.81	0.83	50.2	68.8	31.6

Below-ground biomass

Strata	$\bar{y}h_{st}$	$v(\bar{y}_{st})$	U95	L95	tonnes	U95	L95
A	0.58	0.020	0.86	0.30	22.1	32.7	11.5
L	0.62	0.013	0.84	0.39	23.6	32.3	15.0
D	0.77	0.023	1.06	0.47	29.1	40.4	17.8

Shoot density

Strata	$\bar{y}h_{st}$	$v(\bar{y}_{st})$	U95	L95
A	38.6	89.2	57.1	20.1
L	45.0	87.8	63.3	26.6
D	47.7	82.8	65.5	29.9

TABLE 3

Seagrass cover for each seagrass species in the seven strata identified from photo-interpretation of digitised aerial photographs. Cover for each species was calculated as the proportion of sites in a strata from which it was sampled.

Strata	*Z. capricorni*	*H. ovalis*	*H. spinulosa*	*H. uninervis*
1 Dense seagrass	60	51	23	8
2 Worming area	71	64	0	7
3 Patchy seagrass	37	34	0	0
4 Very patchy seagrass	28	11	0	0
5 St. Helena seagrass	82	36	0	0
6 Oyster Pt. seagrass	63	56	0	0
7 Channel	<1	<1	<1	<1

TABLE 4

Comparison of the precision of the estimates (standard error of the strata mean divided by the stratified mean expressed as a percent) for above and below-ground biomass, and shoot density stratified by aerial photography (Aerial), Landsat satellite data (Landsat), depth and a random design (Random) for the four species of seagrasses sampled in the study area.

Above-ground biomass

	Aerial	Landsat	Depth	Random
Zostera capricorni	17	17	19	37
Halophila ovalis	22	18	16	28
Halodule uninervis	39	39	38	55
Halophila spinulosa	21	19	19	30

Below-ground biomass

	Aerial	Landsat	Depth	Random
Zostera capricorni	17	15	15	31
Halophila ovalis	24	18	16	28
Halodule uninervis	35	35	35	64
Halophila spinulosa	24	18	20	26

Shoot density

	Aerial	Landsat	Depth	Random
Zostera capricorni	24	27	22	60
Halophila ovalis	20	22	26	65
Halodule uninervis	47	45	43	57
Halophila spinulosa	25	21	19	28

FIGURE 1

Fisherman Islands study area

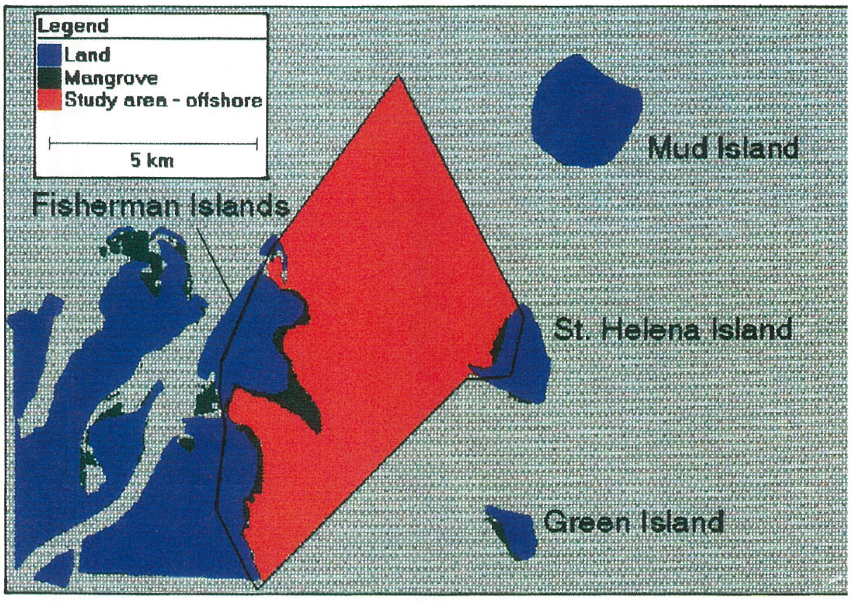


FIGURE 2

Depth contour plot of study area

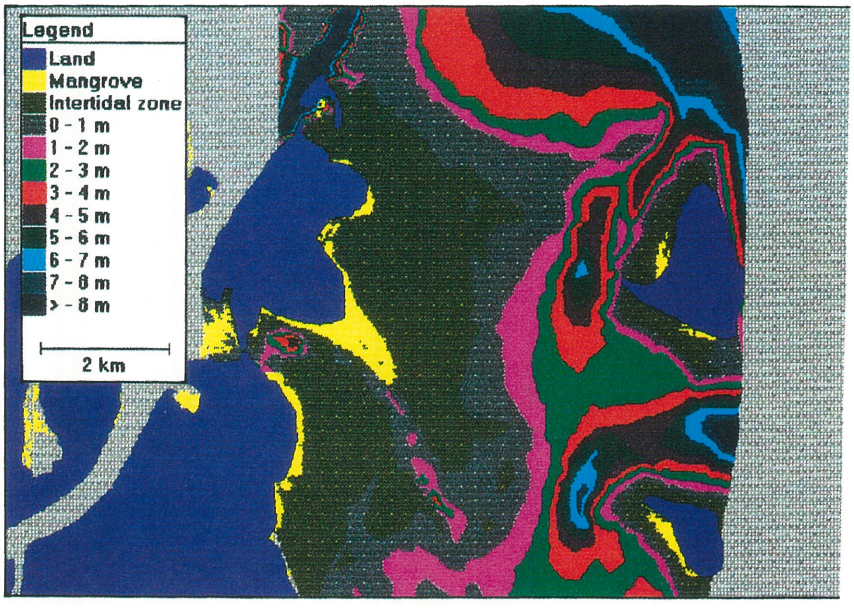


FIGURE 3

Study area strata from photo interpretation of digitised aerial photograph.

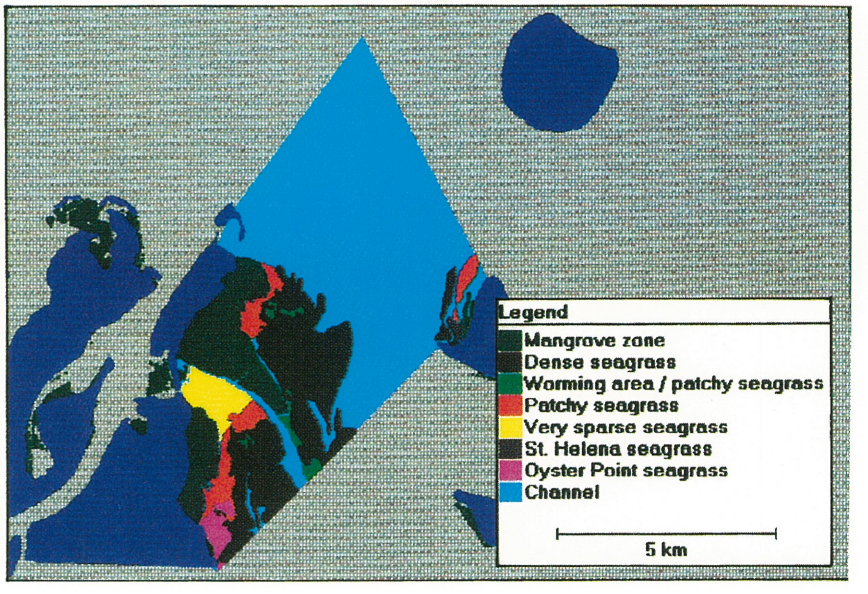


FIGURE 4

Mangroves of Fisherman Islands

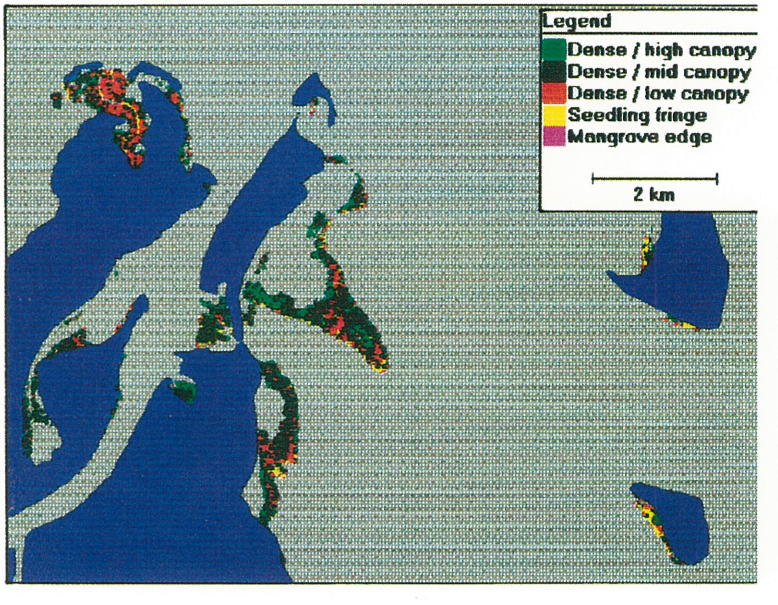


FIGURE 5

Landsat TM map of the study area, classified using blue, green, and red light, showing the mangrove zone and channel areas, and potential seagrass habitat. (Note - this is not a map of actual seagrass areas).

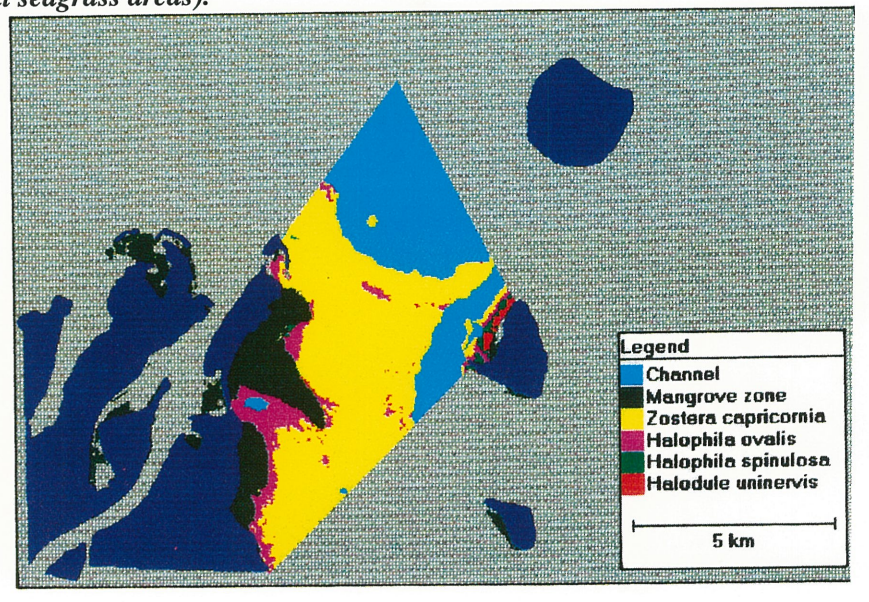


FIGURE 6

Scanned aerial photograph

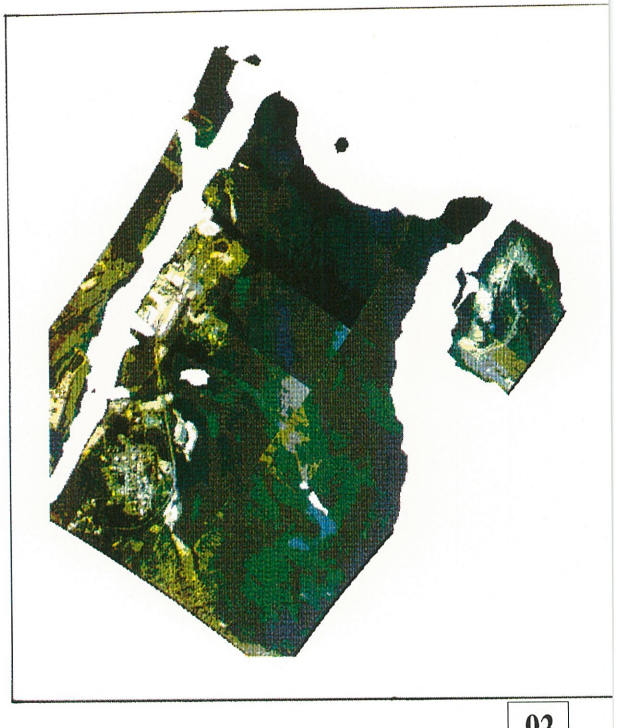


FIGURE 7

Plot of site positions for the pilot study

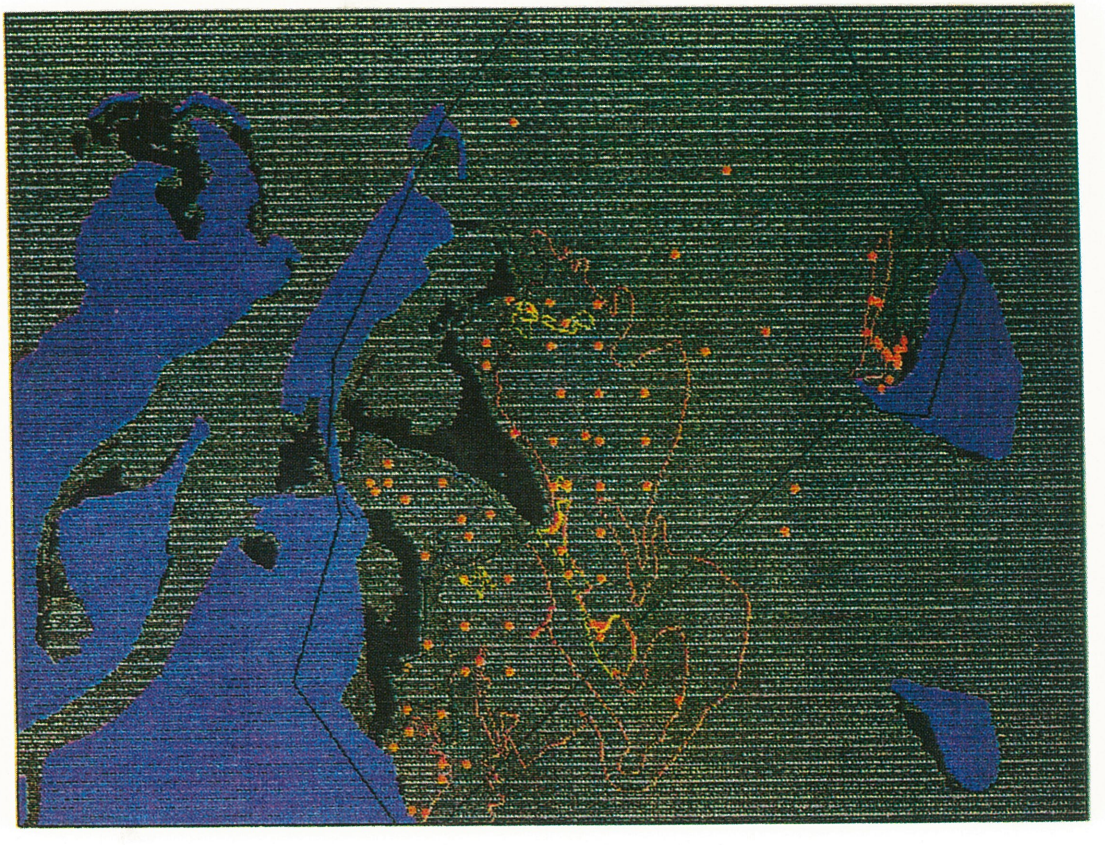


FIGURE 8A

Shoot density (m^2) for Zostera capricorni

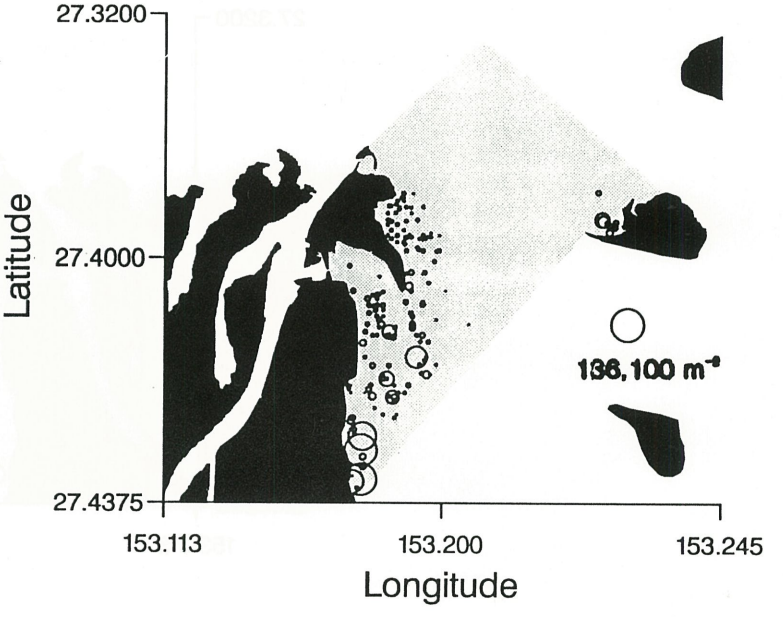


FIGURE 8B

Shoot density (m^2) for Halophila ovalis

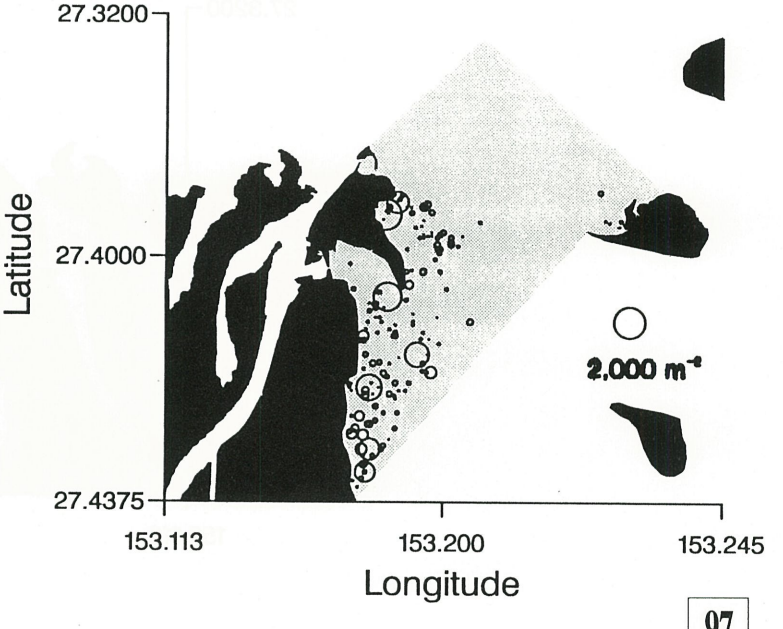


FIGURE 8C

Shoot density (m^2) for Halophila spinulosa

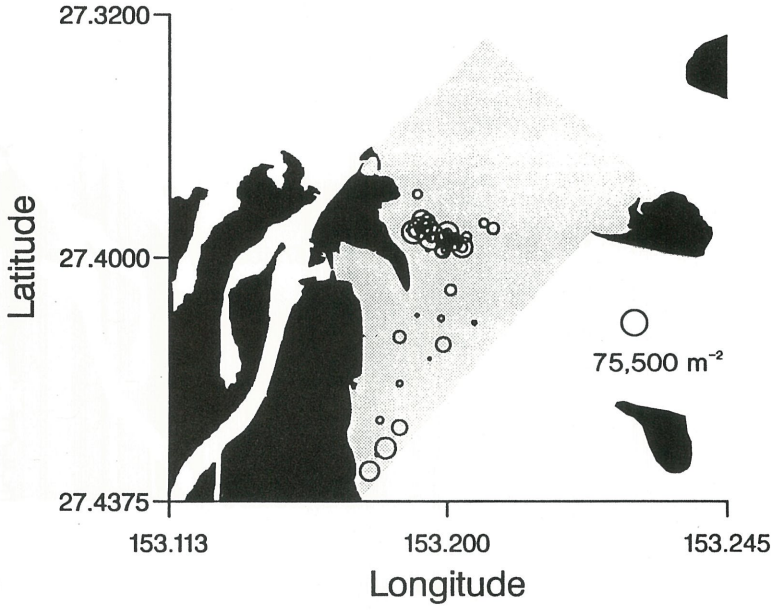


FIGURE 8D

Shoot density (m^2) for Halodule uninervis

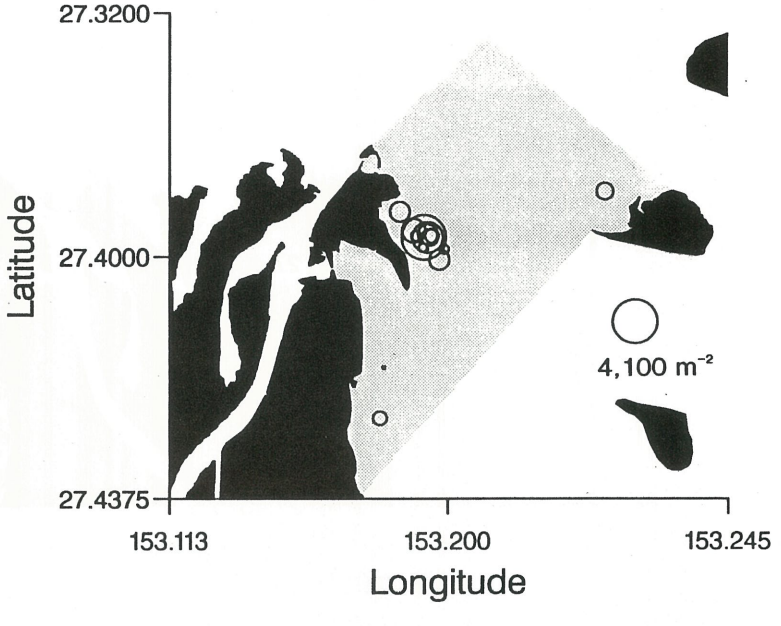


FIGURE 9A

Above-ground biomass ($g.m^{-2}$) for Zostera capricorni

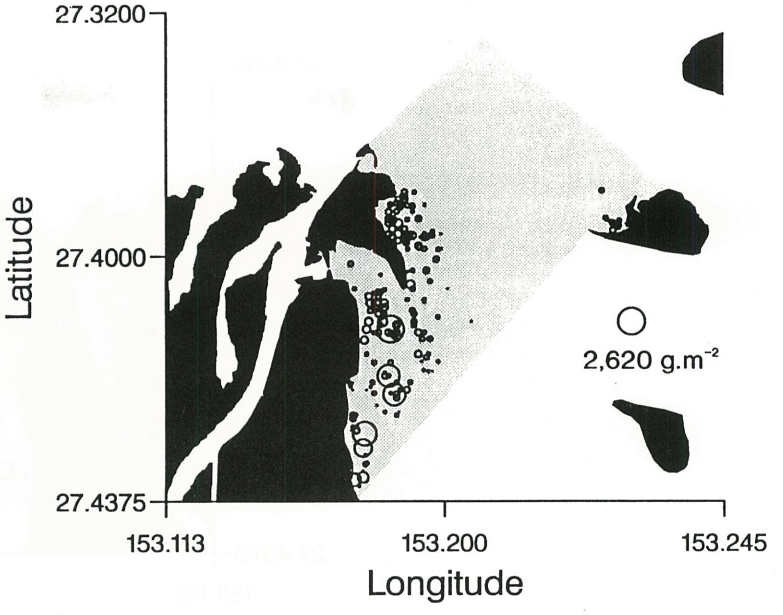


FIGURE 9B

Above-ground biomass ($g.m^{-2}$) for Halophila ovalis

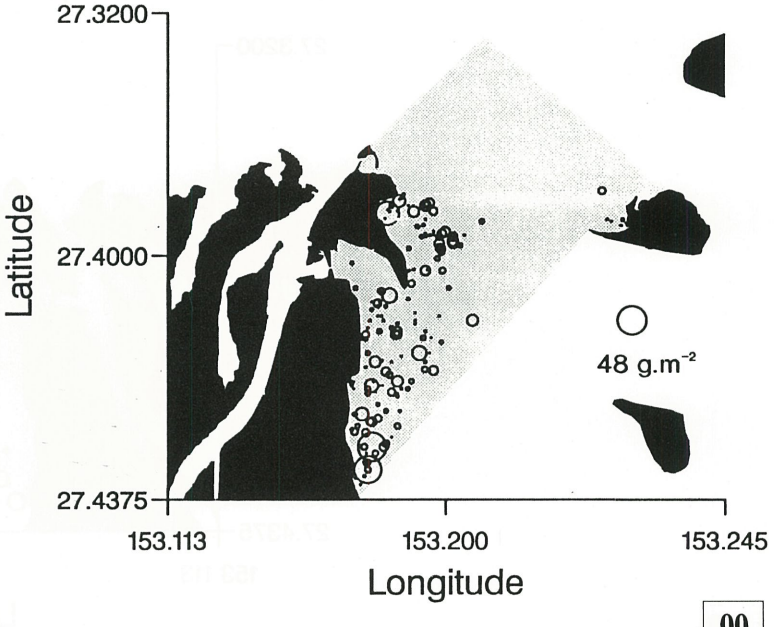


FIGURE 9C

Above-ground biomass ($g.m^{-2}$) for Halophila spinulosa

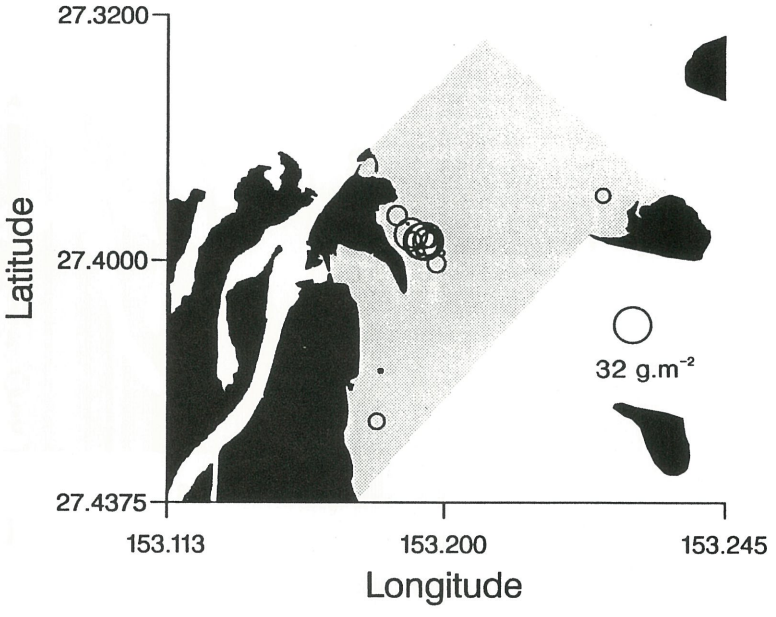


FIGURE 9D

Above-ground biomass ($g.m^{-2}$) for Halodule uninervis

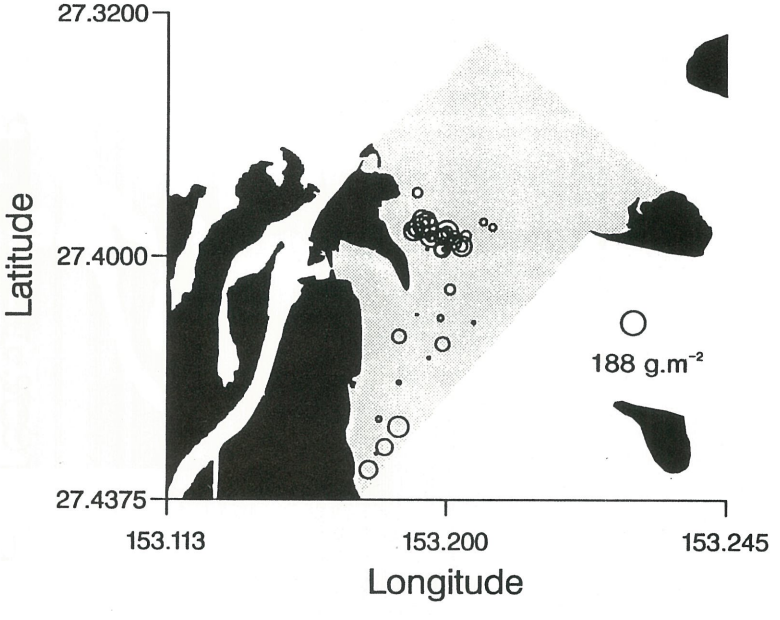


FIGURE 10A

Below-ground biomass ($g.m^{-2}$) for Zostera capricorni

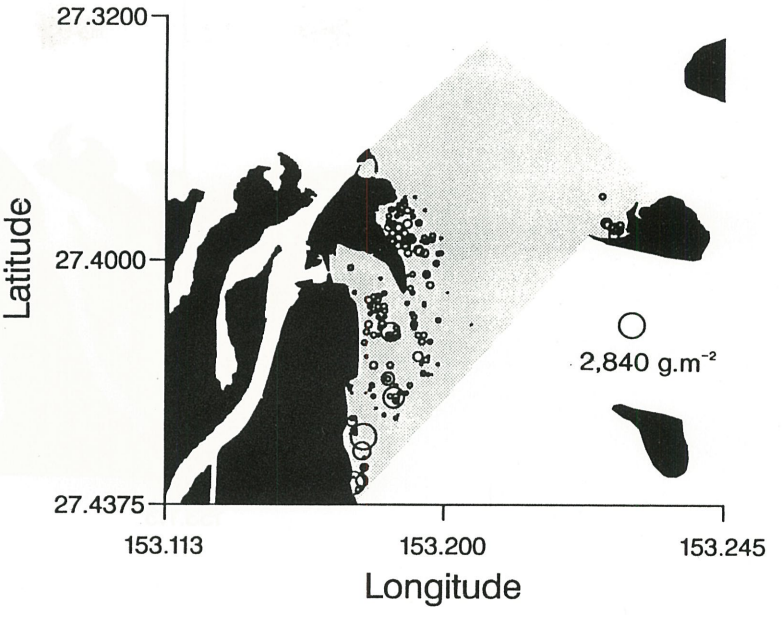


FIGURE 10B

Below-ground biomass ($g.m^{-2}$) for Halophila ovalis

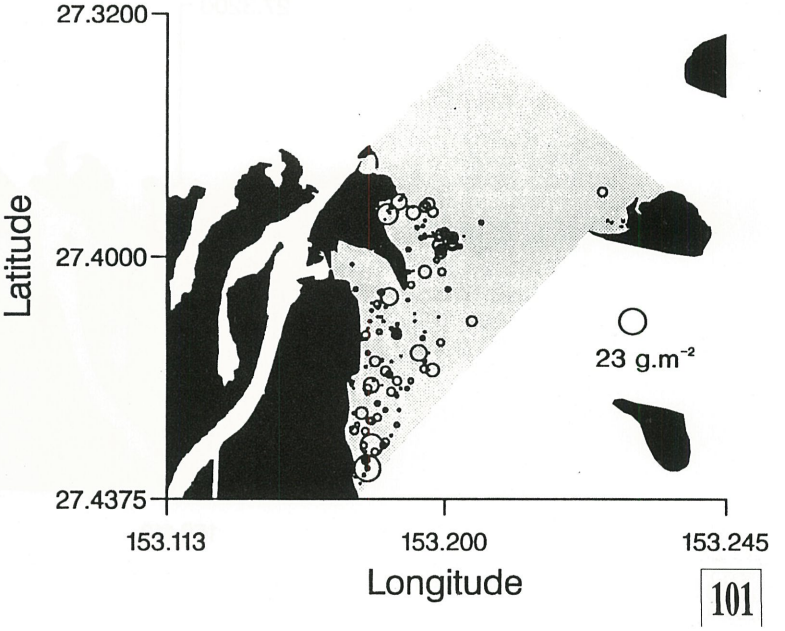


FIGURE 10C

Below-ground biomass ($g.m^{-2}$) for Halophila spinulosa

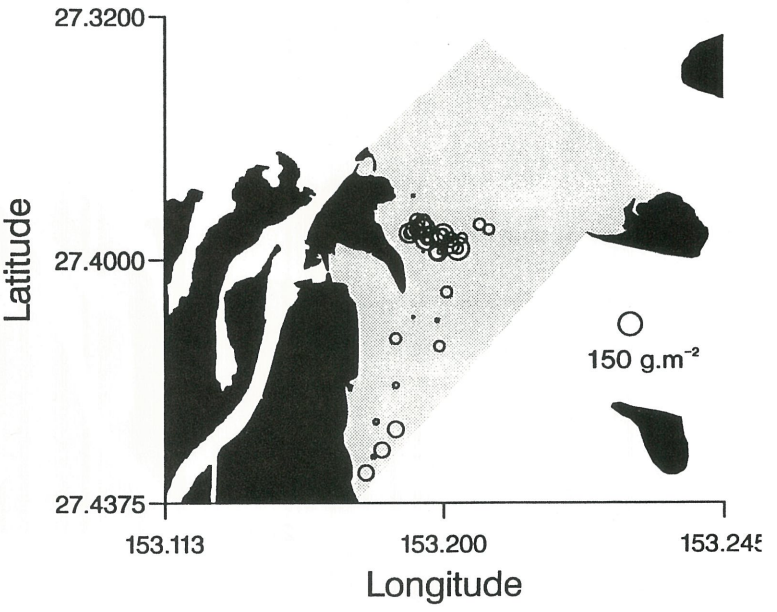


FIGURE 10D

Below-ground biomass ($g.m^{-2}$) for Halodule uninervis

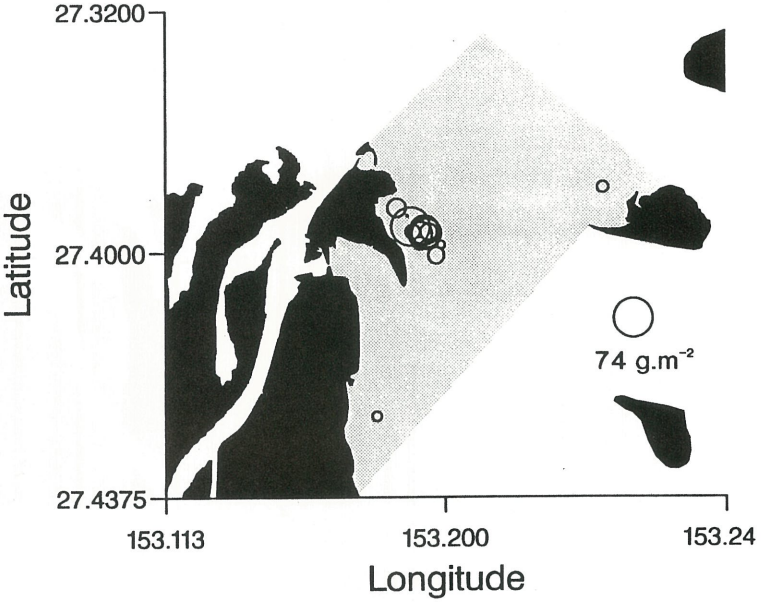


FIGURE 11A

Leaf area ($mm^2.m^{-2}$) for Zostera capricorni

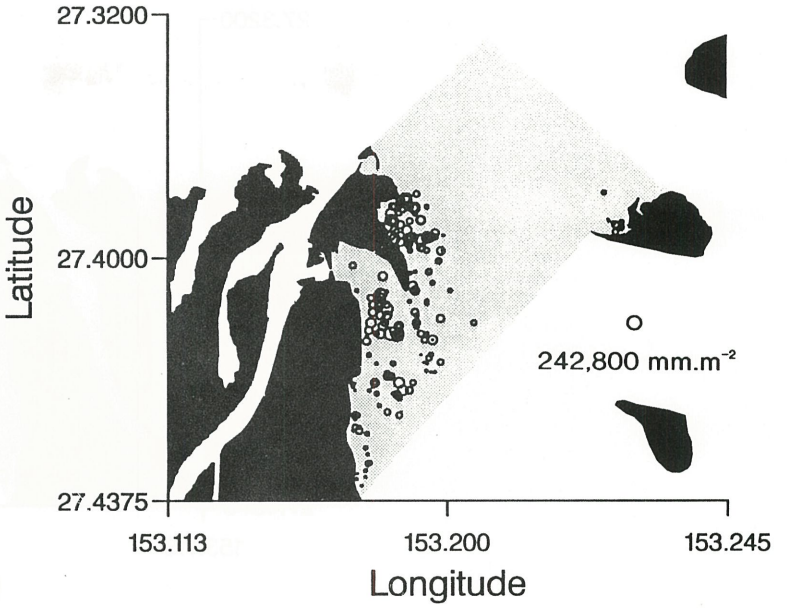


FIGURE 11B

Leaf area ($mm^2.m^{-2}$) for Halophila ovalis

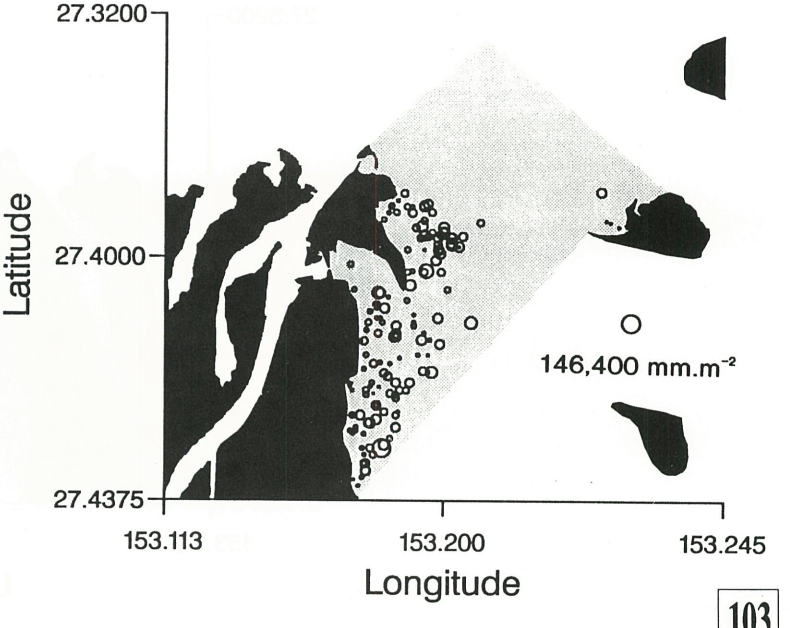


FIGURE 11C

Leaf area ($mm^2.m^{-2}$) for Halophila spinulosa

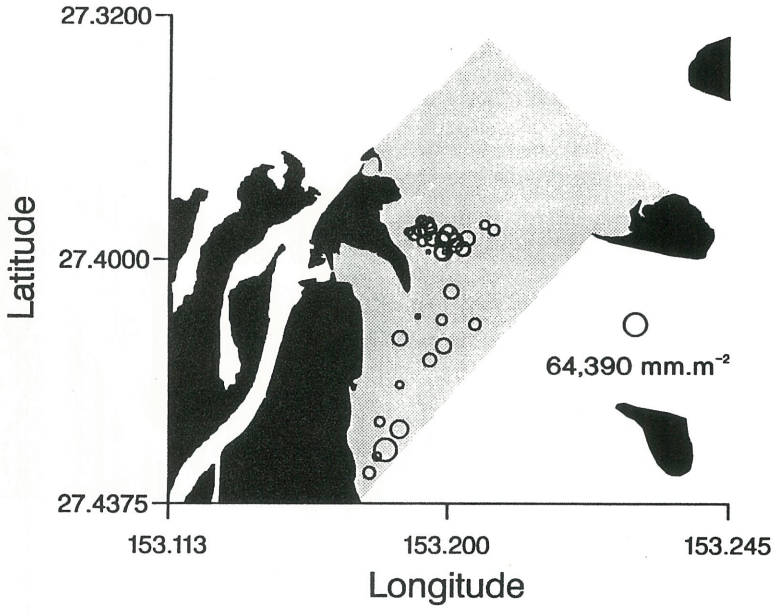


FIGURE 11D

Leaf area ($mm^2 .m^{-2}$) for Halodule uninervis

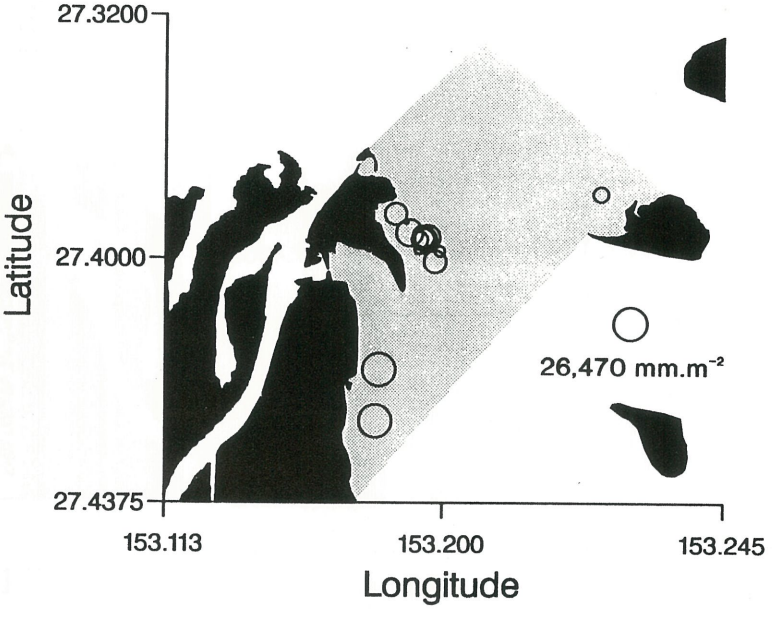
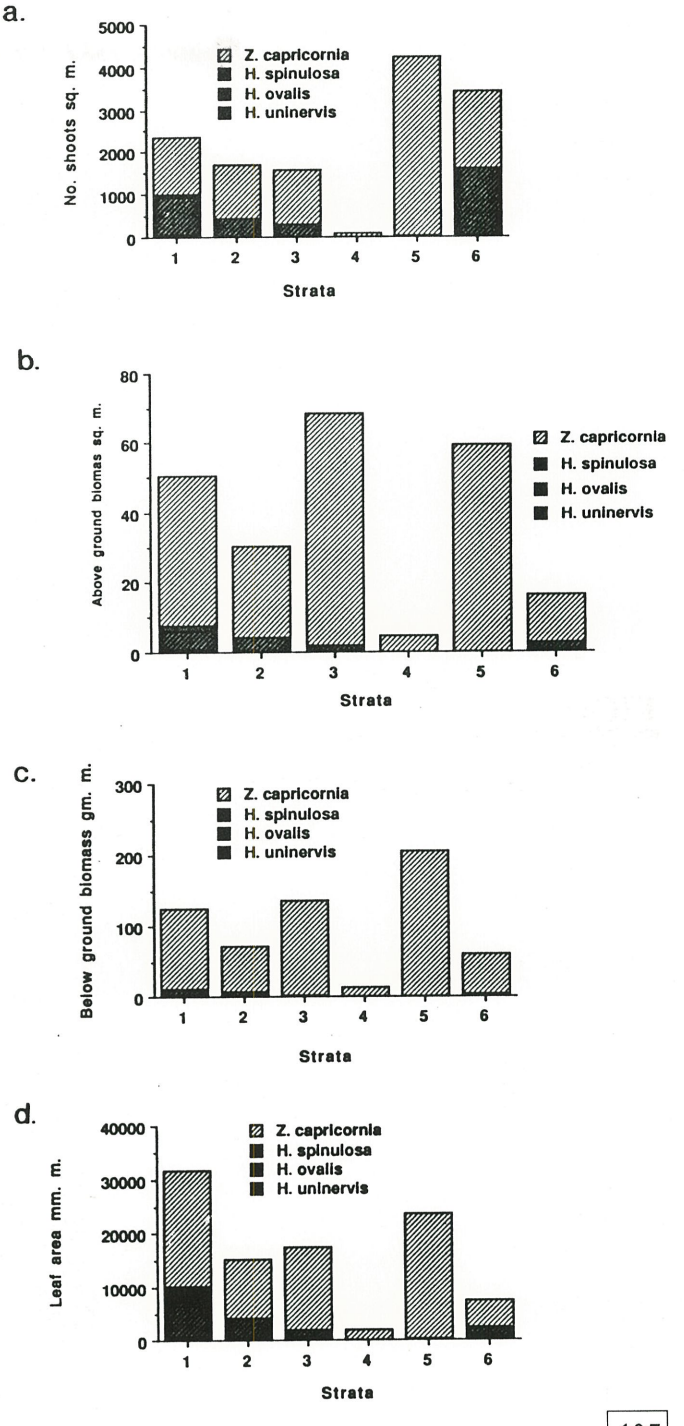


FIGURE 12

(a) Seagrass shoot density; (b) above-ground biomass; (c) below-ground biomass; and (d) leaf area for the four species of seagrass sampled from the six seagrass strata classified for the Fisherman Islands



APPENDIX III

MARINE CURRENTS AND SEDIMENTS NEAR FISHERMAN ISLANDS

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Date: January 1992

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EXECUTIVE SUMMARY

The nature and behaviour of ecological communities in nearshore marine areas is strongly related to the nature of the sediments and the patterns of sedimentation and scour there. These in turn are determined to a significant degree by current patterns induced by wave, tide and wind influences. The principal objective of the present study is to provide an understanding of the general current patterns and velocities in the subject area, as influenced by tide and wind. This has been achieved through the use of computer modelling techniques which provide for definition of the bathymetry of the area from survey data, and input of tidal and wind boundary forcing data. The use of computer modelling offers substantial advantages over direct measurements which provide information only at specific sites and for the particular conditions at the time. A two-dimensional model of the study area has been established. It is linked dynamically to a one-dimensional model of the Brisbane River to ensure correct reproduction of local flow to and from the river. A link via the Boat Passage is also included. Consistent with the commissioning agreement, no specific validation of the model in terms of nearshore flow patterns has been undertaken at this stage. Nevertheless, confidence in the results can be gained from the facts that:

- The model bathymetry is based on reliable chart data.
- The model boundary tides are based on information from the larger Moreton Bay model which water gives level results consistent with extensive recorded information.
- Procedures used are reliable and comprehensive.
- The known flow to and from the river peaking at about 2500 cumecs for the mean spring tide is reproduced in the model.

The key conclusions reached from the bed shear stress information derived from the modelling are as follows:

(i) The study area has five broad zones of distinctly different hydrodynamic character which would be expected to display different sedimentation patterns. These are:

- The northern banks directly east from Bishop Island, with relatively low shear stresses but exposed to wave action from east to north directions.
- A zone of shallow banks with high tidal current related bed shear stresses extending eastward from the northern part of Fisherman Islands and past the northwestern tip of St Helena Island.
- A large more or less circular zone of low bed shear stress adjacent to the central parts of Fisherman Islands, and receiving a significant degree of shelter from waves by St Helena and Green Islands.
- A zone of moderate bed shear stress towards the southern nearshore area, being the principal flowpath to and from the Boat Passage.
- Deeper channels adjacent to St Helena and Green Islands with moderate to high bed shear stress levels.

(ii) Sediment types expected in each of these five zones are as follows:

- Highly variable in northern banks, with areas of silts, sandy silts and silty sands depending on the degree of exposure to wave action. Some exposed shallower patches nearer to Bishop Island may contain relatively clean sand.
- Sand and silty sand on the shallow banks where high bed shear stresses occur.
- Silts and sandy silts in the large sheltered zone southwest of St Helena Island where low bed shear stresses are identified.
- Mixed bed sediments and relatively high water turbidity in the southern areas leading to the Boat Passage, with a net movement of sediments towards the Passage and zones of bed shear capable of continually re-suspending this material.
- Mixed and variable sediments in the deeper scoured channels depending on the tide range conditions, sediment supply and relict sub-surface sediments at any given time and place. Bed armouring and/or cohesive properties may be important in fine silt areas. There may also be zones of coarser sands or exposed bedrock in the higher flow areas.

Sediment sampling has been undertaken to identify bed sediment properties over a wide extent of the study area. Shell and silt content and sample size gradings were determined

Generally, the sediment sample results are consistent with the indications from the modelling. Silty sands are found over most of the study area. The coarser, clean sand along the east-west ridge which extends west from St Helena Island is clearly identified

in the model and in the sample results. The deeper areas between St Helena and Green Islands are high in silts, even in high energy areas, due to a lack of supply of sand there. Extensive shell armouring is evident in these areas.

Seagrass is found in areas of low bed shear stress, generally less than 0.1N/m^2 with some extending up to about 0.12N/m^2. When the limitations of wave exposure and water depth (light penetration) are considered, the modelling provides a useful indicator of areas of potential seagrass development.

INTRODUCTION

1.1 Background

The Port of Brisbane Authority (PBA) is proposing to expand the area available for port related facilities on the southern side of the mouth of the Brisbane River. The port expansion could involve reclamation of intertidal and shallow subtidal lands to the east and southeast of Fisherman Islands.

The nature and behaviour of ecological communities in nearshore marine areas is strongly related to the nature of the sediments and the patterns of sedimentation and scour there. These in turn are determined to a significant degree by current patterns induced by wave, tide and wind influences.

The PBA has commissioned WBM Oceanics to investigate current patterns at and near the Fisherman Islands nearshore area in order to gain a better understanding of the sediment-related ecological processes there.

Two comprehensive two-dimensional numerical hydrodynamic models of Moreton Bay and the Port have been developed previously and used for investigation of potential siltation processes within the Port area itself, as detailed in Reference 2. This report outlines the results of further modelling of currents and sediment patterns in the study area.

1.2 The Site

The study area is shown in Figures 1.1 and 1.2, and is bounded to the west by Fisherman and Bishop Islands and the mainland and to the east by Mud, St Helena and Green Islands.

The site is characterised by large expanses of intertidal and shallow sub-tidal banks with some deeper scoured tidal channels adjacent to the nearshore islands. The Boat Passage channel links the Bay directly to the Brisbane River between Fisherman and Whyte Islands.

As has been shown in other studies (Reference 1), the tide propagates through Moreton Bay predominantly from north to south with some relatively minor influence through South Passage. At the site the tide approaches more or less from the northeast.

There is a marked progressive amplification of the tide from the ocean to the southern parts of the Bay. The tidal range at Redland Bay is some 43% greater than that in the ocean. Within the study area, the range at Wellington Point is about 4% greater than that at Mud Island, and lagged by about five minutes.

1.3 Scope

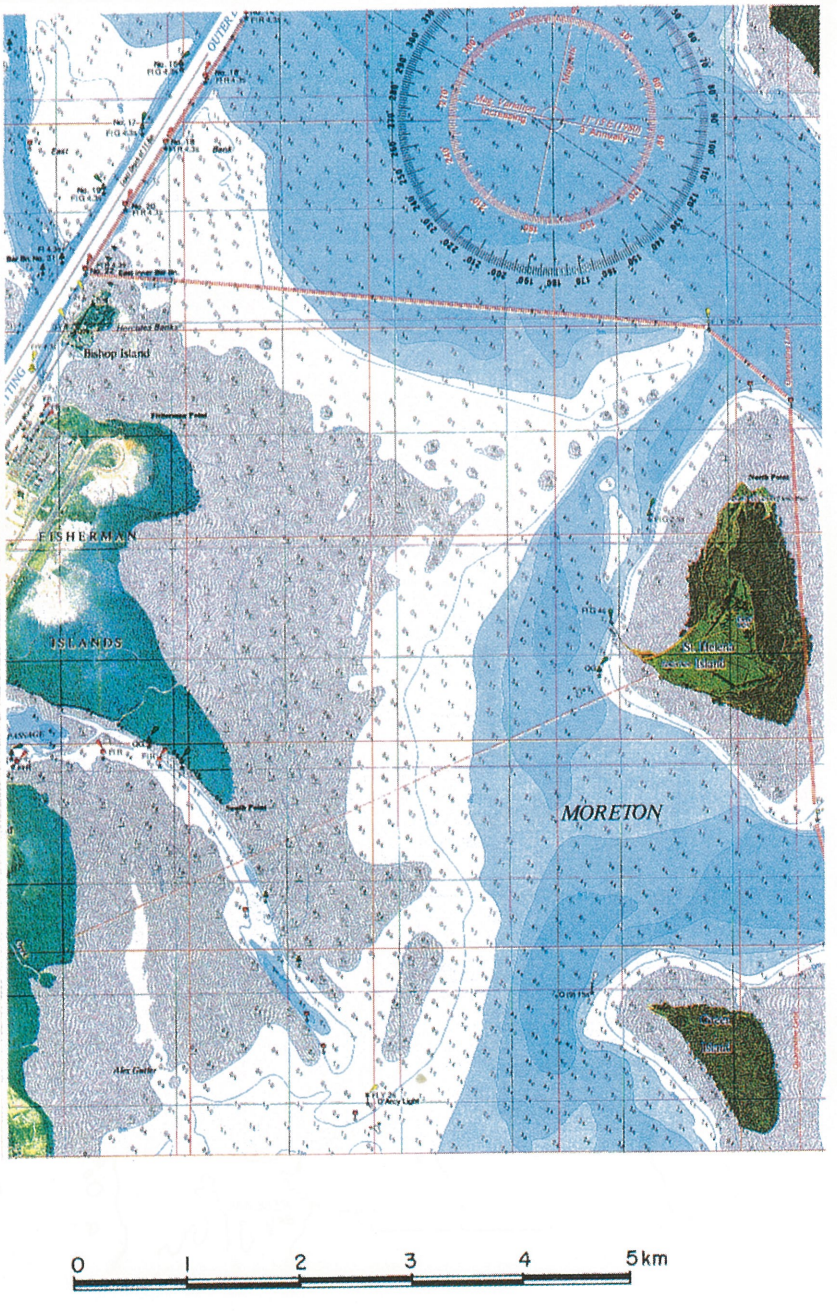
The principal objective of the present study is to provide an understanding of the general current patterns and velocities in the subject area, as influenced by tide and wind. This has been achieved through the use of computer modelling techniques which provide for definition of the bathymetry of the area from survey data, and input of tidal and wind boundary forcing data. The use of computer modelling offers substantial advantages over direct measurements which provide information only at specific sites and for the particular conditions at the time.

After review of the existing WBM Oceanics computer models, it was decided to establish a new third model for this study in order to most comprehensively cover the region of interest. The modelling program TUFLOW has been used (refer Appendix I for details). This program has been developed and rigorously tested in a large number of studies and as part of a research project between WBM and the University of Queensland.

The two-dimensional model of the study area is linked dynamically to a one-dimensional model of the Brisbane River to ensure correct reproduction of local flow to and from the river. A link via the Boat Passage is also included. Consistent with the commissioning agreement, no specific validation of the model in terms of nearshore flow patterns has been undertaken at this stage.

FIGURE 1.1

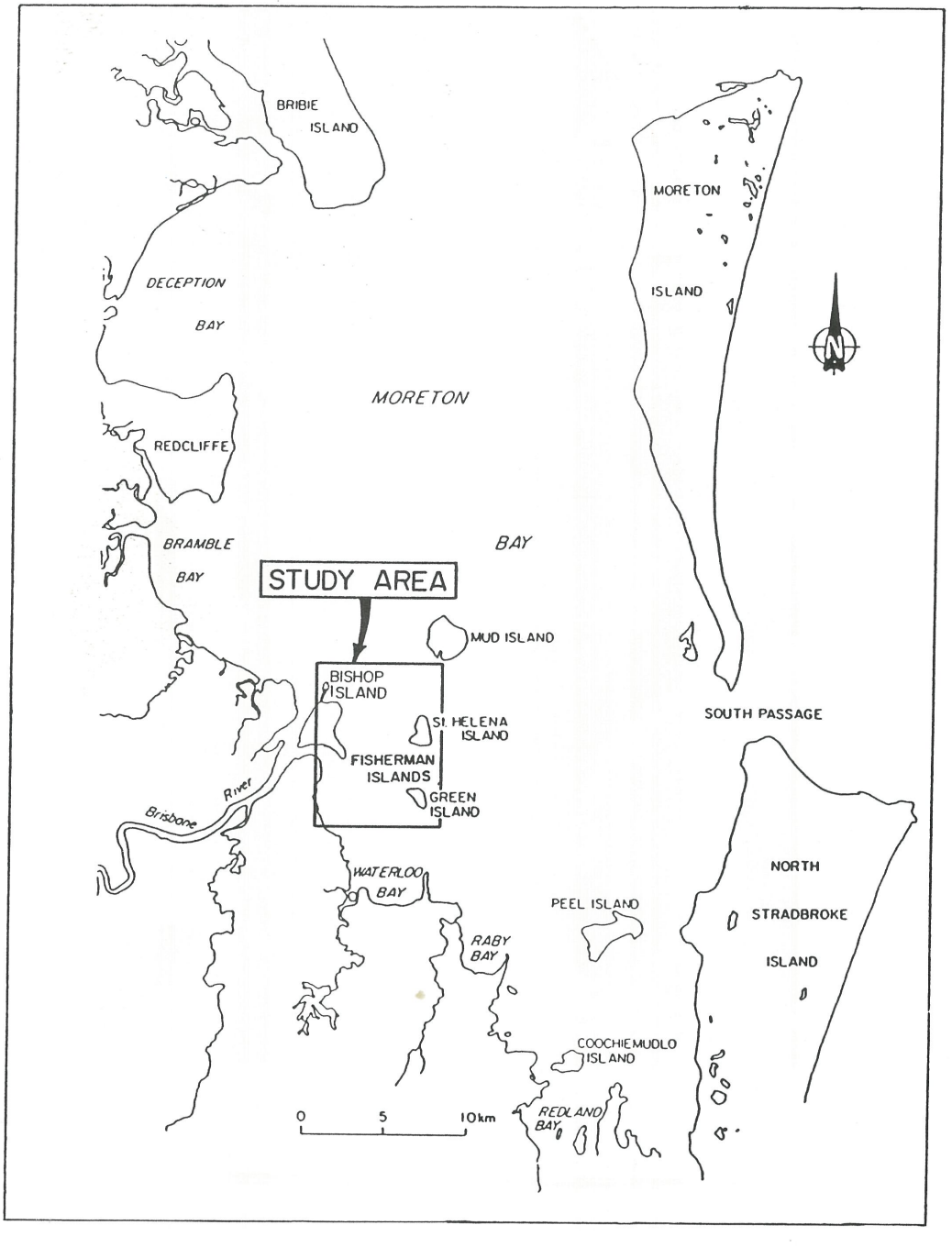
Locality Plan



Small Craft Chart provided by Department of Harbours & Marine Queensland - Coochiemudlo Island to Mooloolaba

FIGURE 1.2

Study Area



Nevertheless, confidence in the results can be gained from the facts that:

- The model bathymetry is based on reliable chart data.
- The model boundary tides are based on information from the larger Moreton Bay model which water gives level results consistent with extensive recorded information.
- The modelling program and procedures used are reliable and comprehensive.

Model results are presented in the form of velocity vector plots over the region of interest, through the tidal cycle for each scenario tested. Plan plots of bed shear stresses are also provided. Discussion of implications in terms of sedimentation processes is included.

2.0 MODEL STUDY

2.1 Computer Model Details

WBM Oceanics has established a new two-dimensional computer model of the study area for this study. Its boundaries extend somewhat beyond those of the study area in order to properly represent the flow patterns throughout the area of interest. Figure 2.1 illustrates the extent of the model.

The grid element size is 100 metres to provide adequate resolution in defining the bathymetry and current patterns. The model provides depth-averaged flow results, and does not allow analysis of processes associated with stratification of fresh and saline waters or vertical velocity profile variations due to wind shear.

The model is linked dynamically to a one-dimensional network model of the Brisbane River. This permits the testing of options to inherently cater for the river flow influences outside the immediate two-dimensional model boundaries.

The downstream model boundary extends out into Moreton Bay for some distance, and is controlled by tidal levels. These levels vary in amplitude and phasing along the boundary. Determination of the appropriate relationships to represent the boundary tides has been made using the separate large-scale WBM model of Moreton Bay. Flow through the Boat Passage is particularly sensitive to the variation of tide level and phasing along the boundaries.

Bathymetric data for the model has been obtained from recent detailed survey charts for the Port area, and existing published boating charts for the surrounding areas and for the Brisbane River. The present status of Port development is thus represented. Bathymetry data sources are: Small Craft Chart - Lower Brisbane River and Approaches, and PBA Hydrographic Surveys - Drawing No. R 9452.

Testing of the model is based on a semi-diurnal sinusoidal Mean Spring Tide, consistent with common practice for tide-related sediment transport studies. For the present purposes, there is no runoff inflow at the upstream end of the Brisbane River, although this could be incorporated into further tests if required. As well, wave action is not included in the modelling.

2.2 Model Results

Model tests have been made for the mean spring tide with superimposed wind stresses. Results of flow velocity vectors and bed shear stresses are obtained hourly through the tide cycle, while at specified key locations, continuous velocity, discharge and water level information are determined.

A check was made of the flow through the Port area and the Boat Passage associated with the mean spring tide. Previous studies by the Hydraulics Research Station, Wallingford have determined a peak discharge of about 2600 cumecs past the alignment of Luggage Point. The WBM model has a peak discharge of about 2500-2550 cumecs, sufficiently close agreement for the present purposes.

Flow through the Boat Passage is known to be almost uniquely from the Bay to the river. The model gives a similar pattern as shown in Figure 2.2. The influence of the wind on the Boat Passage currents is quite marked, with the predominant southeast wind enhancing the uni-directional nature of the flow.

Typical velocity vectors in the Fisherman/St Helena/Green Islands region for the tide/wind scenarios tested are presented in Figures 2.3 - 2.5. Peak tide/wind induced currents over a somewhat wider area extending north of the river channel are shown in Figure 2.6. These peak currents for southeast winds occur during and following the peak of the flood tide.

Bed shear stresses which give a reliable measure of potential sedimentation behaviour have been calculated for hourly increments through the tidal cycle for each scenario tested. Tide-cycle bed shear stress maxima have been determined at each model location for each scenario. These results are presented in Figures 2.7(a)

FIGURE 2.1

Hydrodynamic Model Area

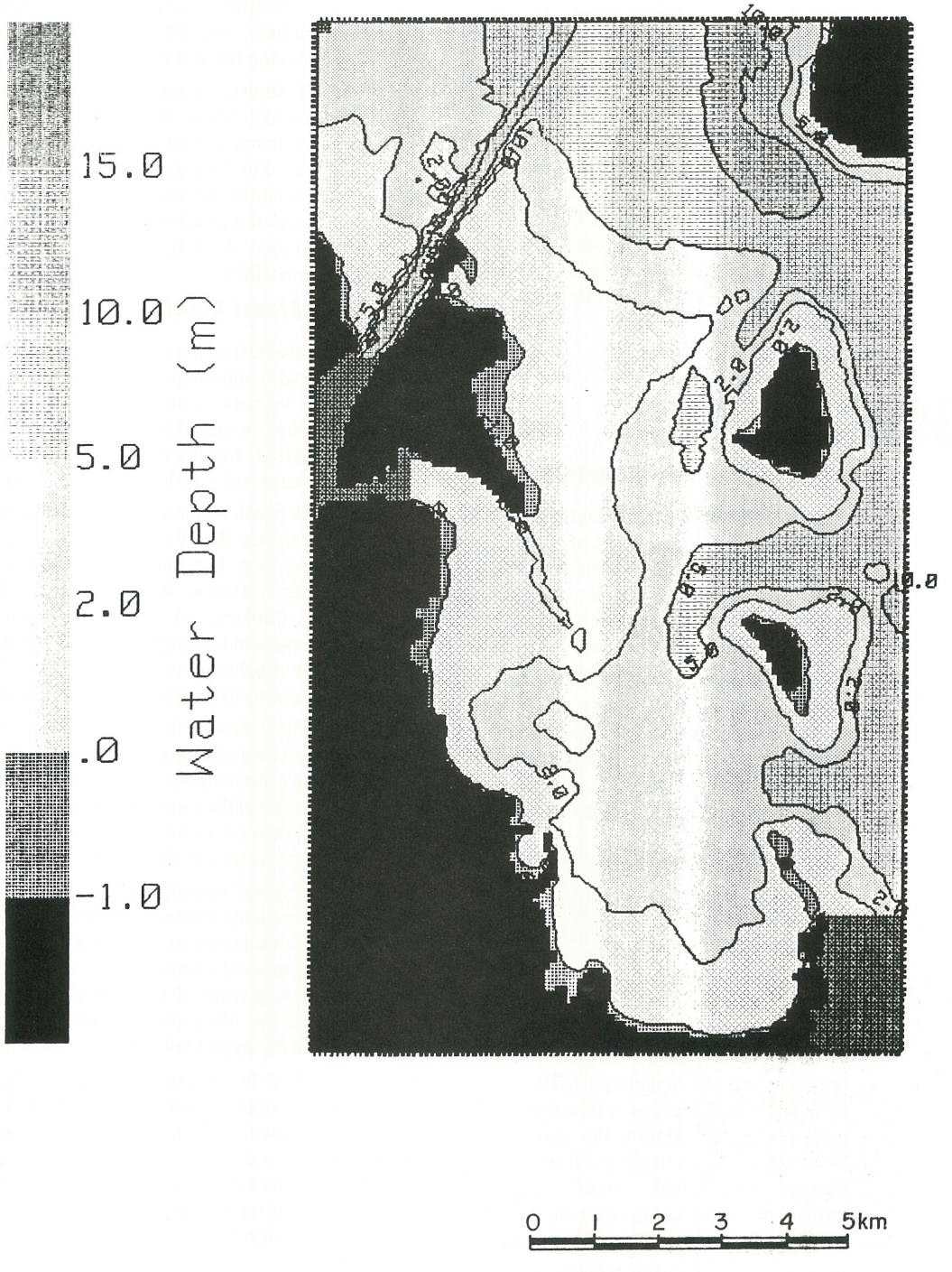
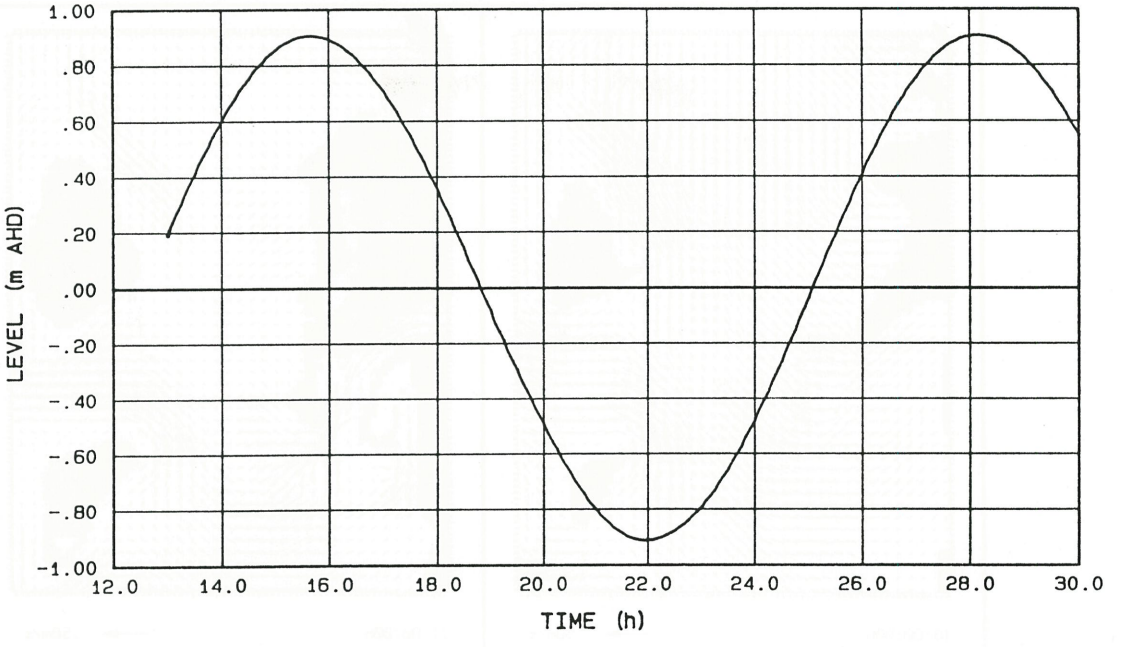
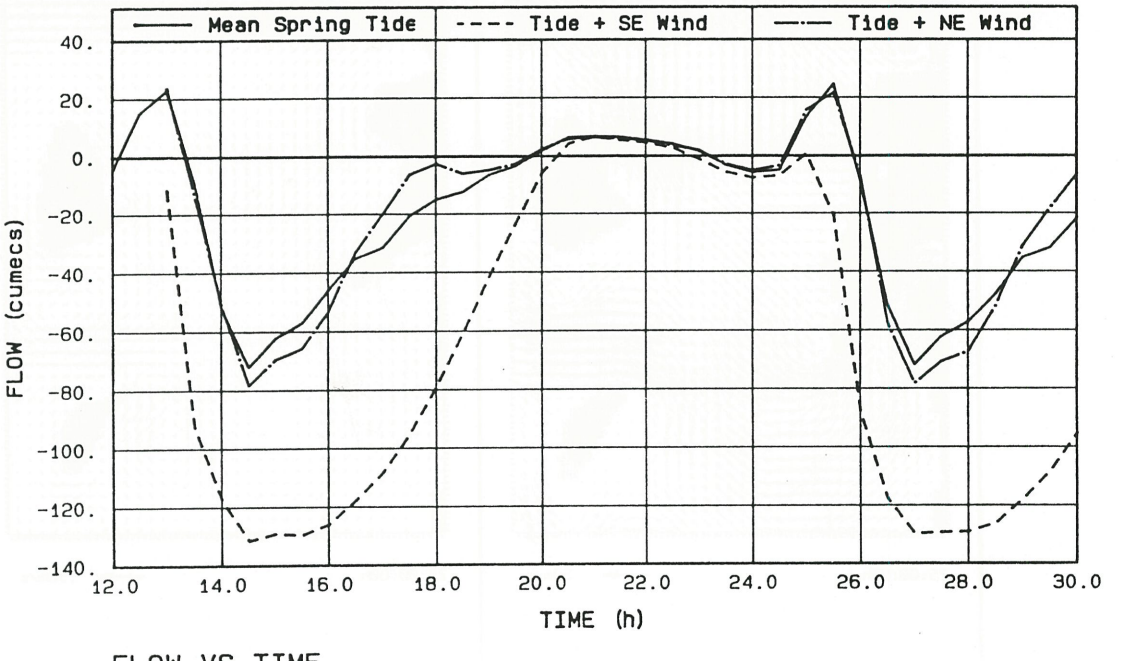


FIGURE 2.2

Flow Through Boat Passage Modelled Tide and Wind Scenarios



TIDE LEVEL VS TIME



FLOW VS TIME

FIGURE 2.3

Current Velocity Vectors Mean Spring Tide

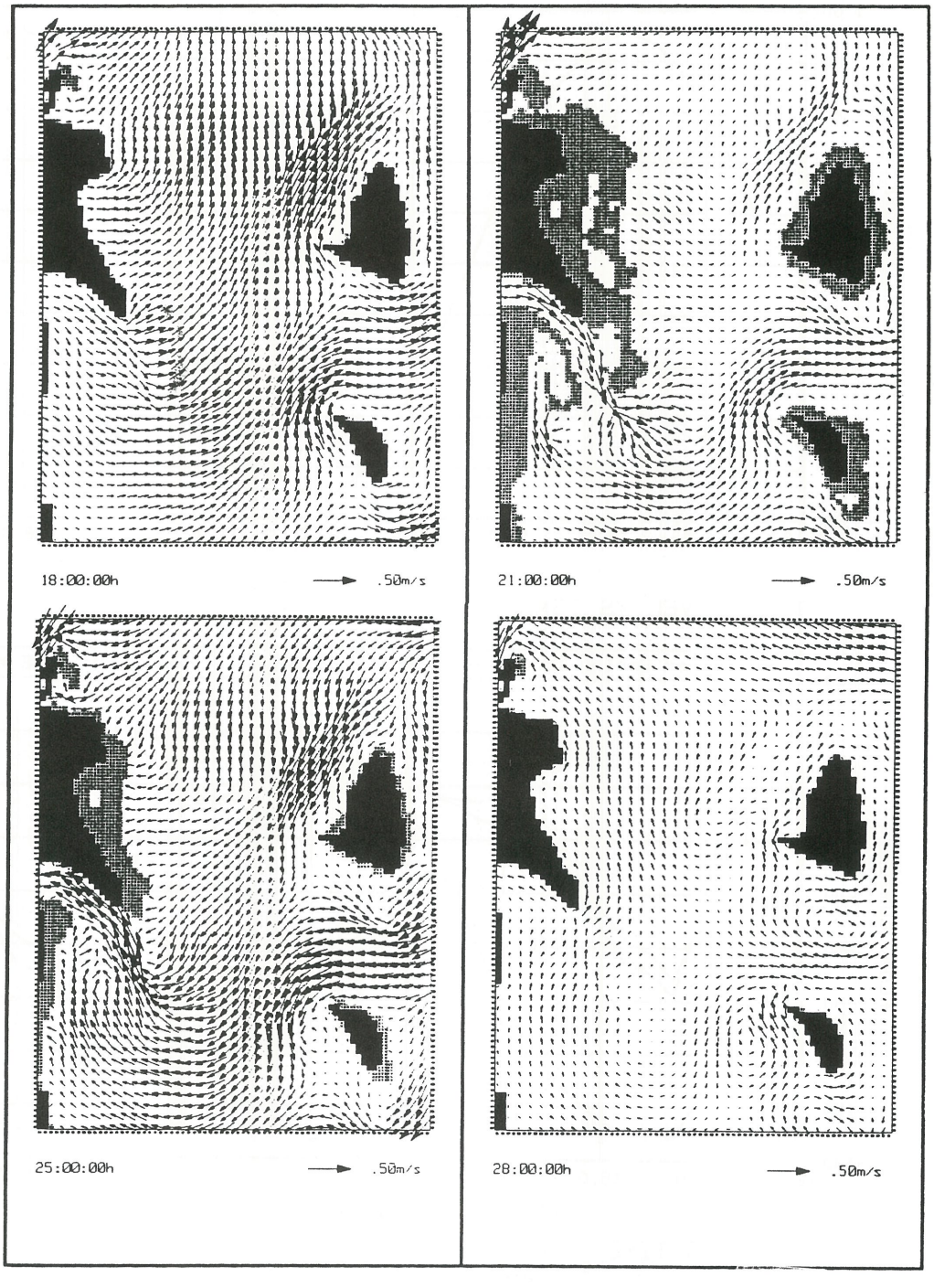


FIGURE 2.4

Current Velocity Vectors Mean Spring Tide Plus Southeast Wind

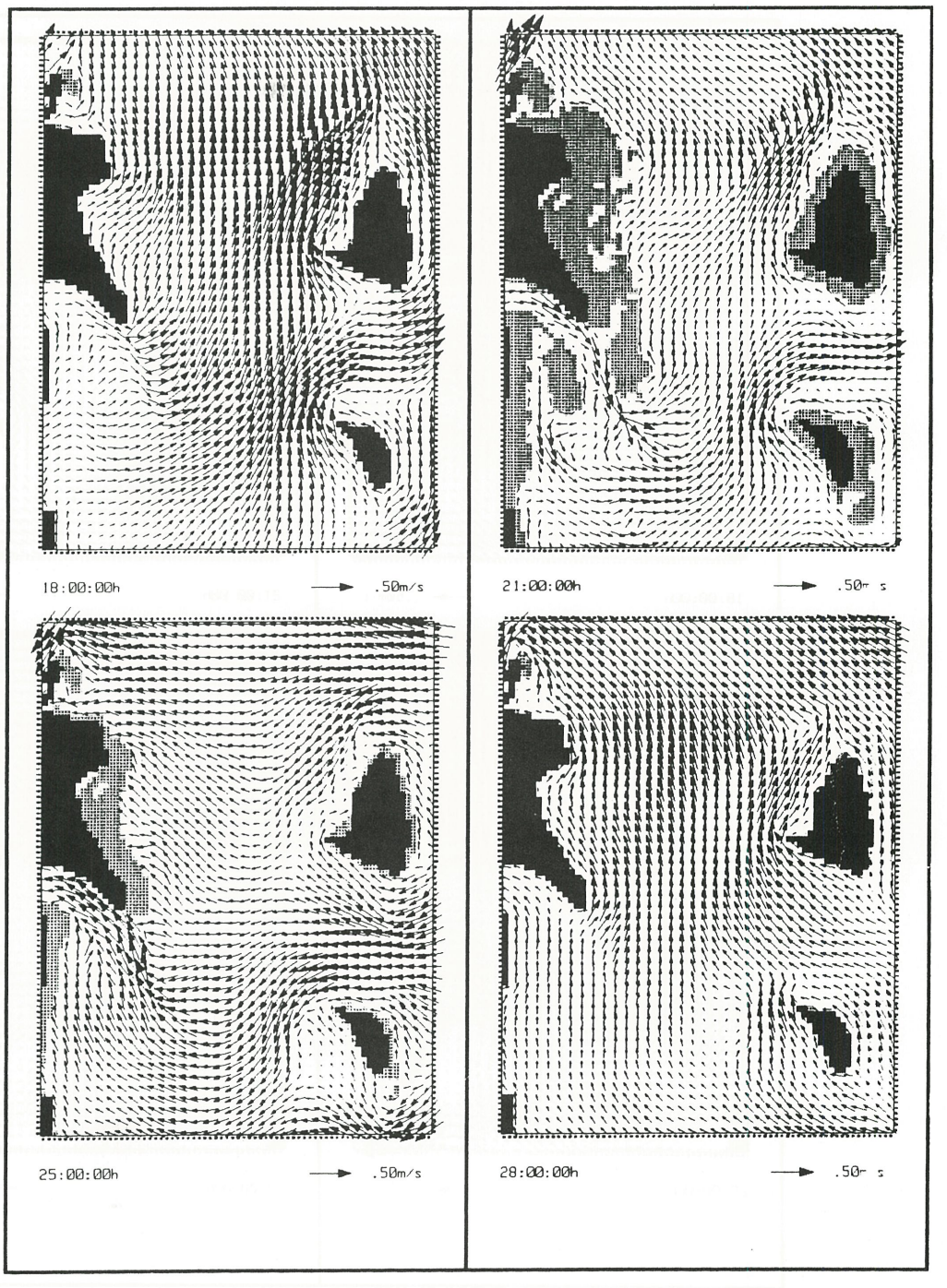
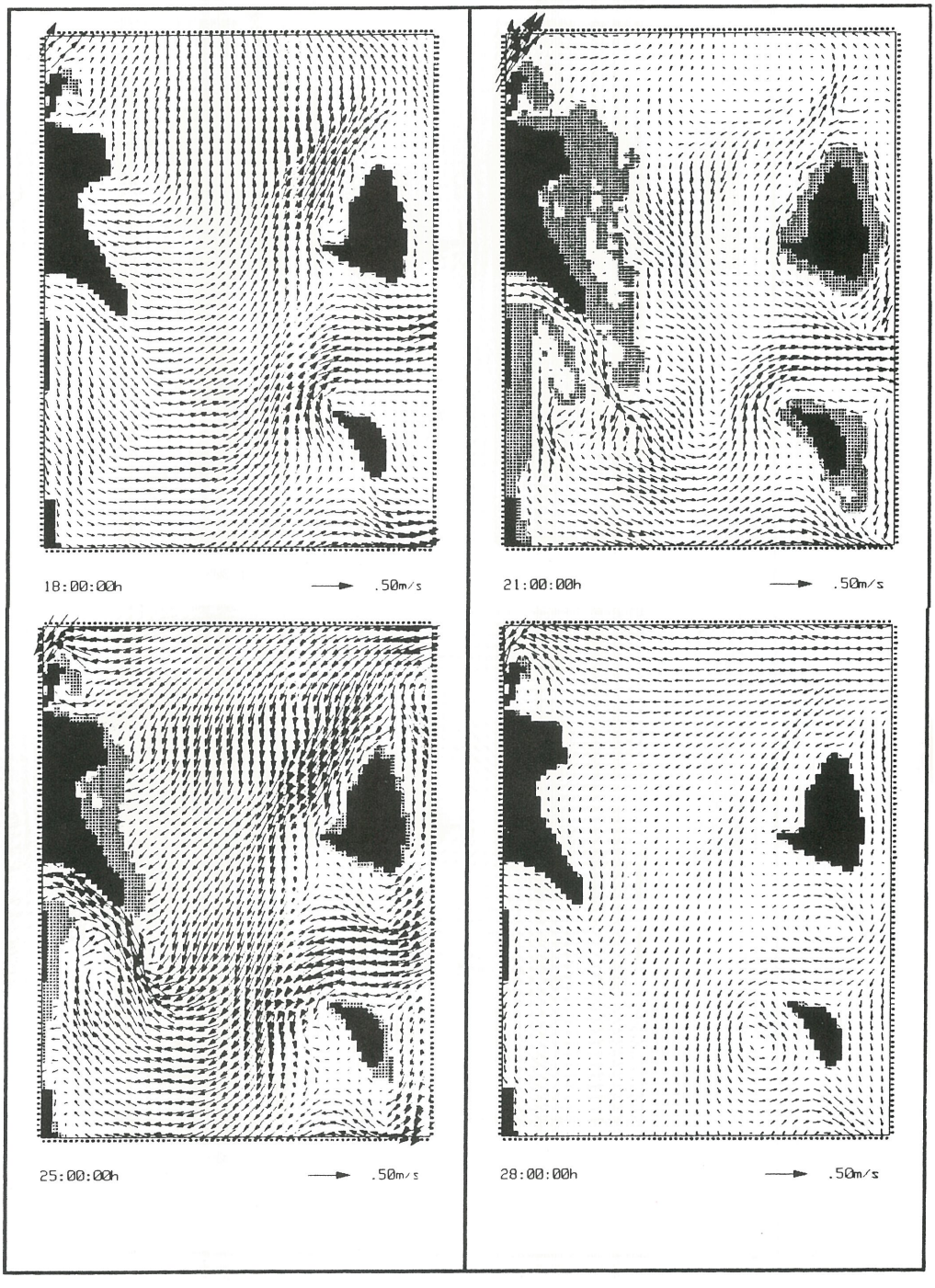


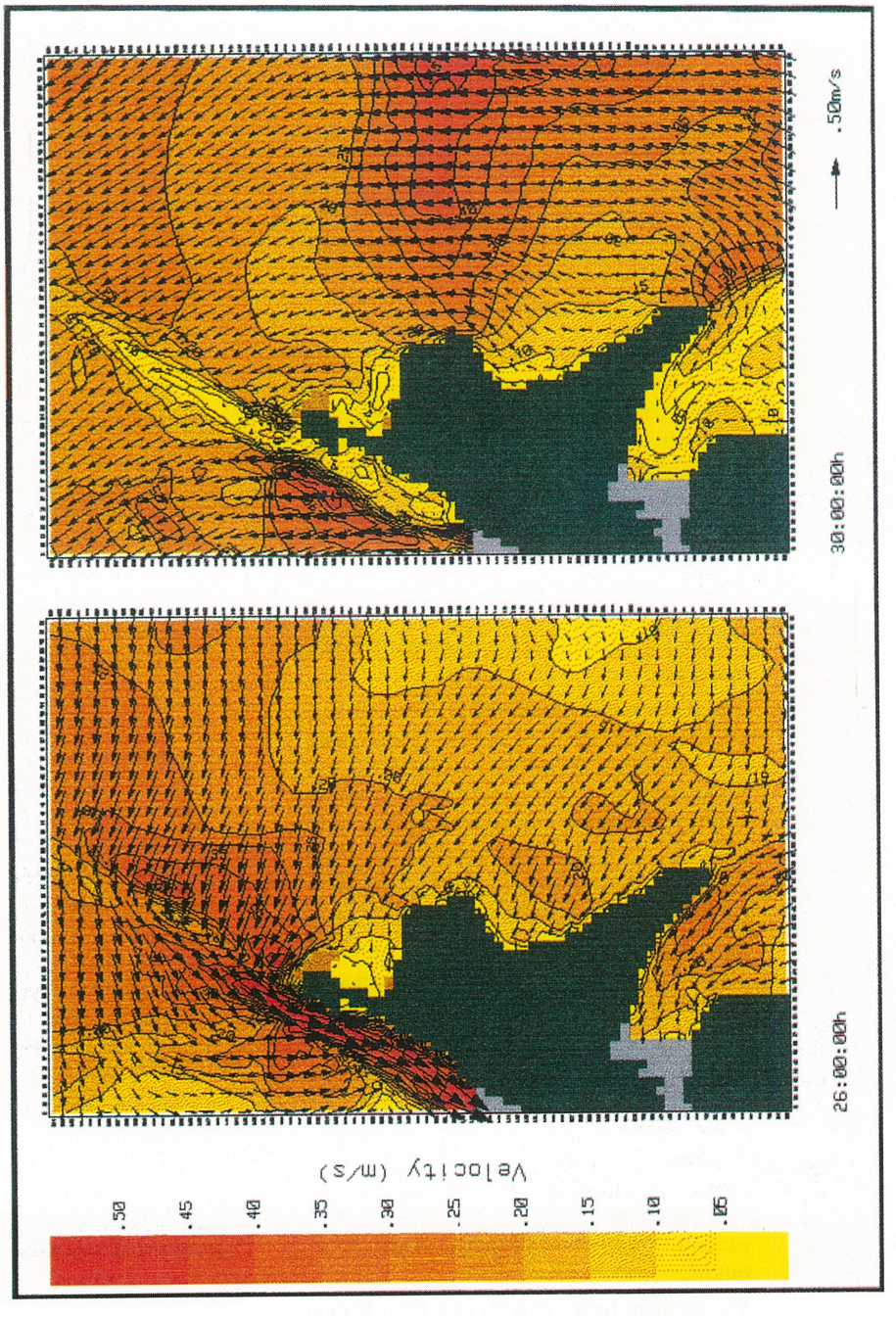
FIGURE 2.5

Current Velocity Vectors Mean Spring Tide Plus Northeast Wind



IGURE 2.6

Peak Tide/Wind Currents (SE Wind)



On the basis of these tide-cycle maxima, a measure of the longer term representative bed shear stresses has been derived by apportioning the relative effective of each scenario in the following adopted proportions:

Tide only:	40%
Tide plus SE wind:	40%
Tide plus NE wind:	20%

The resulting representative longer term bed shear stress maxima are shown in Figure 2.8. These should be regarded as indicative only, but are considered to provide a useful guide for assessing potential broad sedimentation patterns

2.3 Interpretation of Results

As reported in the Hydraulics Research Station studies, areas with a bed shear stress of 0.2 N/m^2 or greater will generally not accumulate sediments, and may be areas of net scour. Areas where the shear stress is less than 0.1 N/m^2 may be susceptible to siltation particularly by finer silts and muds. Clearly, no hard and fast rule can be established for this as other factors may also play a role in some areas. These factors could include:

- Wave action which tends to stir sediment from the bed and prevent deposition of the finer silts and muds.
- Variability in the hydrodynamic processes and/ or extremes in the rate of sediment supply, such that the nature of the bed sediments is not necessarily in direct equilibrium with the hydrodynamic processes at any particular time.
- Armouring of predominantly fine silty bed sediments by even relatively small quantities of coarser sediment or shells .
- Development of strong cohesion within fine silt/ mud bed sediments providing resistance to erosion by strong currents.

The key conclusions reached from the bed shear stress information derived from the modelling are as follows:

- The study area has five broad zones of distinctly different hydrodynamic character which would be expected to display different sedimentation patterns. These are illustrated in Figure 2.9 as follows:
- The northern banks directly east from Bishop Island, with relatively low shear stresses but exposed to wave action from east to north directions.
- A zone of shallow banks with high tidal current related bed shear stresses extending eastward from the northern part of Fisherman Islands and past the northwestern tip of St Helena Island.
- A large more or less circular zone of low bed shear stress adjacent to the central parts of Fisherman Islands, and receiving a significant degree of shelter from waves by St Helena and Green Islands.
- A zone of moderate bed shear stress towards the southern nearshore area, being the principal flowpath to and from the Boat Passage.
- Deeper channels adjacent to St Helena and Green Islands with moderate to high bed shear stress levels.

Sediment types expected in each of these five zones are as follows:

- Highly variable in the northern banks, with areas of silts, sandy silts and silty sands depending on the degree of exposure to wave action. Some exposed shallower patches nearer to Bishop Island may contain relatively clean sand.
- Sand and silty sand on the shallow banks where high bed shear stresses occur.
- Silts and sandy silts in the large sheltered zone southwest of St Helena Island where low bed shear stresses are identified.
- Mixed bed sediments and relatively high water turbidity in the southern areas leading to the Boat Passage, with a net movement of sediments towards the Passage and zones of bed shear capable of continually re-suspending this material.
- Mixed and variable sediments in the deeper scoured channels depending on the tide range conditions, sediment supply and relict sub-surface sediments at any given time and place. Bed armouring and/ or cohesive properties may be important in fine silt areas. There may also be zones of coarser sands or exposed bedrock in the higher flow areas. WBM Oceanics has undertaken sediment sampling over the study area, as discussed in Section 3.

3.0 BED SEDIMENTS

3.1 General Considerations

Generally, the nature and behaviour of bed sediments will reflect the influences of the waves and currents affecting them. Exceptions may occur where

FIGURE 2.7(A)

Bed Shear Stresses Mean Spring Tide

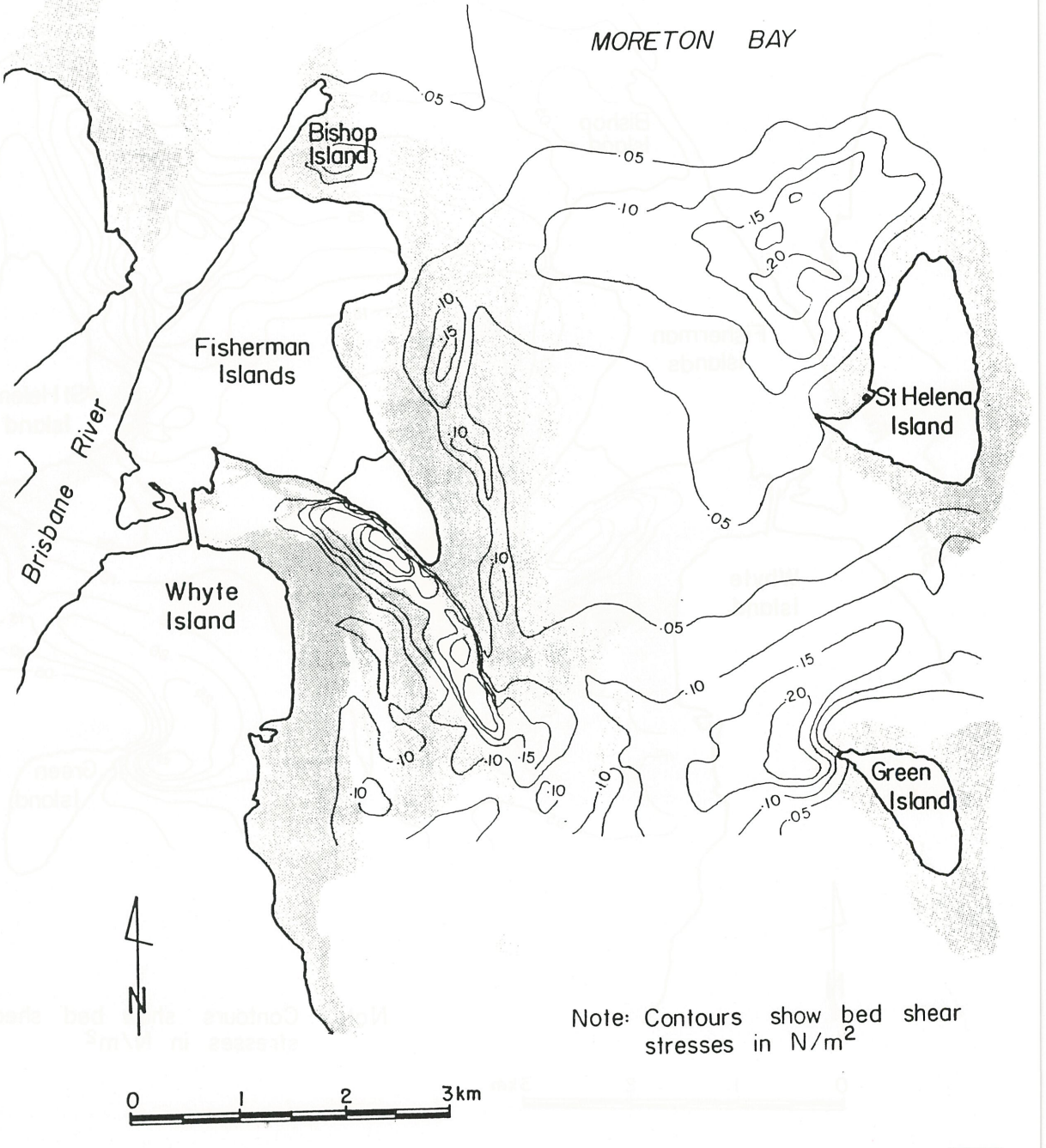
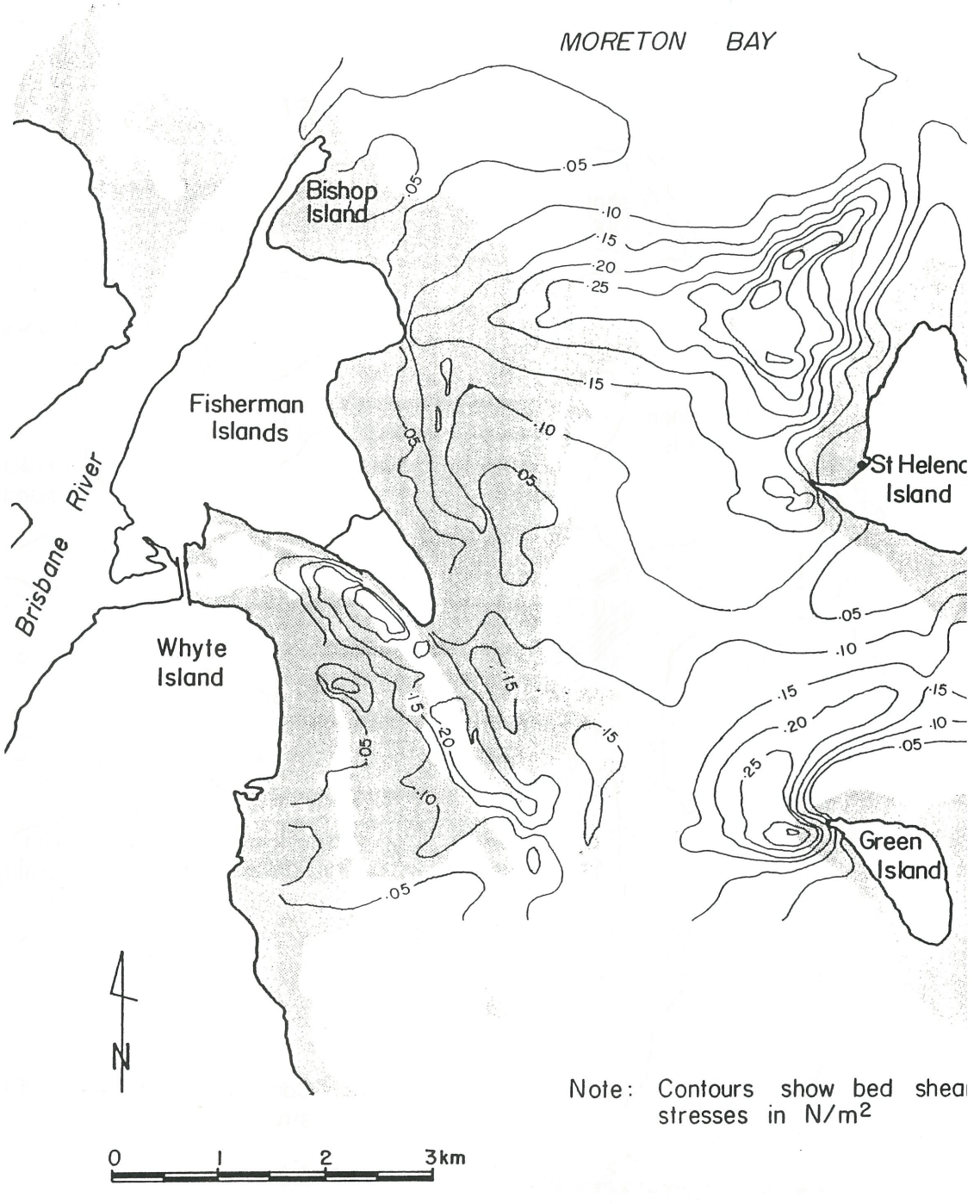


FIGURE 2.7 (B)

Bed Shear Stresses Mean Spring Tide Plus Southeast Wind



Note: Contours show bed shear stresses in N/m^2

FIGURE 2.7 (C)

Bed Shear Stresses Mean Spring Tide Plus Northeast Wind

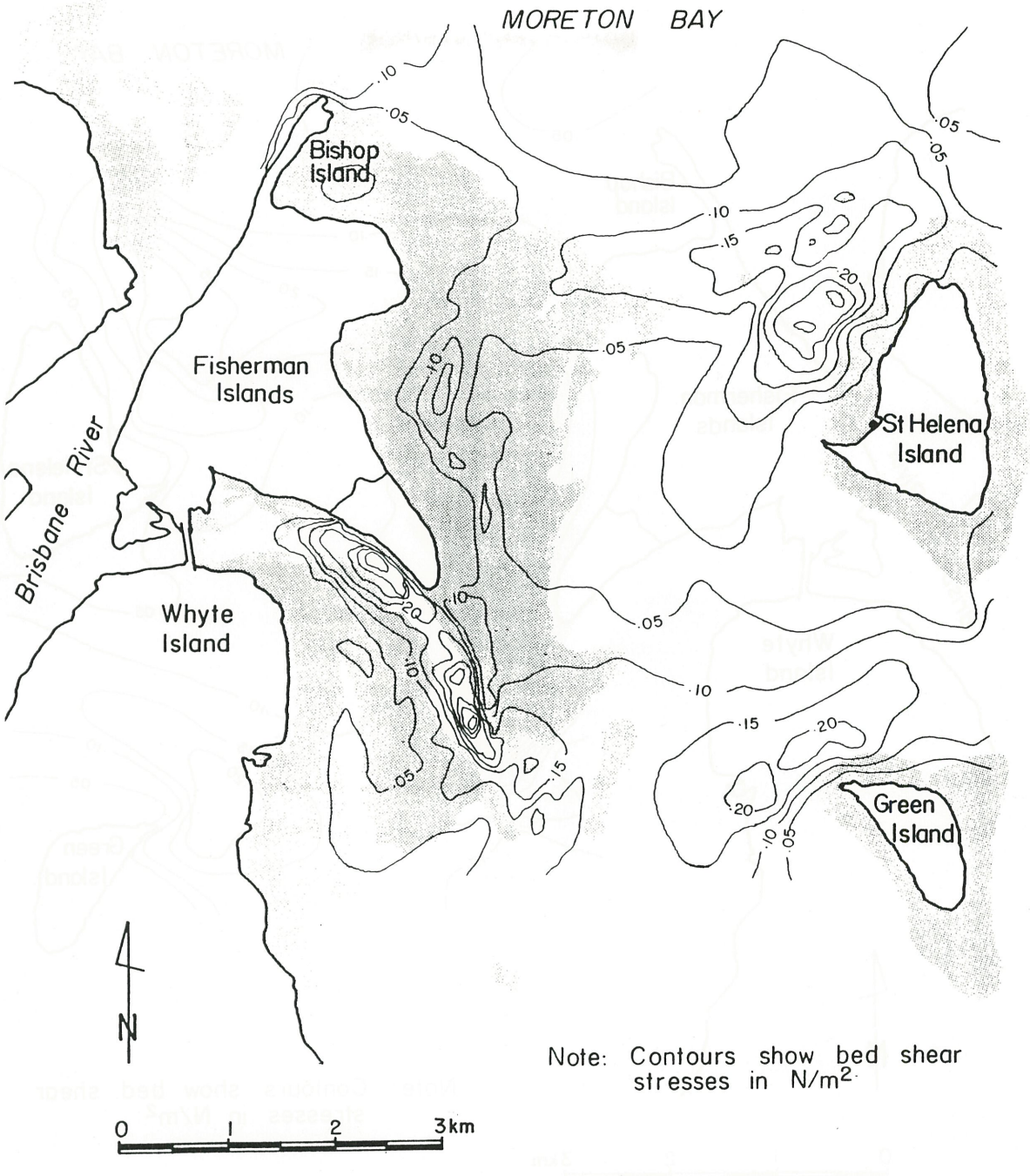
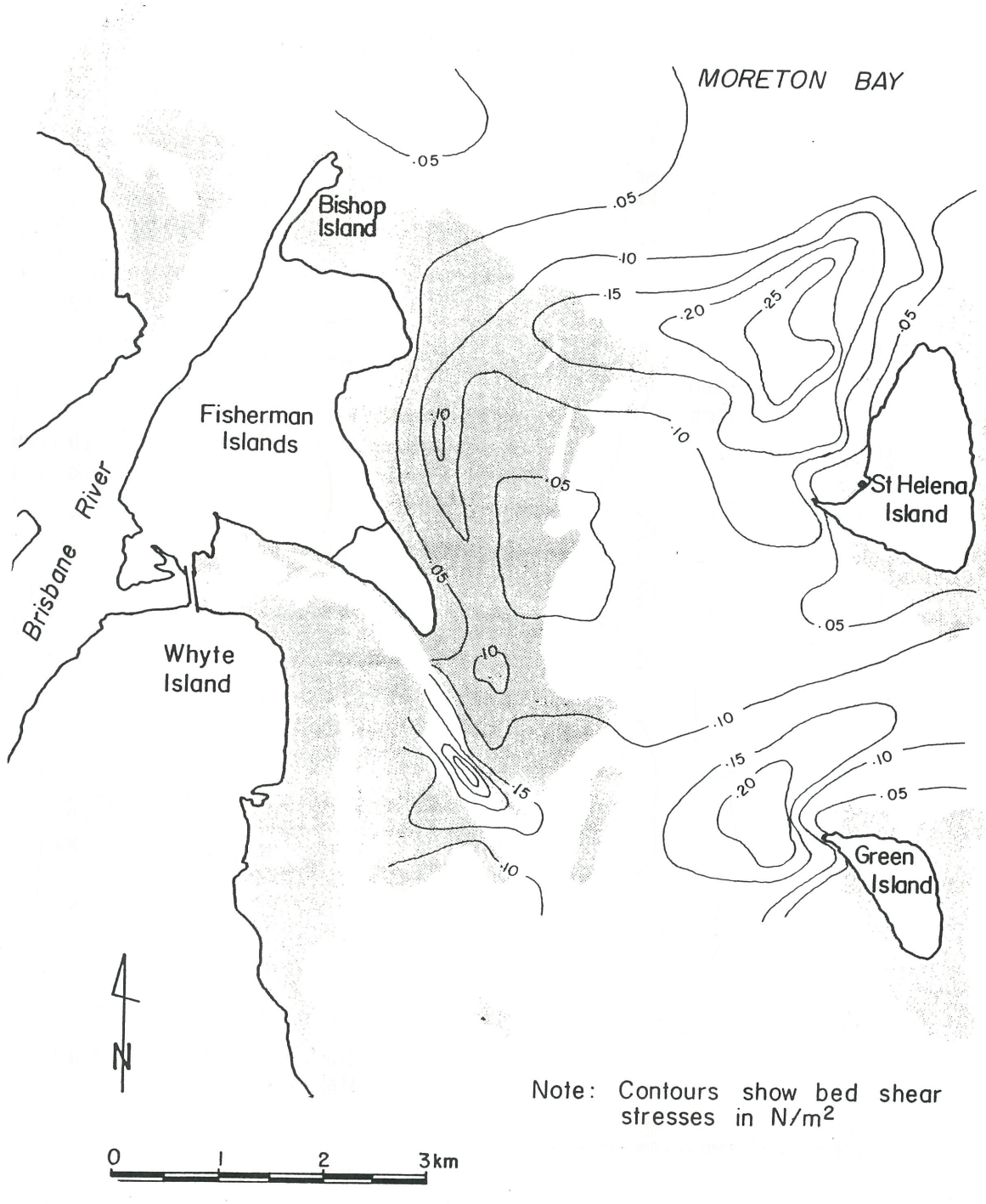


FIGURE 2.8

Representative Long Term Bed Shear Stresses



the sediments are relict deposits from a previous sea level regime or where cohesion or armouring of the sediment has occurred. It is expected that the Fisherman Islands study area is characterised by geologically recent Brisbane River sand and silt sediments and that there is a marked relationship between the hydrodynamic and sedimentological regimes.

The present study has involved numerical hydrodynamic modelling to quantify the tide-induced currents and associated bed shear stresses as outlined in Section 2. These stresses have been mapped as detailed in Figures 2.7(a)-(c) and Figure 2.8. Waves also affect the area, although a significant degree of shelter is provided by Mud, St Helena and Green Islands. While wave processes have not been investigated, it is expected that they would cause higher bed shear stresses in the more exposed parts of the northern bank area.

Sediment sampling and analyses have been undertaken in order to provide baseline data and a quantitative basis for correlating sedimentation patterns with the modelled hydrodynamic processes. The results of the sampling are outlined below, together with discussion of their significance in terms of the wave/current processes over the study area

3.2 Sediment Sampling/ Analysis Programme

Twenty-nine bed sediment grab samples were collected from the study area for laboratory analysis. Other samples were taken during the field sampling exercise for visual inspection to ensure that those analysed were reasonably representative of the study area, particularly in the seagrass zones where obtaining sediment with the Van Veen sampler was difficult.

TABLE 3.1

Summary of Sediment Properties

Sample	Shell Content (%)	Sand Content (%)	Silt Content (%)	Median Grain Size (mm)
1	5.1	88.9	6.0	0.220
2	35.4	47.1	17.5	0.170
3	5.1	92.4	2.5	0.234
4	5.9	85.1	9.0	0.130
5	4.2	88.3	7.5	0.181
6	20.2	35.8	44.0	0.067
7	3.5	90.25	6.25	0.135
8	3.5	92.75	3.75	0.195
9	15.3	80.7	4.0	0.345
10	3.4	96.6	0.0	0.320
11	11.3	81.2	7.5	0.212
12	4.4	88.1	7.5	0.196
13	2.9	84.6	12.5	0.087
14	16.9	17.1	66.0	0.030
15	8.67	13.3	0.0	12.0
16	13.2	74.3	12.5	0.175
17	4.7	84.8	10.5	0.272
18	8.4	71.6	20.0	0.160
19	11.5	23.5	65.0	0.012
20	4.5	87.5	8.0	0.230
21	18.0	69.5	12.5	0.185
22	13.6	52.4	34.0	0.075
23	34.8	21.2	44.0	0.075
24	14.6	39.4	46.0	0.067
25	7.5	75.5	17.0	0.180
26	8.6	71.4	20.0	0.093
27	48.0	14.5	37.5	0.094
28	31.1	47.9	21.0	0.212
29	10.4	84.6	5.0	0.212

FIGURE 3.1

Sediment Sample Results

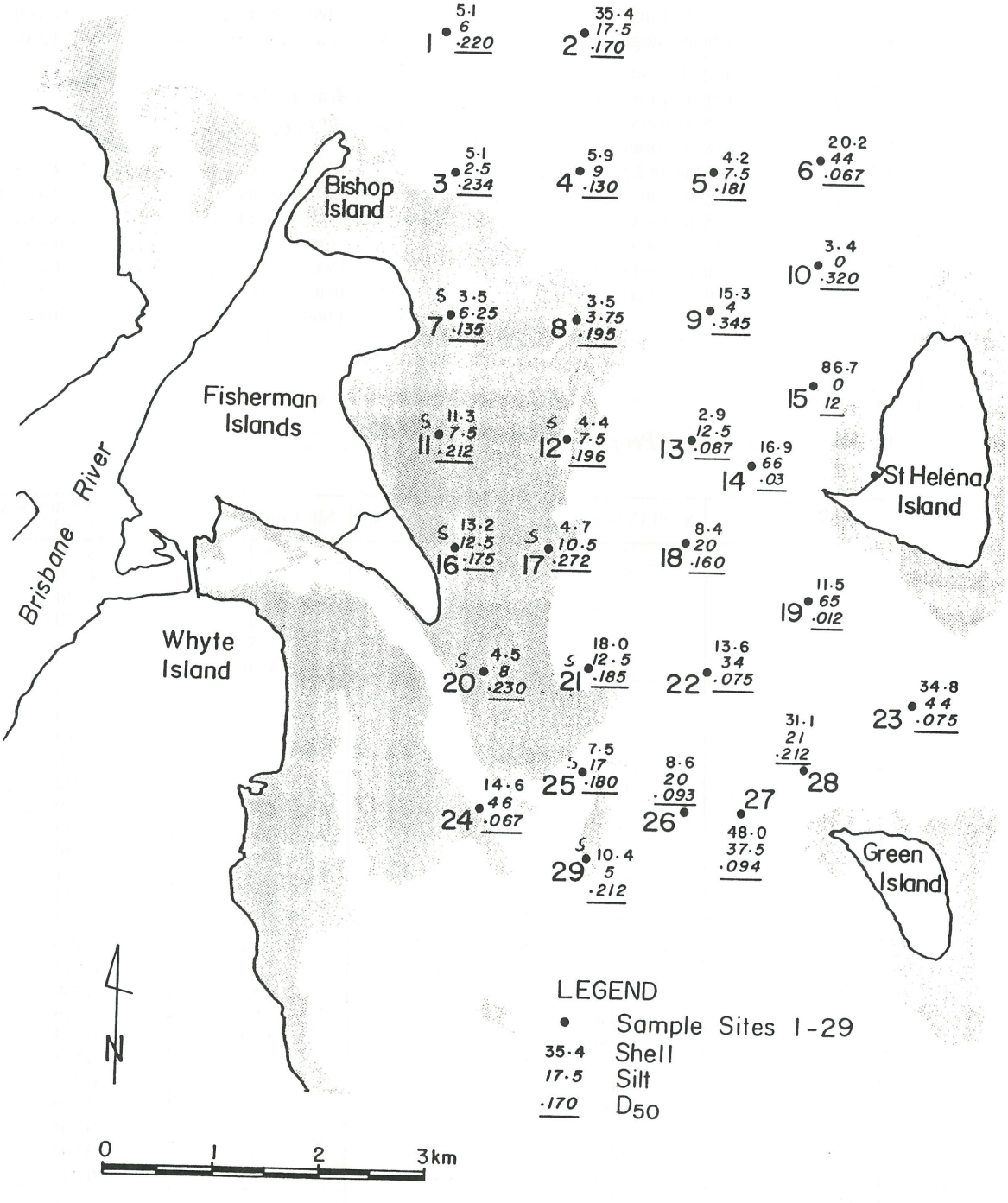


FIGURE 3.2

Median Grain Size Distribution

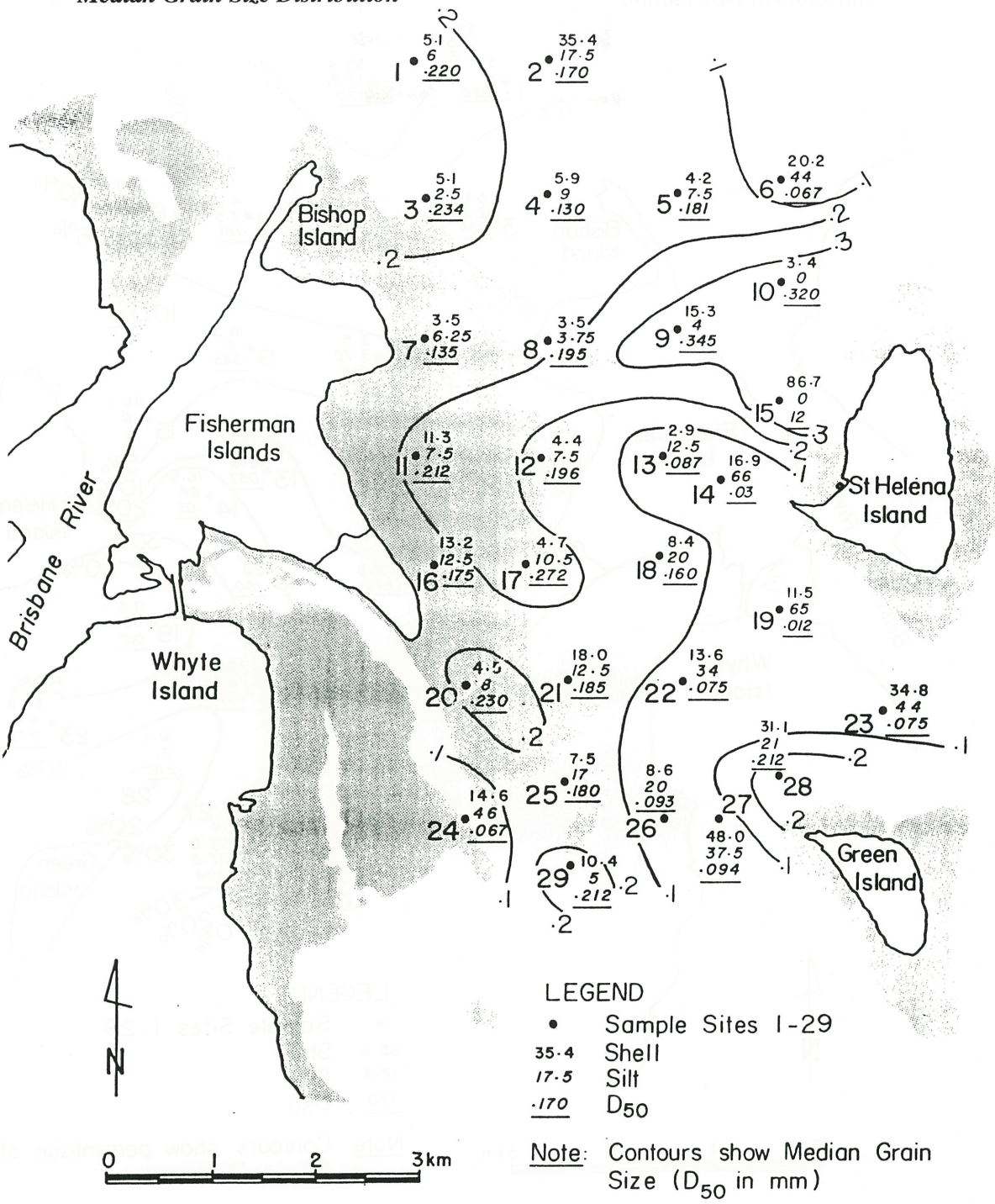
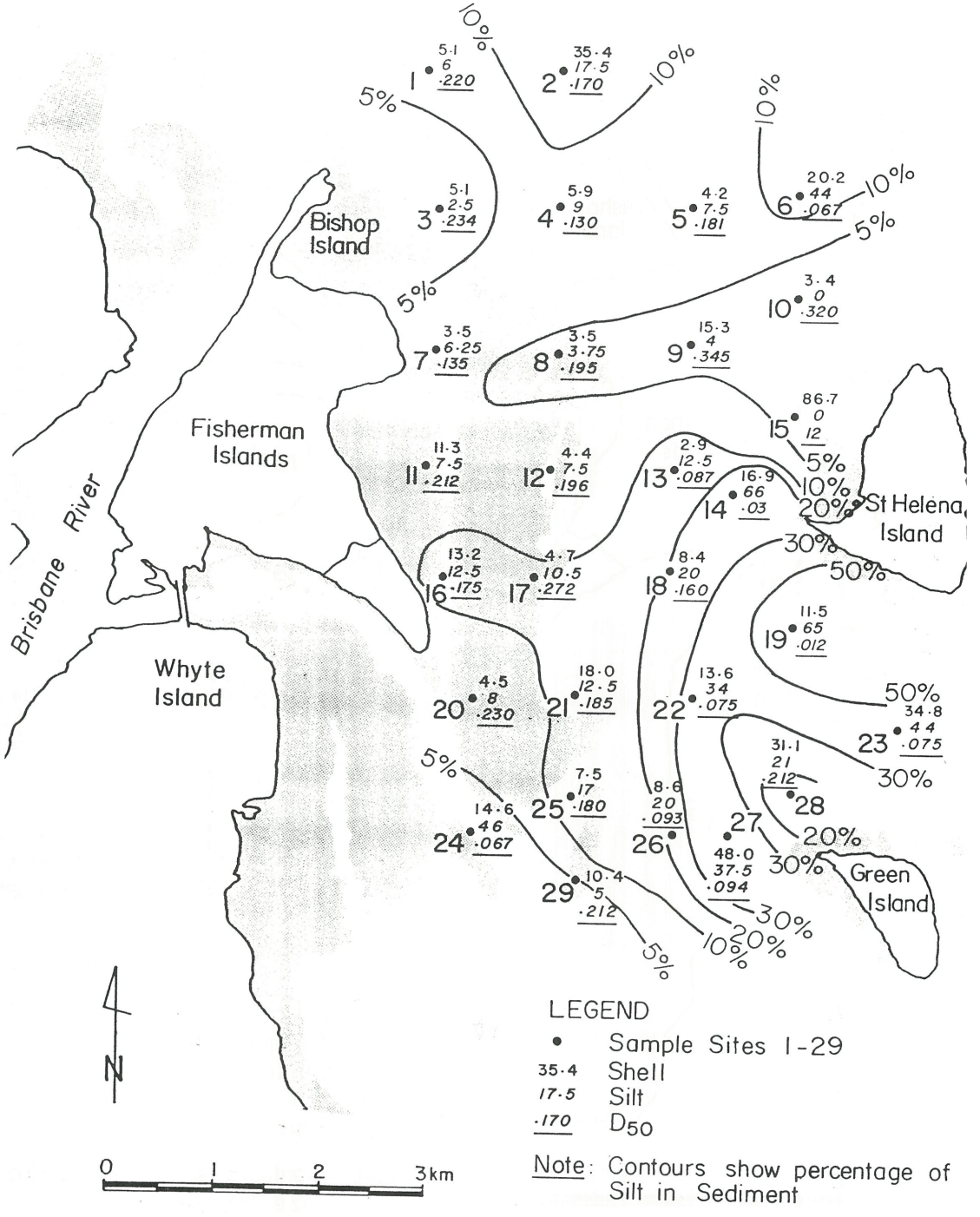


FIGURE 3.3

Silt Content Distribution



Samples of about 1.0 kg (dry weight) were taken and analysed for the following properties:

- shell content
- sand/silt content
- size grading

The analyses were undertaken by NATA registered laboratory G.M. Laboratories.

Figure 3.1 shows the sample locations and the analysed results for shell content, silt content and median grain size. These locations were chosen on the basis of both a grid pattern in the layout design and the modelled bed shear information as outlined in Section 2. Table 3.1 lists a summary of these analysis results.

Seagrass was found at Site No's 7, 11, 12, 16, 17, 20, 21, 25 and 29. This distribution is consistent with that found by CSIRO in their study of the area.

Figures 3.2 and 3.3 show contours of median grain size and silt content respectively. These figures should be used with some caution because of the relative sparseness of the sampling sites and the absence of replication of the samples for each site.

Generally, these results are consistent with the modelled bed shear indicators discussed in Section 2. The only notable exception is the cleaner and coarser sand found at Site 17 where the model would indicate predominantly silt. This is an area of dense seagrass where samples were difficult to obtain. More intensive sampling in that area would be needed to confirm or revise the sediment pattern found there.

The zone between St Helena and Green Islands contains a low proportion of sand, being predominantly silt and shell. The sand content increases progressively west from this region towards shallower areas near Fisherman Islands. This indicates that the shallow sandy deposits are part of the original river mouth delta and that there is little supply of sand-sized sediment to the deeper zones. Thus, in the deeper parts, the sediment is commonly silt and shell even in the higher energy areas.

The seagrass distribution found in the sampling is consistent also with the indication of the model together with other constraints as follows:

- bed shear stress less than 0.12 N/m^2
- areas protected from wave activity, and
- areas sufficiently shallow to permit light penetration, in this case generally above1m (LWD)

4.0 CONCLUSIONS

Hydrodynamic modelling has identified the patterns of currents and the associated bed shear stresses throughout the study area. Both the tide and wind play a significant role in forcing these currents. Figures 2.3 -2.8 in Section 2 illustrate the results of the modelling.

Interpretation of the model results indicates the existence of a wide range of bed sediment regimes relating to areas of high or low bed shear stress.

Generally, high bed stress areas will contain mobile sandy sediments with little silt, while areas with bed stress levels less than about 0.1 N/m^2 may be susceptible to siltation if there is a supply of sediment available. Exceptions to these patterns may occur due to armouring by coarser material (eg. shell) and/ or development of strong cohesion in muds such that fine silts may occur even in some high energy areas.

Sediment sampling has been undertaken to identify bed sediment properties over a wide extent of the study area. Shell and silt content and sample size gradings were determined.

Generally, the sediment sample results are consistent with the indications from the modelling. Silty sands are found over most of the study area. The coarser, clean sand along the east-west ridge which extends west from St Helena Island is clearly identified in the model and in the sample results. The deeper areas between St Helena and Green Islands are high in silts, even in high energy areas, due to a lack of supply of sand there. Extensive shell armouring is evident in these areas.

Seagrass is found in areas of low bed shear stress, generally less than 0.1 N/m^2 with some extending up to about 0.12N/m^2. When the limitations of wave exposure and water depth (light penetration) are considered, the modelling provides a useful indicator of areas of potential seagrass development.

5.0 REFERENCES

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APPENDIX IV

ASSESSMENT OF BIRD POPULATIONS OF THE ENVIRONS OF FISHERMAN ISLANDS

Report Prepared for the Port of Brisbane Authority, Peter V. Driscoll, Ph. D.

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1. INTRODUCTION

The study was designed to assess the birdlife in the vicinity of the Fisherman Islands port facilities at the mouth of the Brisbane River. Major shipping, storage and rail freight facilities already occupy much of the site and over a wider area are a number of other major facilities, including oil refineries, sewage processing plants and Brisbane Airport. Nevertheless, there remain significant areas of relatively undeveloped natural habitat and other areas that are used by birds despite human interference. The area generally appears to be highly productive with patches that have a very high diversity and abundance of birdlife.

Careful management of natural resources, including bird populations, along the coastline of South East Queensland is necessary in view of the current population surge in the region. There are considerable habitat changes occurring throughout Moreton Bay and parts of Fisherman Islands sustain high populations of certain bird species. The need for a study of birdlife around Fisherman Islands was even more important in view of planned extensions and changes to the port facilities. Hopefully, information from this study will aid in ameliorating the impact on birdlife of future developments. Present and future impacts on local bird habitat include the complete removal of natural conditions and vegetation and more indirect effects such as nutrient enrichment, pollution, and digging for polychaete worms in seagrass beds by commercial and amateur operators.

2. LOCAL HABITATS AND BIRDLIFE

Even before the extensive changes and developments that have occurred on Fisherman Islands, habitats in the area would have predominantly been those of the littoral zone, that is, intertidal areas including mangroves, herbland, closed grassland and mudflats, with or without seagrass. Woodland habitats of paperbark or eucalypts may have once occurred on higher ground with low open forest of *Casuarina glauca* situated behind mangroves, forblands and claypans. To what extent this range of typical habitats of the region existed around Fisherman Islands would require a specific historical assessment.

Purely terrestrial bird species on Fisherman Islands have limited diversity due to the scarcity of forest cover other than mangroves. The mangroves cater for a small group of mangrove specialists and several other species that are typical of a range of forest types. The areas covered with reeds and tall grasses as a result of disturbances and clearing on Fisherman Islands harbour several grassland species.

By far the most diverse grouping of birds includes waders and waterbirds that utilise the site primarily because of the extent and nature of local intertidal feeding areas. In contrast, pelicans, gulls, terns and cormorants rest in mangroves or on sand and forage in local waters, or farther out in Moreton Bay on fish and other foods. Recent studies by Thompson (1990) and Driscoll (1991) indicate that there are discernible patterns to resource use by waders in the Moreton Bay region but there are few details recorded about birds that frequent Fisherman Islands and nearby feeding areas. Parts of Bishop Island (or Fisherman Islands) are used as a main high tide roost site by waders while the extensive intertidal feeding grounds to the south-east of the Islands, until now, had not been properly surveyed. Thousands of waders and other shorebirds are known to feed during summer at Luggage Point and many of these birds use roost sites on Fisherman Islands.

The objectives of this study were to determine the distribution, relative density and movement patterns of birds around Fisherman Islands and where appropriate, relate these findings to other areas of Moreton Bay. The focus of the study is on birds using the littoral zone which is still largely intact. Less detailed consideration is given to forest (mangrove) birds or birds that mainly occur in open grassland that has been artificially created on Fisherman Islands.

Because of the dramatic seasonal changes that are a feature of much of the birdlife around Fisherman Islands, three periods of fieldwork were undertaken with a winter sampling in July, spring sampling in October and summer sampling in January. The fieldwork was most thorough during spring at the time of highest numbers of birds during the southward migration of migratory waders. Furthermore, because the tide has an overriding influence on the activity of birds that feed on intertidal mudflats much of the assessment of local distribution is for times of both high tide and low tide with a consideration of the positioning of high tide roosts with respect to low tide feeding areas.

3. MIGRATORY WADERS

The term "wader" (or "shorebird") applies to a collection of small (12 cm) to medium size (66 cm) wading birds, which have a wide variety of bill structures. They are usually gregarious and inhabit wetland areas, where they feed and breed. Some species are highly migratory, breeding in high northern latitudes and migrating to the tropics and south of the equator. Others are resident in temperate and tropical regions. In scientific terms, waders belong to the order Charadriiformes (which also includes the gulls, skuas, terns and auks). The order has 12 families and most of the 214 "waders" throughout the world belong in the families Charadriidae (Lapwings, Plovers etc) or Scolopacidae (Sandpipers, Snipes, etc) (Howes and Bakewell, 1989)

The terms "wader" or "shorebird" give an indication of the habitat preferences and behaviour of the majority of these birds during the non-breeding period. However, most species breed inland (away from the shore) and some in quite dry habitats (e.g. steppes or deserts).

Migration can be defined as the regular movement between two geographical locations - usually a breeding area and a non-breeding area. Most of our migratory waders breed in the Siberian tundra, and the steppes and deserts of Mongolia and extreme Northern China. After breeding, they fly south along various routes within Asia, to spend the non-breeding period either in Asia, New Guinea, Australia or New Zealand. Some species fly as far as 13,000 km between the breeding grounds and wintering area or a return journey of 26,000 km.

Particular emphasis in the report is placed on migratory waders for three reasons. Firstly, as a group they are increasingly subject to environmental constraints throughout their migratory range from distant regions of the Northern Hemisphere to southern parts of Australia. Many species are restricted to coastal feeding zones where locally they may appear abundant but have restricted distributions.

Secondly, because these species rely upon feeding and breeding areas in a number of countries, their requirements have been the focus of inter-governmental discussion. A large proportion of the migratory waders that occur in Moreton Bay are subject to international migratory bird agreements, namely the Japanese-Australia Migratory Bird Agreement (JAMBA) and the Chinese-Australia Migratory Bird Agreement (CAMBA). Migratory bird habitat can also come under the RAMSAR convention (Convention on Wetlands of International Importance especially as Waterfowl Habitat - adopted in Ramsar, Iran in 1971).

The JAMBA and CAMBA agreements are aimed at promoting conservation of migratory species between the two countries, endangered species within each country and critical habitats used by the birds mentioned in the agreements. They commit the signatories to study migratory birds and conservation needs in each country and in the flyway, and to provide support and equipment for training and education. Another agreement of this type between the ASEAN countries and Australia and Japan is currently being developed.

Thirdly, Moreton Bay is arguably the most important feeding area for migratory waders along the coastline of eastern Australia. During their non-breeding season (southern summer) thousands of migratory waders occupy various parts of Moreton Bay including the environs of Fisherman Islands. Even during winter, Moreton Bay caters for large populations of migratory birds less than a year old which generally stay in Australia rather than migrate to breed. It is likely that many of these young birds have moved short distances up the east coast to spend their first winter at lower latitudes. However, very little is know about such local movements of first year birds. In fact, many of the finer details of movements and the final distribution pattern of migratory waders within Australian are still unclear and much general research is still needed. For example, it is now apparent that not only first year Eastern Curlews overwinter in Australia but that second year birds may also (pers. comm. C. Minton).

Populations of migratory waders fluctuate seasonally in Moreton Bay being highest during the peak periods of southward migration (September-October) and northward migration (March-April). On the southward migration it is not only birds that are arriving in Moreton Bay for the summer that suddenly appear but many thousands stopover in Moreton Bay on their journey to other feeding grounds farther south in Australia and New Zealand. Similarly, the fluctuation in numbers in March and April relates to the passage of birds through Moreton Bay and the departure of individuals that have been resident through the austral summer. Even though summer populations are comparatively stable, movements of the different species are not synchronised and different species prefer different parts of Australia in which to spend their non-breeding season.

4. METHODS

The study area includes the mangroves, claypans and all high ground on Fisherman Islands and the surrounding intertidal mudflats and seagrass beds. Other sites in the vicinity that were visited include adjacent foreshores on the western side of the Brisbane River and the southern shoreline of the Boat Passage. Observations were also made around nearby islands (Mud, St Helena and Green), the Wynnum foreshore, and "Lytton roost" near the disused refuse tip on Whyte Island. These additional observations were necessary to ascertain how the birdlife of Fisherman Islands may have differed from neighbouring areas and to detect daily movements of birds to and from Fisherman Islands (Figure 1).

After preliminary observations, sampling effort was concentrated where birds were known to be plentiful. Nevertheless, a few areas were sampled less intensively than I would have liked because of lack of time. These included sites adjacent to Fisherman Islands on Luggage Point and the eastern side of Whyte Island towards Wynnum. On Fisherman Islands, the mangroves and confined feeding area on the south western corner warranted more attention than time permitted. However, these are small limitations to meeting the objectives of the study and at least for Luggage Point other sources of data are available.

Three systematic approaches to sampling were employed. Firstly, within closed mangrove forest a single transect (Figure 1) of bird counts was undertaken in each of the three sampling periods. Birds were counted along a 1 km route through a process of stopping every 65 m (approx.) or 15 times to record birds seen and heard for 5 minutes within a 60 m radius.

Whereas the transect counts sampled the mangrove bird community, two approaches were taken to systematically record the waders and waterbirds of the area in the same way as in previous studies conducted in Moreton Bay by Thompson (1990) and in Pumicestone Passage by Driscoll (1991). At low tide, exposed intertidal areas were sampled using a telescope (20x lens) and records of birds made within a radius of up to 150 m of a point through an arc of between 40° and 340°. Sites were mostly approached by canoe but also from the land so that bird counts were not necessarily taken from the edge of the water. In the three sampling periods, 11, 25 and 11 counts were made in August, October and January respectively.

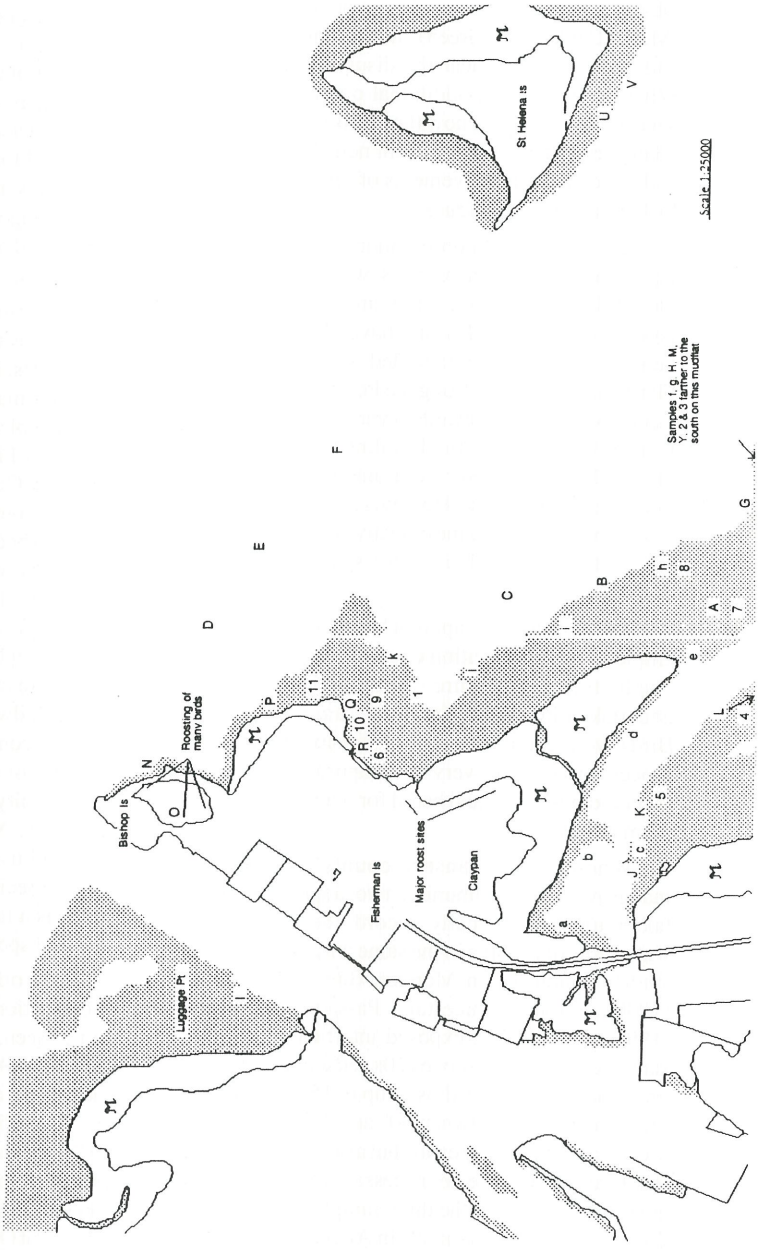
Scan counts are primarily intended to give the percentage representation of the different species being counted and are not a measure of the absolute number of birds in an area. However, during the October survey, one series of low tide counts were conducted as a sequence which was intended as an absolute count of birds over a discrete area of mudflat off the eastern side of Fisherman Islands. This estimate of absolute numbers is very approximate and, because there was no opportunity to repeat the exercise, no measure of the reliability of the estimate can be given. Problems in the field arise because birds tend to withdraw from the observer. Secondly, it is difficult to be precise about the boundaries of an area being observed for each scan and thirdly, birds often feed in clumps and concentrate in different areas as the tide changes. Observations were made within 90 minutes of only one low tide in order to minimise this last effect.

The final systematic approach to fieldwork involved estimating the total number of birds at high tide roosts, in particular the roost on the northern tip of Fisherman Islands, although two other sites were also sampled in this way. Counts were conducted at the main Fisherman Islands roost once in August, twice in October, and twice in January. Getting a reliable count of all species at a high tide roost is very difficult because with few exceptions, individuals of a species will not be obvious because of size or a tendency for some birds to roost in or under mangroves, or as scattered flocks. There are two clear exceptions to this tendency of dispersed roosting and these exceptions can act as "key" species. Bar-tailed Godwits and, to a lesser extent, Eastern Curlews, readily congregate in coherent flocks at a limited number of select high tide roosts and offer a good opportunity for gaining an accurate assessment of numbers. Numbers of other wader species can be inferred using the ratio of low tide scan counts of other species to that of the key species given that there is a fairly accurate estimate of the numbers of the key species from the roost counts.

All other fieldwork involved unsystematic observations to record the number and location of birds seen, whether they were feeding, flying or roosting. A large body of incidental sightings was accrued at all stages of the tide and these are mapped in Appendix E and/or referred to directly in the text. Also, I have past knowledge of the roost at Fisherman Islands, having on several occasions caught birds there for banding when working with J. Thompson (Univ. of Qld) using bands issued under the Australian

FIGURE 1

Map of a large section of the study area giving the location of scan counts of feeding birds taken in August (a-k), October (a-y) and January (1-11), Refer to Appendix A for data from the counts. Not recorded are locations S (Whyte Is.), T(Wynnum), W (Green Is.) & X (Green Is.). Areas in grey are intertidal feeding areas and those marked "M" are mangroves. Details in Section 5.1.4. on roost counts.



Bird and Bat Banding Schemes. Data from these banding exercises are presented in this report.

Data from the scan counts are subjected to classification analyis (Section 5.3.1 and 5.3.2) using counts of waders only, providing a species was observed during at least two scan counts. Details of the analysis technique can be found in Clifford & Stephenson (1975), Gauch (1982) and Williams (1976). Counts are transformed to the percentage contribution for each species and the resulting two-way table of species versus sites where counts were made, is subjected to a form of classification which is hierarchical and agglomerative using the BIOΣTAT suite of programs (Pimentel and Smith 1986) for microcomputers. Prior to the classification, the two-way table is used to calculate a dissimilarity matrix between sites based on Gower's General Similarity Coefficient. The classification is then run using flexible sorting with a beta value of -0.25. The classification sets out the scan counts in a dendrogram showing the various grouping of sites where the counts were made and sequence in which sites were linked to one another on the basis of their similarities in terms of the feeding bird community.

5. RESULTS

The 84 bird species recorded during the fieldwork are listed in Table 1 with an indication of their habitat and food preferences and their regional abundance. About 10% are uncommon around Moreton Bay (coded 1 in the Table) with the Red-rumped Parrot being the least regularly seen of this uncommon group of species. About 30% of species could be considered moderately common and the remaining 60% common to very common (coded "3") around Moreton Bay for at least part of the year.

In terms of the food categories known to be eaten by the bird species listed in Table 1, the categories of small vertebrates, seeds, and other plant products (either nectar, fruit or soft shoots etc) are each consumed by about 20% of the avifauna. Fish is consumed by a higher percentage (25%), and terrestrial invertebrates by about 45% of the avifauna. Aquatic invertebrates are consumed by the highest number of species (about 55%). These food categories are not mutually exclusive and do not necessarily apply to the actual foods consumed around Fisherman Islands, however, they give some indication.

Further details of habitat utilisation by birds throughout the study area will be given in later sections. However, as a generalisation, Table 1 assigns species to one or more of five broad habitat categories. Sixty-one percent of species are "coastal" and will utilise the intertidal mudflats and/or open water, and 32% utilise mangroves and 10% may be found in open areas of grass and reeds. The two other habitat categories of freshwater swamps and forest are less easily defined on Fisherman Islands. The former category would include some of the drainage canals across the Islands and much of the grassland area in time of wet weather when there is local inundation. Fifty-two percent of species fall into this category which includes many of the waders which will opportunistically use freshwater marshes but tend to be more restricted to the intertidal area. The forest category (37% of species) relates to many of the species noted under mangroves or freshwater marshes, that will also use eucalypt forest. As mentioned earlier, very little forest cover other than mangroves is left on Fisherman Islands.

The remainder of the presentation of results will be largely on the basis of various areas. Appendix E maps the sightings of species in the immediate vicinity of Fisherman Islands and should be used together with the text that follows as explanation of the local distribution of species. Note that the data presented on the roost counts and scan counts has not been mapped and some other general comments are not necessarily verifiable from the maps presented.

5.1 Open terrestrial habitats and roost sites

5.1.1 Buildings

Much of Fisherman Islands has been cleared or is being cleared and reclaimed as dry land for the establishment of Port facilities. Where the change in land use has not been completed, which includes most of the land to the east and north of the railway line, a range of bird species can still be found. In contrast, amongst the developed area to the west of the railway line there is little bird activity other than that of introduced species (Feral Pigeon, House Sparrow and Common Starling). On the shoreline near the wharves, wader activity is confined to two small enclaves (see Section 5.4.4).

5.1.2 Grassed areas, ponds and channels

Behind the bund walls on the eastern side on the railway bird activity has also been curtailed but over much of the remainder of the Islands birds can still be found and fall into three categories of occupancy.

TABLE 1

Bird species recorded during fieldwork around Fisherman Islands.

The naming and ordering of species is in accordance with the Atlas of Australian Birds (Blakers et al. 1984). The information below refers to the various column headings, as indicated. A: Species listed under the China-Australia Migratory Bird Agreement (CAMBA) or the Japan-Australia Migratory Bird Agreement (JAMBA) are indicated with Cor J respectively.

B: Species marked on a 3 point scale (1-3) were recorded during the compilation of data for the Atlas between 1977 and 1982 from the one-degree grid square that includes the study area, centred on 27°30'E, 153°30'S. The scale value is indicative of the reporting rate for species and gives a rough measure of the ubiquity or commoness of each species in the area. The scale is based on the number of times a species was recorded in relation to the number of bird lists submitted to the Atlas for the relevant area. For a scale of 1 this proportion is less than 12%, for 2 it is between 12% & 40% and for 3 it is over 40%.

C: Breeding records of species recorded under B. Habitat: The habitats where species are likely to be found are indicated with the following codes: S (freshwater swamps, creeks, creek verges) - P (pastures, fields, grasses), F (forest, woodland), M (mangroves), C (coastal, including intertidal areas). Food: The food preferences of species are indicated with the following codes: - V (vertebrates - terrestrial), I (invertebrates - terrestrial), H (plant material other than seeds), S (seeds), A (aquatic invertebrates, F (fish). N.B. Habitat and feeding preferences are largely compiled from information in Atlas of Australian Birds (Blakers et al. 1984).

Species		A B C	Habitat [S P F M C]	Food [V I H S A F]
Pelicanidae	Pelecaniformes:			
Pelecanus conspicillatus	Australian Pelican	3	[....*]	[.....*]
Sulidae				
Morus serrator	Australasian Gannet	1	[....*]	[.....*]
Anhingidae				
Anhinga melanogaster	Darter	3	[....*]	[*.....*]
Phalacrocoracidae				
Phalacrocorax carbo	Great Cormorant	2	[....*]	[.....*]
Phalacrocorax varius	Pied Cormorant	3	[....*]	[....*.*]
Phalacrocorax sulcirostris	Little Black Cormoran	3 #	[*....*]	[.....*]
Phalacrocorax melanoleucos	Little Pied Cormorant	3 #	[*....*]	[.....*]
Ardeidae	Ciconiiformes:			
Ardea novaehollandiae	White-faced Heron	3 #	[*..*..*]	[*..*..*.*]
Egretta alba	Great Egret	CJ 3	[*..*..*]	[*....*.*]
Egretta garzetta	Little Egret	2	[*.*..*.*]	[*....*.*]
Egretta intermedia	Intermediate Egret	2	[*..*..*]	[*.*....]
Butorides striatus	Striated Heron	2	[...*.]	[....*.*]
Plataleidae				
Threskiornis aethiopica	Sacred Ibis	3	[*....*]	[*....*.]
Platalea regia	Royal Spoonbill	3 #	[*....*]	[....*.*]
Anatidae	Anseriformes:			
Anas superciliosa	Pacific Black Duck	3 #	[*....]	[..*.*.*.]
Anas gibberifrons	Grey Teal	2	[*....*]	[.*.*.*.*.]
Anas castanea	Chestnut Teal	3 #	[*....*]	[.*.*..*.]
Pandionidae	Falconiformes:			
Pandion haliaetus	Osprey	2 #	[*....*]	[.....*]
Accipitridae				
Elanus notatus	Black-shouldered Kite	3 #	[.*.*..*]	[*.*....]
Haliastur indus	Brahminy Kite	3 #	[*..*.*.*]	[*.*....*.*]
Haliastur sphenurus	Whistling Kite	3 #	[*..*..]	[*....*.]
Accipiter fasciatus	Brown Goshawk	1 #	[..*..]	[*.*....]

Table 1 Continued

Haliaeetus leucogaster	White-bellied Sea-Eagle	C 2 #	[*. . . .*]	[*. . . . .*]
Haematopodidae	Charadriiformes:			
Haematopus longirostris	Pied Oystercatcher	2 #	[. . . .*]	[. . . .*.]
Charadriidae				
Vanellus miles	Masked Lapwing	3 #	[*.*. . .*]	[.*. .*.*.]
Pluvialis squatarola	Grey Plover	CJ 1	[. . . .*]	[. . . .*.]
Pluvialis dominica	Lesser Golden Plover	CJ 2	[*.*. . .*]	[.*. . .*.]
Charadrius mongolus	Mongolian Plover	CJ 2	[. . . .*]	[. . . .*.]
Charadrius leschenaultii	Large Sand Plover	CJ 2	[. . . .*]	[. . . .*.]
Charadrius ruficapillus	Red-capped Plover	2 #	[*. . . .*]	[.*. .*.*.]
Recurvirostridae				
Himantopus himantopus	Black-winged Stilt	3 #	[*. . . .*]	[. .*. .*.]
Recurvirostra novaehollandiae	Red-necked Avocet	1	[*. . . .*]	[.*. . .*.]
Scolopacidae				
Arenaria interpres	Ruddy Turnstone	CJ 2	[*. . . .*]	[. . . .*.]
Numenius madagascariensis	Eastern Curlew	CJ 3	[. . . .*]	[. . . .*.]
Numenius phaeopus	Whimbrel	CJ 3	[. . .*.*]	[. . . .*.]
Tringa brevipes	Grey-tailed Tattler	CJ 3	[. . .*.*]	[. . . .*.]
Tringa hypoleucos	Common Sandpiper	CJ 2	[*. . .*.*]	[. . . .*.]
Tringa nebularia	Greenshank	CJ 2	[*. . . .*]	[. . . .*.*]
Tringa stagnatilis	Marsh Sandpiper	CJ 3	[*. . . .*]	[. . . .*.]
Tringa terek	Terek Sandpiper	CJ 3	[*. . .*.*]	[. . . .*.]
Limosa limosa	Black-tailed Godwit	CJ 2	[*. . . .*]	[. . .*.*.]
Limosa lapponica	Bar-tailed Godwit	CJ 3	[. . . .*]	[. . . .*.]
Calidris canutus	Red Knot	CJ 3	[. . . .*]	[. .*. .*.]
Calidris tenuirostris	Great Knot	CJ 2	[. . . .*]	[. . . .*.]
Calidris acuminata	Sharp-tailed Sandpiper	CJ 3	[*. . . .*]	[.*. .*.*.]
Calidris ruficollis	Red-necked Stint	CJ 2	[*. . . .*]	[. .*.*.*.]
Calidris ferruginea	Curlew Sandpiper	CJ 3	[*. . . .*]	[*. . . .*.]
Laridae				
Larus novaehollandiae	Silver Gull	3	[*. . . .*]	[. . . . .*]
Chlidonias leucoptera	White-winged Tern	CJ 2	[*. . . .*]	[. . . . .*]
Gelochelidon nilotica	Gull-billed Tern	3	[*. . . .*]	[*.*. . .*.*]
Hydroprogne caspia	Caspian Tern	CJ 3	[*. . . .*]	[. . . . .*]
Sterna hirundo	Common Tern	CJ 2	[. . . .*]	[.*. . . .*]
Sterna albifrons	Little Tern	CJ 3	[. . . .*]	[. . . . .*]
Sterna bergii	Crested Tern	2	[. . . .*]	[. . . . .*]
Columbidae	Columbiformes			
Columba livia	Feral Pigeon	3 #	[. . . .]	[.*.*.*.*.]
Geopelia humeralis	Bar-shouldered Dove	3 #	[*. .*.*.]	[. . .*. .]
Platycercidae	Psittaciformes:			
Platycercus adscitus	Pale-headed Rosella	3 #	[. .*. .]	[.*.*.*. .]
Psephotus haematonotus	Red-rumped Parrot	1	[. .*. .]	[. .*.*. .]
Cuculidae	Cuculiformes:			
Cuculus variolosus	Brush Cuckoo	2	[. .*.*.]	[.*. . . .]
Alcedinidae	Coraciiformes:			
Halcyon chloris	Collared Kingfisher	3 #	[. .*.*.]	[*.*. . .*.]
Meropidae				
Merops ornatus	Rainbow Bee-eater	J 3 #	[. .*.*.]	[.*. . . .]
Hirundinidae	Passeriformes			
Hirundo neoxena	Welcome Swallow	3 #	[*. .*.*.]	[.*. . . .]
Cecropis nigricans	Tree Martin	3 #	[*. .*.*.]	[.*. . . .]

Table 1 Continued

Cecropis ariel	Fairy Martin	3 #	[*. .*.+.]	[.*. . .]
Motacillidae				
Anthus novaeseelandiae	Richard's Pipit	2 #	[.*. . .]	[.*.*.*.*.]
Campephagidae				
Coracina novaehollandiae	Black-faced Cuckoo-shrike	3 #	[. .*.+.]	[.*.*.*. .]
Lalage leucomela	Varied Triller	1	[. .*.*.]	[.*.*.*. .]
Pachycephalidae				
Pachycephala rufiventris	Rufous Whistler	3 #	[. .*.+.]	[.*. . . .]
Colluricincla harmonica	Grey Shrike-thrush	3 #	[*. .*.+.]	[*.*. . . .]
Myiagridae				
Myiagra rubecula	Leaden Flycatcher	2 #	[. .*.*.]	[.*. . . .]
Rhipiduridae				
Rhipidura rufifrons	Rufous Fantail	2	[. .*.*.]	[.*. . . .]
Rhipidura fuliginosa	Grey Fantail	3 #	[. .*.*.]	[.*. . . .]
Rhipidura leucophrys	Willie Wagtail	3 #	[. .*. .]	[.*. . . .]
Sylviidae				
Megalurus gramineus	Little Grassbird	1 #	[*.*.*. .]	[.*. . .*.]
Cisticola exilis	Golden-headed Cisticola	3 #	[*.*. . .]	[.*. . . .]
Acanthizidae				
Gerygone laevigaster	Mangrove Gerygone	3 #	[. .*.*.]	[.*. . . .]
Climacteridae				
Cormobates leucophaea	White-throated Treecreeper	2 #	[. .*.+.]	[.*. . . .]
Meliphagidae				
Lichenostomus fasciogularis	Mangrove Honeyeater	3	[. . .*.]	[.*.*. .*.]
Zosteropidae				
Zosterops lateralis	Silvereye	3 #	[. .*.*.]	[.*.*. . .]
Passeridae				
Passer domesticus	House Sparrow	3 #	[.*. . .]	[.*.*.*. .]
Ploceidae				
Lonchura castaneothorax	Chestnut-breasted Mannikin	2 #	[*.*. .*.]	[. . .*. .]
Sturnidae				
Sturnus vulgaris	Common Starling	3 #	[*.*.*. .]	[*.*.*. . .]
Grallinidae				
Grallina cyanoleuca	Australian Magpielark	3 #	[*.*.*. .]	[.*. . . .]
Corvidae				
Corvus orru	Torresian Crow	3 #	[.*.*.+.]	[*.*.*. . .]

A handful of grassland species live amongst the tall grasses and reeds and include Richard's Pipit, Little Grassbird, Golden-headed Cisticola, and Chestnut-breasted Mannikin. The Double-barred Finch and introduced Nutmeg Mannikin are also likely to be present. These grassed areas are also used by species that move to and from neighbouring tree cover onto the ground (Bar-shouldered Dove, Pale Headed Rosella, Red-rumped Parrot, Willie Wagtail, Australian Magpielark, Torresian Crow and Black-shouldered Kite) or forage out over open spaces (Rainbow Bee-eater, Welcome Swallow, Fairy Martin and Tree Martin). Waterbirds will opportunistically use grassed areas following temporary flooding or where ponding occurs. These species include the egrets, ibises and ducks. However, with the exception of the ponding within the railway loop where Sacred Ibis were seen, and a few waders and egrets along the drainage channels, little of this type of activity was noted during the fieldwork. With the possible exception of Sharp-tailed Sandpipers, the waders tended to forage along the built drains closest to the mangroves on the eastern side of the Islands.

5.1.3 Intact claypan

To the south and south east of the Islands the natural claypan behind the mangroves is still very extensive and in use by both foraging and roosting birds. In addition to feeding activity of several species

at the roost site in the extreme south east (Section 5.1.4.1), Sharp-tailed Sandpipers and Red-capped Plovers were prevalent in small groups throughout the claypan in October and much less so in January. Use of the claypan depends on how wet it is from tidal waters and rain and the time of the tide. Several waders (Curlew Sandpiper, Marsh Sandpiper, Red-capped Plover and Sharp-tailed Sandpiper) were using the claypan when conditions were suitable as an auxiliary feeding area to the intertidal mudflat. Several flocks of up to 20 Sharp-tailed Sandpipers were seen feeding throughout the claypan area during a high tide in October (not mapped). Activity on the claypan tended to be concentrated towards the south east where there is a roost, and to a lesser extent towards the prong of mangroves that run up beside the railway line where small flocks of White-faced Heron, Sacred Ibis and larger groups of Sharp-tailed Sandpipers were seen (see Appendix E - occurrence of 24 Sharp-tailed Sandpipers at this site). The intact substrate and more regular presence of what seems to be freshwater near this prong of mangroves serves to attract birds.

5.1.4 Roost sites

5.1.4.1 Claypan in the south east

A concentration of roosting birds occurs on the south eastern section of claypan which is surrounded on three sides by mangroves (Figure 1). The site was visited on at least one occasion during each of the periods of fieldwork and birds were always there at high tide. Even at low tide, a residual number were present either resting or feeding in and around the shallow, wide pools at the site. It is a regularly frequented high tide roost that especially caters for the Eastern Curlew and Sharp-tailed Sandpiper but also a number of other species. The counts made are summarised below.

In winter the diversity of waders at the site was low but 212 Eastern Curlew were roosting there over a high tide together with 110 Black-winged Stilt and 12 Sharp-tailed Sandpiper.

In October, more species were noted including 4 Greenshank, 30 Whimbrel, 55 Curlew Sandpiper, 15 Bar-tailed Godwit in addition to 6 Black-winged Stilt, 42 Sharp-tailed Sandpiper, and 87 Eastern Curlew. Another 212 Eastern Curlew were counted on the same high tide in partially disturbed claypan behind the main cove on the east of the Island (Appendix E). That is, about 300 Eastern Curlew were roosting on Fisherman Islands at the time and this Figure is used in Section 6 for estimating the number of other species in the area.

Similarly, in summer the site was intensively used by a variety of species including 75 Australian Pelican, 25 Crested Tern and small numbers of Caspian Tern, Great Egret, Little Egret, Greenshank and Lesser Golden Plover. Waders that were present in high numbers included 190 Eastern Curlew, 131 Bar-tailed Godwit, 50 Whimbrel, 60 Black-tailed Godwit, 38 Black-winged Stilt, 20 Sharp-tailed Sandpiper, 30 Curlew Sandpiper, 25 Red-necked Stint and 15 Marsh Sandpiper.

5.1.4.2 Back of the cove

Another location nearby was also serving as a high tide resting place for birds but mostly a different set of species. Many egrets, spoonbills and ibises were spending the high tide just at the back of the main cove on the east of the island and simply moving out from here at low tide to forage on the mudflat and seagrass, or under the mangroves. Birds were either on the main wall that was recently constructed just behind the cove, in the dead or dying trees that surrounded this road at the southern end of the base of the cove, or around the open ponds that formed as a consequence of bunding for the road.

In this area, there were invariably groups of up to 10 or more White-faced Herons, Great Egrets, Little Egrets, Sacred Ibis, Black-winged Stilts, and irregular occurrences of a number of wader species including as many as 60 Curlew Sandpiper and 40 Sharp-tailed Sandpipers in summer. Furthermore, Little Pied Cormorants and Little Black Cormorants were using the dead trees here as roosting sites and in one tree a pair of Ospreys have nested. Similarly, Tree Martins and a Pacific Black Duck were noted nesting in this patch of trees. Sightings of the Brahminy Kite, Whistling Kite and White-breasted Sea-eagle were made in the vicinity.

5.1.4.3 Bishop Island and northern tip of Fisherman Islands

The main wader roost and seabird roost on Fisherman Islands is at the northern end of the Islands, and on Bishop Island. The whole area is considered together because it forms a single dispersed roost site that is changing all the time as a result of ongoing filling and road construction. When Bishop Island was separate from Fisherman Islands, birds would mostly roost on the isthmus running off to the east of Bishop Island but they have slowly started to predominantly roost on Fisherman Islands with scattered enclaves of various species on open sand or near mangroves on Bishop Island. More recently, Bishop Island has been joined in two places with

TABLE 2

Counts of birds made on 5 occasions at the Fisherman Islands/Bishop Island and once at the Lytton roost.

Species (Wader)	Date	13 Aug	10 Oct	24 Oct	16 Jan	17 Jan	Lytton 17 Jan	Totals
Haematopus longirostris	Pied Oystercatcher	79	64	21	22	11		179
Pluvialis squatarola	Grey Plover		98	12	46	82		238
Pluvialis dominica	Lesser Golden Plover			9				9
Charadrius mongolus	Mongolian Plover	+	50	12	35	248		345
Charadrius leschenaultii	Large sand Plover		+	16	95	176		287
Charadrius ruficapillus	Red-capped Plover		10			+		10
Himantopus himantopus	Black winged Stilt	123	19	19				161
Recurvirostra novaehollandiae	Red-necked Avocet	22	30	52	95	130		329
Aremaria interpres	Ruddy Turnstone		23	16	4			43
Numenius madagascariensis	Eastern Curlew		473	8		8	30	519
Numenius Phaeopus	Whimbrel		28	3	10		50	91
Tringa brevipes	Grey-tailed Tattler		3	25			330	358
Tringa nebularia	Greenshank						40	40
Tringa terek	Terek Sandpiper			5	+			5
Limosa limosa	Black-tailed Godwit			350		146	130	626
Limosa lapponica	Bar-tailed Godwit	167	1480	575	423	704	440	3789
Calidris canutus	Red Knot		150	5				155
Calidris tenuirostris	Great Knot		2600	1050	545	392	300	4887
Calidris acuminata	Sharp-tailed Sandpiper		45	8				53
Calidris ruficollis	Red-necked Stint		+	192	+	40	+	232
Calidris ferruginea	Curlew Sandpiper	142	201	32		21	50	446
	Totals	533	5274	2410	1275	1958	1371	
Species (other)								
Pelecanus conspicillatus	Australian Pelican		11		34	18		63
Phalacrocorax sulcirostris	Little Black Cormorant					19		19
Anas castanea	Chestnut Teal				+	23		23
Larus novaehollandiae	Silver Gull	24	47	62	1350	610		2093
Chlidonias leucoptera	White-winged Tern				95	20		115
Gelochelidon nilotica	Gull-billed Tern	2		8			8	18
Hydroprogne caspia	Caspian Tern	31	12	12	74	90		219
Sterna hirundo	Common Tern	3			27			30
Sterna albifrons	Little Tern		113	80	14	65		272
Sterna bergii	Crested Tern	73	110	40	280	209		712

TABLE 3

Captures of birds at the Fisherman Island/Bishop Islands roost. All birds have been banded and released.

Species	Date	17-11 1989	16-1 1990	21-10 1990	19-1 1991	3-4 1991	13-10 1991
Haematopus longirostris	Pied Oystercatch.		6				
Charadrius mongolus	Mongolian Plover	38				2	
Charadrius leschenaultii	Large Sand Plover	3				44	
Arenaria interpres	Ruddy Turnstone					1	
Numenius madagascariensis	Eastern Curlew						2
Tringa terek	Terek Sandpiper	3					
Limosa limosa	Black-tailed Godwit			31			
Limosa lapponica	Bar-tailed Godwit	90		5	16	58	51
Calidris canutus	Red Knot	1		55			1
Calidris tenuirostris	Great Knot	16	8	8	9	101	50
Calidris ferruginea	Curlew Sandpiper			14			3
Gelochelidon nilotica	Gull-billed Tern						2
Sterna albifrons	Little Tern	4			1		

Fisherman Islands and the water in between is now a lagoon that has restricted tidal flow. Previously, on low tide the mudflat between the two islands attracted considerable feeding activity but this is no longer possible because the water does not drain away. Presumably the whole lagoon is to be reclaimed through the pumping of sand as fill to make the islands contiguous.

The counts of roosting birds is given in Table 2 and some indication of general distribution of roosting birds is shown in Figure 1. Also, since 1989 a number of cannon netting exercises have been undertaken at this roost and the resulting captures are summarised in Table 3. All birds were banded under the Australian Bird and Bat Banding Schemes and more recently all of the Bar-tailed Godwits have also been tagged with a small dark green leg flag which is the colour assigned to south east Queensland. En route through Asia and on their breeding grounds these birds can be identified from a distance as non-breeding visitors to Moreton Bay.

The roost is used by the highest number of birds in October, during the southward migration when numbers of migratory waders peak in Moreton Bay. Far fewer species are present in August and the non-migratory species (Black-winged Stilt, Avocet, Pied Oystercatcher and Red-capped Plover) form a significant proportion of the total roost counts. Those migratory species that were counted in August are most likely to be first year birds which during their first austral winter do not return to the northern hemisphere to breed, e.g. Bar-tailed Godwits, Curlew Sandpipers, Sharp-tailed Sandpipers Mongolian Plover, and Eastern Curlews (Table 2 and Section 5.1.4.1). It is possible some of the Eastern Curlews are second year birds which may also not return to breed or some may be adult birds that have in already made the return journey back from their breeding grounds by August.

In October and January, but especially in October, there is a high diversity of birds on the roost with consistently high numbers of Bar-tailed Godwits and

Great Knots. Eastern Curlews will occasionally use the site but tend to prefer more secluded locations such as the claypan roost discussed above. The numbers of several other species is also impressive considering that they are generally far less plentiful in Moreton Bay than the most numerous species on the roost, i.e. the Great Knot and Bar-tailed Godwit. These species include the Black-tailed Godwit, Mongolian Plover, Large Sand Plover, Grey Plover, Red-necked Avocet, Ruddy Turnstone, Pied Oystercatcher and Red Knot. The Red Knot does not sustain a summer population in Moreton Bay but passes through to New Zealand and New South Wales (high count in October and refer to Table 2).

The roost regularly sustains as many as 2000 birds and during periods of migration these numbers can easily double. This is in addition to the fairly regular high numbers of Crested and Little Terns and a variety of other species that occur less consistently (Caspian Tern, Gull-billed Tern, White-winged Tern, Chestnut Teal). During the January count a large number of Silver Gull occurred at the roost and it is unclear whether this is to become a normal feature of the site. The changing conditions may well be more suitable to some species than others.

There are two wader species that are common on the surrounding feeding grounds but are not well represented at any of the roost sites already mentioned. Grey-tailed Tattlers and Whimbrels in particular will roost in mangroves over high tide and do not necessarily seek out a ground roost like the majority of species. Consequently, these species become far less obvious over high tide.

5.2 Mangroves

Extensive stands of mangrove are still prevalent on Fisherman Islands, especially along the eastern and southern sides of the island including an isolated stand on the south western corner. A long tongue of mangroves extends northward up the centre of the island beside the railway line and forms the western edge of the main area of claypan (Section 5.1.3). All these patches of mangrove are still being used by a typical range of mangrove inhabiting species, although only at one site was a transect count of birds undertaken in each of the three sampling periods (Table 4). Local bird species that are specialist inhabitants of mangroves were present, i.e. the Collared Kingfisher, Mangrove Honeyeater, Mangrove Warbler and Striated Heron. The latter species was not as common as expected and was not recorded during transect counts. However, Mangrove Warblers and Collared Kingfishers were especially abundant.

Unexpectedly, a number of other species more typical of eucalypt forest were also abundant in the tallest stands of mangrove which lined the foreshore to a width of up to 200 m. In particular, there was a high population of White-throated Treecreepers which are generally not a mangrove inhabitant and were probably present on Fisherman Islands due to the tall stature of the mangroves and the open nature of the understorey. Quite high densities of other species such as the Grey Fantail, Rufous Whistler and Grey Shrike Thrush were indicative of a high diversity and high overall bird abundance in these mangroves, particularly where the stands were tallest around the foreshore. Many Sacred Ibis are also using the open feeding areas beneath the mangrove canopy for foraging as well as feeding out in the open on the mudflats. Where mangroves become shorter or more open, the birdlife is less diverse primarily because the habitat becomes simplified and offers fewer feeding opportunities for typical forest species.

A total of 18 species were recorded during the three mangrove transects on Fisherman Islands with a minimum of 10 species and 86 total counts from any one transect (Table 4). In comparison, transect counts of birds I have conducted in a similar fashion in mangroves of Deception Bay and Tin Can Bay, yielded totals counts of 33 and 36 respectively and species tallies of 12 and 7 respectively. On the basis of this fairly superficial comparison, the mangroves on Fisherman Islands compare very favourably as habitat for birdlife, especially in terms of local population density. A short visit to some of the tallest mangroves between Wynnum and the Boat Passage indicated that a similar type of bird community is inhabiting parts of these forests as occur on Fisherman Islands.

Preservation of the mangroves of Fisherman Islands would be of considerable benefit to local resident bird populations and to other forest species which would use the site opportunistically in transit along the coast during seasonal movements. That is, species additional to those listed in Table 1 are likely to occur in the mangroves at Fisherman Islands from time to time.

5.3 Intertidal scan counts

5.3.1 General analysis of wader counts

The habitat that was given by far the most attention was the intertidal mudflats and seagrass beds adjoining Fisherman Islands. A number of nearby areas were also visited.

TABLE 4.

Species		Aug	Oct	Jan	Total
Threskiornis aethiopica	Sacred Ibis	11	12	42	65
Pandion haliaetus	Osprey	3			3
Haliastur sphenurus	Whistling Kite	1		2	3
Platycercus adscitus	Pale-headed Rosella			2	2
Halcyon chloris	Collared Kingfisher	6	17	25	48
Coracina novaehollandiae	Black-faced Cuckoo-shrike		4		4
Lalage leucomela	Varied Triller		3		3
Pachycephala rufiventris	Rufous Whistler	10	2	7	19
Colluricincla harmonica	Grey Shrike-thrush	3	2	8	13
Myiagra rubecula	Leaden Flycatcher		4		4
Rhipidura rufifrons	Rufous Fantail	1	2		3
Rhipidura fuliginosa	Grey Fantail	11	6	12	29
Rhipidura leucophrys	Willie Wagtail	2			2
Gerygone laevigaster	Mangrove Gerygone	22	21	29	72
Cormobates leucophaea	White-throated Treecreeper	9	5	8	22
Lichenostomus fasciogularis	Mangrove Honeyeater		10		10
Zosterops lateralis	Silvereye	7			7
Corvus orru	Torresian Crow			2	2
Totals		86	88	137	311

TABLE 5

The percentage contribution of species of wader to the scan count totals for the spring survey around Fisherman Islands. Data for various sites, as indicated by the column headings, have been combined on the basis of the classification analysis reported on in Section 5.3.2 and Figure 2. These same data have been summarised and graphed in Figure 3.

Species	ABG MPTY	CF	QS	KL	DEH	UV	WX	R	N	O	J	I	Total
Pied Oystercatcher (po)	2				7	3	5						2
Grey Plover (gp)	2			9	2				20		5	8	3
Lesser Golden Plover (lgp)	1			4			2						+
Mongolian Plover (mp)	+					1			7	3		1	1
Large Sand Plover (lsp)	2				+	3	5		7	1	5	1	2
Red-capped Plover (rcp)									15		1	1	1
Black-winged Stilt (bws)	+		11	1				5		5	1	2	1
Red-necked Avocet (rna)										8			1
Ruddy Turnstone (rt)	1					12	2		2				1
Eastern Curlew (ec)	6	57	8	21	2	10	7	11	4	6	1		8
Whimbrel (w)	6	6	12	10	6	11	39	5	2	2	4		6
Grey-tailed Tattler (gtt)	31	8	7	18	11	11	19		2	1	4		15
Greenshank (g)	2	4	6	3	1	1	3						1
Terek Sandpiper (ts)	1		1			3		1		7	3		1
Black-tailed Godwit (bltg)	+							5		7	5		1
Bar-tailed Godwit (btg)	17	19	36	19	12	37	17	14	2	15	31	17	19
Red Knot (rk)	+				3	1			7	3	17	14	4
Great Knot (gk)	1				+	1				1	1	20	2
Sharp-tailed Sandpiper (sts)	25	6	17	15	50	3	2	22		12	7	1	20
Red-necked Stint (rns)					2	1			13			1	1
Curlew Sandpiper (cs)	1		2		3	1		36	19	30	16	34	9
Totals	738	89	84	68	322	184	59	99	54	184	166	178	2225

These areas are feeding grounds for a wide variety of species of migratory waders (e.g. Eastern Curlew, Whimbrel), resident waders (e.g. Black-winged Stilt, Red-capped Plover, and Pied Oystercatcher), the Chestnut Teal, and a variety of ibis, egret and heron (see Appendix A). All of these species tend to feed at low tide under mangroves or out on the mudflats. Moreton Bay generally has high numbers of many of these species and, for the migratory species, Moreton Bay is a major international site.

Perhaps the highest density of waders in Moreton Bay occurs on Luggage Point (Thompson 1990) and the present study indicates a very high feeding density of birds around Fisherman Islands. However, the mix of species is quite different from Luggage Point due to a generally muddier substrate and prevalence of seagrass.

Data from the scan counts are analysed in detail to determine zones of different feeding areas around Fisherman Islands and the species that characterise such zones. The complete set of data from scan counts at low tide is given in Appendix A but for the time being only the community of waders (i.e. Families of Charadriidae and Scolopacidae) are being considered. In total, for the three sampling periods, 47 scan counts (locations in Figure 1) were taken with widely varying total counts. The percentage count for each species from each scan is given in Appendix B. On the basis of these data a classification of scan counts was performed as described in Section 4 and the result was a determination of three main groups of scans. The dendrogram is not shown but the general makeup of the groups was as follows. Almost all of the winter sampling was separated off into a group whereas one of the other two groups was made up of just five of the counts made in spring. The remaining scan counts formed a third, large group.

5.3.2 Analysis of October wader counts

The broad scale analysis highlighted the seasonal changes that had occurred in the bird community but also tended to cloud a clear assessment of spatial variation in the intertidal feeding areas. Therefore, seasonal aspects are dealt with in Section 5.3.3 and to appreciate the spatial arrangement of feeding areas a second classification was computed using only the spring data which included 25 scan counts (Appendix B). The dendrogram that resulted from this analysis is shown in Figure 2 and has been used as the basis of selecting 12 groupings of the 25 scan counts (Appendix B) made in October.

The percentage contribution of species to total counts for each of these 12 new groupings is given in Table 5 and illustrated graphically in Figure 3. Based on the analysis, the following interpretation of variation in the intertidal feeding areas for waders is made and a subjective assessment of the intertidal zones that are represented in the analysis is given in Figure 1.

The most extensive and uniform intertidal zone for feeding waders is represented by sites "ABGMPTY" and has a high species diversity with the Grey-tailed Tattler, Sharp-tailed Sandpiper and Bar-tailed Godwit accounting for about 73% of the individuals (Figure 3). This zone is most extensive out from the south eastern corner of Fisherman Islands and is mostly shallow seagrass beds on muddy substrate that has a relatively firm sub-surface. In many places the surface varies from firm ridges free of seagrass to deep troughs as a result of large holes dug by fisherman when searching for worms. The implication of this type of disturbance is unclear and although it may create local heterogeneity of substrate and encourage a wider of range of wader species it may also be having long term detrimental effects on the productivity of the area if practised too intensively.

The zone represented by "CF" is deeper seagrass beds that in many tides are only accessible by the larger waders, notably the Eastern Curlew. The White-faced Heron and Sacred Ibis are also quite comfortable feeding in this deeper water. The zone will vary with the tide height but even on the lowest tides is still quite extensive lying along the eastern perimeter of the intertidal areas of Fisherman Islands and down the shoreline towards Wynnum.

The next zone is not well defined and may be an artifact of transient high densities of birds, notably Bar-tailed Godwits, as they disperse more widely onto feeding areas. Nevertheless, the two locations that have been grouped, Q (north eastern Fisherman Islands) and S (eastern side of mangroves at Lytton), were similar, in that they were close inshore and had relatively firm substrate with little seagrass.

The area to the south eastern side of the Boat Passage, represented by "KL" had fairly even counts in the range of 10-20% for six species and could be considered a combination of the two major zones around Fisherman Islands, i.e. "ABGMPTY" and "CF". The sites "DEH" could also be considered a localised variation of the main feeding area where Sharp-tailed Sandpipers are very abundant. This tended to occur amongst the seagrass beds but where the seagrass was least dense.

FIGURE 2

Dendogram showing the results of a classification of low tide scan counts of waders taken from 25 sites (A-Y) during October 1991 in the vicinity of Fisherman Islands. The sites are mapped on Figure 1. Details of the analysis procedure are given in Section 4 and an interpretation of these results is given in Section 5.3.2.

The grouping of sites is indicated by the capital letters beneath the legs of the dendogram. The percentage contribution made by species of wader to the combined counts for each of the defined groups is given in Table 5 and graphically illustrated in Figure 3.

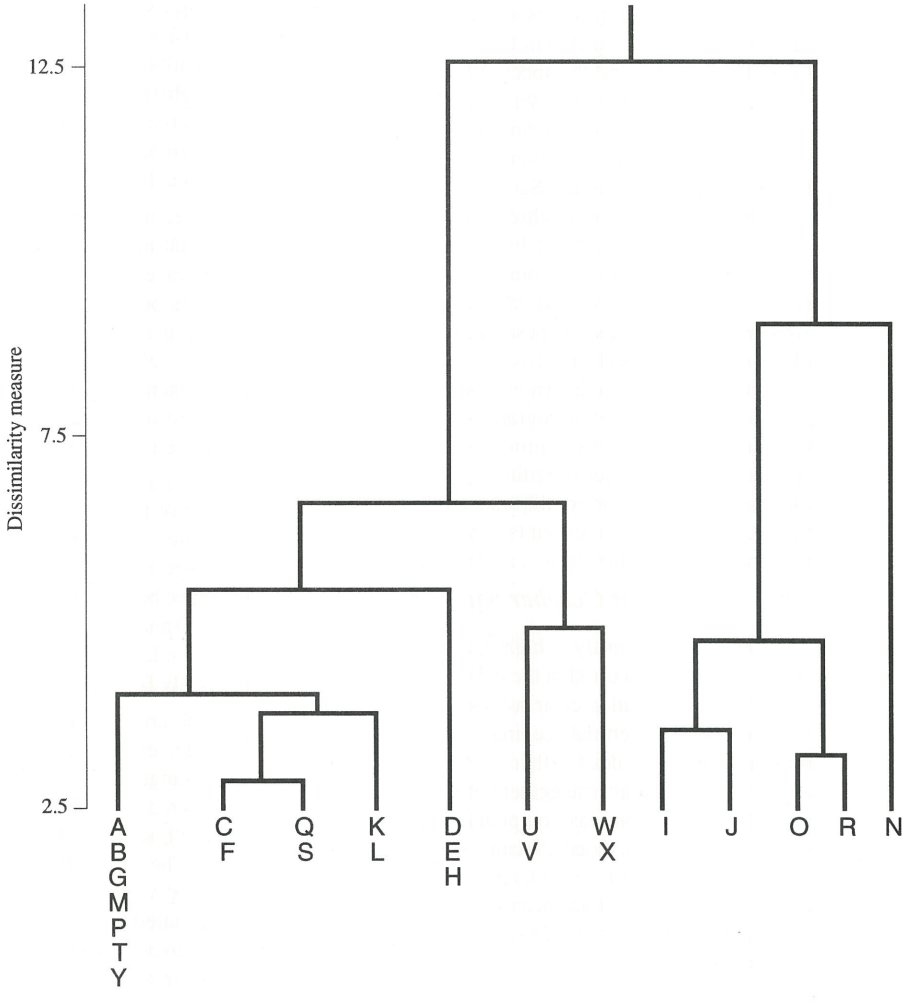
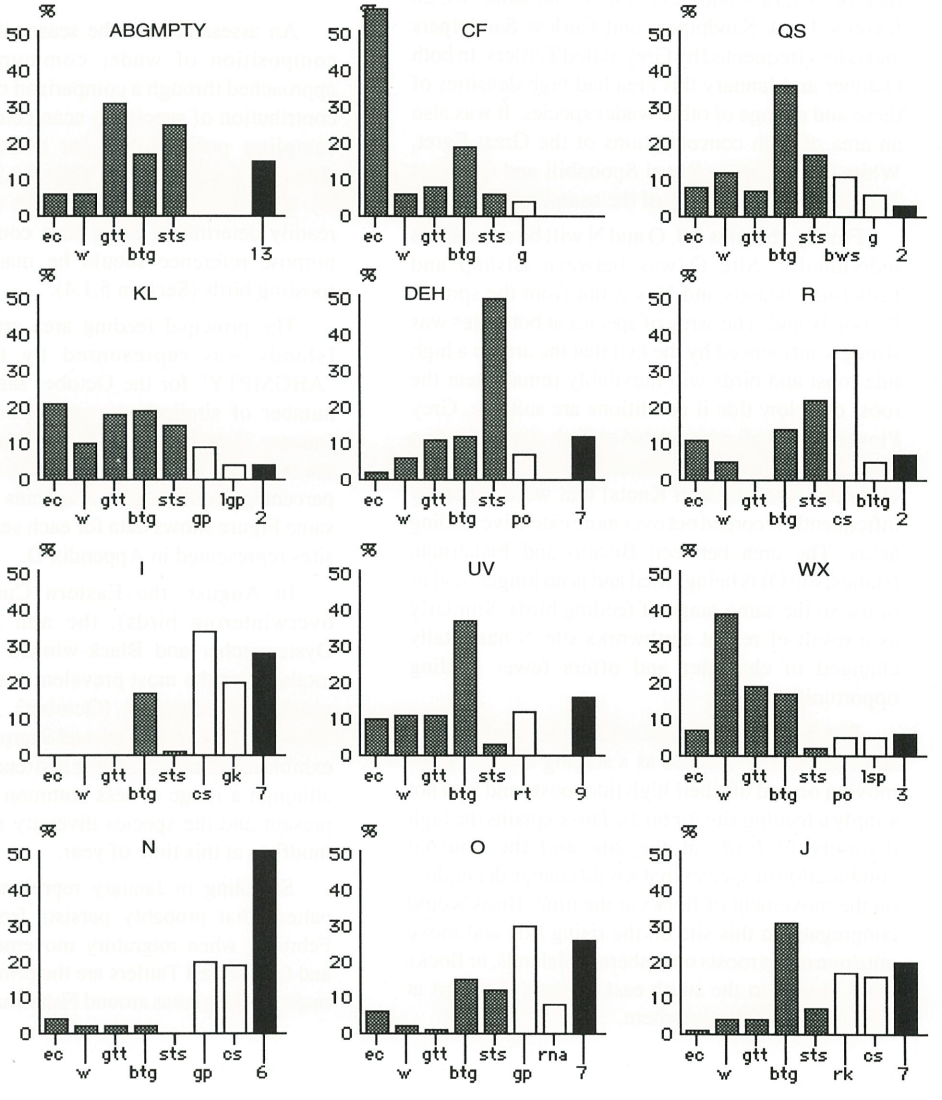


FIGURE 3

Graphical summary of the percentage contribution of species of wader to low tide scan counts for the 12 site groups defined in the classification of October counts (Figures 1 &2 , and Section 5.3.2.). The data are the same as in Table 5 except only the five species that were most common overall are plotted consistently for each group (grey columns) and include the Eastern Curlew (ec) Whimbrel (w), Grey-tailed Tattler (gtt), Bar-tailed Godwit (btg) and Sharp-tailed Sandpiper (sts). Values for a possible two additional species are plotted if their individual contributions exceeded 3% (white columns), whereas the percent contribution for all other species is combined into a single value (black column) and the number of species involved indicated at the base of the column. For the initials of other species refer to Table 5.



All of the remaining scan count sites for October have been clearly separated from sites already mentioned and could be considered to offer quite different conditions to those found in areas of seagrass around Fisherman Islands. Sites "UV" and "WX" are from St Helena Island and Green Island respectively and will be mentioned later in dealing with these islands. Site R is representative of feeding conditions at the back of the cove on the eastern side of Fisherman Islands. This area was difficult to sample which is why only one scan count was taken but a special effort was made in January to collect more data from here (Appendix B). The combination of species using this site is different from elsewhere around Fisherman Islands and this is most likely due to the lack of seagrass and very muddy substrate which favours Terek Sandpipers and Curlew Sandpipers and is less frequented by Grey-tailed Tattlers. In both October and January this area had high densities of these and a range of other wader species. It was also an area of high concentrations of the Great Egret, White-faced Heron, Royal Spoonbill and Chestnut Teal during one or more of the sampling periods.

Finally, the sites I, J, O and N will be considered individually. Site O was between Bishop and Fisherman Islands and N was out from the spit off Bishop Island. The array of species at both sites was strongly influenced by the fact that the area is a high tide roost and birds will inevitably remain near the roost over low tide if conditions are suitable. Grey Plover were well represented at both sites as were a number of other species (Sand Plovers, Black-tailed Godwits, Avocets, Red Knots) that were generally infrequently recorded out over more extensive feeding areas. The area between Bishop and Fisherman Islands(site O) is being filled and is no longer tidal or of use to the same range of feeding birds. Similarly as a result of recent earthworks site N has totally changed in character and offers fewer feeding opportunities.

Site J, on the south side of the Boat Passage, was atypical because it acted as a staging area for birds moving on and off their high tide roosts and was not simply a feeding site for birds. This explains the high diversity of birds at the site and the unusual combination of species that would change depending on the movement of flocks at the time. Birds would congregate on this site on the rising tide and move onto one of the roosts on Fisherman Islands, or flocks would travel to the south east towards the roost at Lytton or perhaps elsewhere.

Finally, Luggage Point was sampled on one occasion and this extensive feeding area was found to cater for a different mix of species than the major feeding areas around Fisherman Islands. In particular, the Great Knot, Red Knot, and Curlew Sandpiper were plentiful which differed from the generally high numbers of Sharp-tailed Sandpipers, Eastern Curlews and Grey-tailed Tattlers that characterise much of the intertidal area to the east and south east of Fisherman Islands. The birds using Luggage Point will be considered again in Section 6 when data collected by Thompson is compared with information from this study.

5.3.3 Seasonal changes in wader communities

An assessment of the seasonal changes in the composition of wader communities has been approached through a comparison of the percentage contribution of species to scan counts for the three sampling periods and for different zones, as determined in the last Section 5.3.2 (see Appendix D). Seasonal changes in absolute numbers are not readily determined using scan counts and for this purpose reference should be made to counts of roosting birds (Section 5.1.4).

The principal feeding area around Fisherman Islands was represented by the site group "ABGMPTY" for the October sampling and by a number of similarly placed sites for August and January. Data from scan counts at these selected sites are combined for each season and illustrated as the percentage contribution of species in Figure 4. The same Figure shows data for each season from all the sites represented in Appendix D.

In August, the Eastern Curlew (probably overwintering birds), the non migratory Pied Oystercatcher and Black-winged Stilt (combined totals) were the most prevalent waders. During the southward migration (October), the Grey-tailed Tattler, Bar-tailed Godwit and Sharp-tailed Sandpiper exhibit an influx of numbers and tend to predominate, although a range of less common species are also present and the species diversity is highest on the mudflats at this time of year.

Sampling in January represents a more stable pattern that probably persists from December to February when migratory movements have ceased and Grey-tailed Tattlers are the principal users of the major feeding areas around Fisherman Islands that are

characterised by seagrass. Nevertheless, four other species (Eastern Curlew, Whimbrel, Bar-tailed Godwit and Sharp-tailed Sandpiper) each contribute over 10% to the total number of birds on these feeding grounds in January. The Pied Oystercatcher and Lesser Golden Plover are also well represented. Eight more species were recorded on the "ABGMPTY" zone (see Appendix D, Figure 4). For all zones combined (summer), the pattern differs from the "ABGMPTY" zone in that the prevalence of Eastern Curlews in deeper water, and Bar-tailed Godwits on a wide range of substrates, tends to influence the relative proportion of species. A moderately high population of the Sharp-tailed Sandpiper persists through the summer, although their numbers are highest during the migration as they move through on their way farther south.

5.3.4 Counts of species other than waders

High densities of species other than waders (Families Charadriidae and Scolopacidae) occurred on the intertidal areas around Fisherman Islands. The raw counts of these species are given in Appendix A for each of the scan counts and reference will be made to the general mapping of observations of all species (Appendix E). The Australian Pelican was recorded in large groups on roost sites (tip of Fisherman and claypan site) and in smaller groups on the edge of the mudflats around Fisherman Islands. Similarly, other fish eating species, the Pied and Little Pied Cormorants were regularly recorded during scan counts loafing on intertidal mudflats or roosting at high tide on mangroves or artificial structures (Appendix E). The Silver Gull and four species of tern (Appendices A and E) were similarly seen on or around the mudflats, although with the exception of the Little Tern, were less often seen feeding. Flocks of the Little Tern fed as the tide rose around the Boat Passage and out over the main area of seagrass to the south east of Fisherman Islands and in the cove to the east of the Island.

White-faced Herons, Great Egrets, Little Egrets, Sacred Ibis and Royal Spoonbills were all common on the mudflats in densities I would judge to be equal to, or higher than in other parts of Moreton Bay. Royal Spoonbills were most prevalent in August at a time when inland freshwater feeding areas were perhaps relatively scarce. Similarly, Chestnut Teals were present in very high numbers at this time and both species had congregated around the edges of the cove on the eastern side of Fisherman Islands.

The White-faced Heron and Sacred Ibis were abundant during all three sampling periods although most common in August. They primarily fed amongst the intertidal seagrass but also used the mudflat closer to mangroves and fed beneath the mangroves. Like the Eastern Curlew, they could tolerate feeding in fairly deep water and were distributed not only to the east and south east of Fisherman Islands but down the mangrove lined foreshore of Whyte Island towards Wynnum. Their density was probably highest around the cove at Fisherman Islands and on the southern side of the Boat Passage.

There was a small colony of Great Egrets that was based on the southern side of the cove (eastern Fisherman Islands) and they were noted roosting back from the shoreline on the ground or in dead trees (Section 5.1.4.2) or feeding out in front of the mangroves and amongst the seagrass. Little Egrets are more solitary and were occasionally encountered on the mudflat during scan counts, mostly close to mangroves. Note the records of Collared Kingfishers that venture out to feed on the open mudflats (Appendix A). The density of this species was particularly high throughout tall mangroves in the area.

5.4 Additional intertidal areas

5.4.1 Mud Island

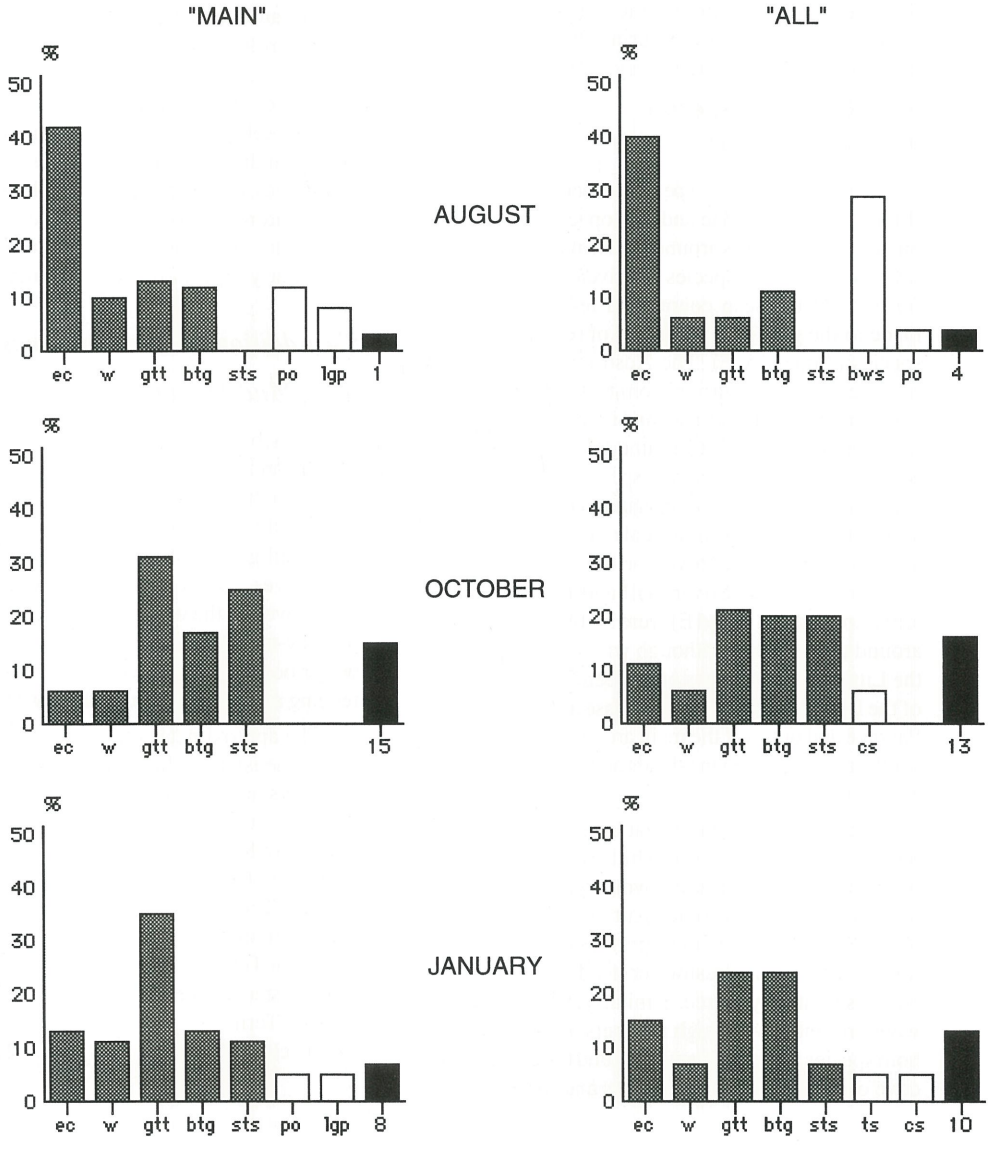
Birds, particularly cormorants, were noted around Mud Island at high tide, roosting on piles of coral debris on the south east, east and north of the island but mainly in the south east. Scattered individuals and small groups of cormorants were also noted in mangroves. On a sand bar extending out from mangroves on the western side of the island, a group of Grey-tailed Tattlers was noted. Other species of wader occurred on the piles of rubble. The low tide feeding areas around Mud Island were not assessed.

The approximate counts of birds on a round trip of the island at high tide in August were:

Australasian Gannet	1
Little Egret	3
Brahminy Kite	1
Little Pied Cormorant	62
Caspian Tern	60
Pied Cormorant	250
Common Tern	98
Pied Oystercatcher	18
Crested Tern	15
Red-necked Stint	210

FIGURE 4

A seasonal comparison of scan counts using a summary of the percentage contribution of species of wader to low tide scan counts for the "MAIN" feeding area (based on the "ABGMPTY" group of Figure 2) for each of the 3 sampling periods (see Section 5.3.3). For each of the same 3 sampling periods, values for "ALL" feeding areas around Fisherman Islands are also plotted. The data are the same as in Appendix D except only the five species that were most common overall are plotted (grey columns) consistently for each group and include the Eastern Curlew (ec), Whimbrel (w), Grey-tailed Tattler (gtt), Bar-tailed Godwit (btg) and Sharp-tailed Sandpiper (sts). Values for a possible two additional species are plotted if their individual contributions exceeded 3% (white columns), whereas the percent contribution for all other species is combined into a single value (black column) and the number of species involved indicated at the base of the column. For the initials of other species refer to Table 5.



Eastern Curlew	43
Ruddy Turnstone	60
Great Egret	2
Sacred Ibis	2
Grey-tailed Tattler	230
White-bellied Sea-Eagle	1
Little Black Cormorant	8
White-faced Heron	3

Similarly in October the approximate counts were:

Bar-tailed Godwit	300
Large Sand Plover	?
Crested Tern	?
Pied Cormorant	1500
Eastern Curlew	30
Ruddy Turnstone	?
Grey-tailed Tattler	?

5.4.2 St Helena and Green Islands

Low tide feeding areas around St Helena were briefly looked at in October and two scan counts taken at the southern end (sites U, V) where the substrate was fairly sandy with very little cover of seagrass. There is a strip of intertidal area all around the island and small high tide roosts occur at the northern end on the narrow beach and amongst the open lagoon under the radio masts. In the south west of the island birds were roosting in the vicinity of the beach that faces into the cove and in mangroves nearby. Some Eastern Curlews possibly roost behind mangroves on the south eastern side on the island.

High tide records for roosts at the northern end of St Helena are as follows (underlined entries are for October, plain are for August):

Black-winged Stilt	2
Osprey	1
Chestnut Teal	55
Pied Cormorant	10
Crested Tern	25
Pied Oystercatcher	46
Grey Plover	10
Pied Oystercatcher	70
Grey-tailed Tattler	3
Royal Spoonbill	4
Little Egret	3
Sacred Ibis	5
Masked Lapwing	3
Silver Gull	15
Masked Lapwing	4
White-faced Heron	2
Bar-tailed Godwit	50
Little Pied Cormorant	37

High tide records for roosts at the southern end of St Helena are as follows (underlined entries are for October, plain are for August):

Black-winged Stilt	8
Little tern	8
Great Egret	1
Mongolian Plover	30
Grey Plover	40
Pied Cormorant	15
Large Sand Plover	200
Pied Oystercatcher	24
Little Egret	2
Ruddy Turnstone	45

Ruddy Turnstones, Large Sand Plovers, Mongolian Plovers, Eastern Curlews and Bar-tailed Godwits were all counted at low tide as well as a range of other species. Scan counts from St Helena and Green Island were classified into a different group from those around Fisherman Islands (Figure 2) indicating a difference in the mix of species from the two areas (Table 5). There is movement on the falling tide of birds from St Helena to the northern and eastern sides of Green Island. The substrate around Green Island is relatively sandy with scattered patches of broken coral and small areas of muddy substrate. In addition to records from the scan counts the following species were noted during a brief inspection of the western side of Green Island on a falling tide: Chestnut Teal (4), White-faced Heron (4), Great Egret (?), Little Egret (3), Pied Oystercatcher (10), Bar-tailed Godwit (2), Eastern Curlew (9), Sacred Ibis (?).

5.4.3 Wynnum

Two visits were made to parts of the eastern foreshore of Whyte Island and south towards Wynnum. In August, on a rising tide birds roosting in mangroves were counted along this strip of foreshore with the following results:

Chestnut Teal	84
Royal Spoonbill	6
Great Egret	+
Sacred Ibis	6
Little Pied Cormorant	90
Striated Heron	+
Pied Cormorant	+
White-faced Heron	5

Furthermore, a scan count was taken on the mudflat out from the Lytton roost past the mangroves (site S) and another looking out from

Wynnum (site T). The actual counts are given in Appendix A and in the classification analysis site T was grouped with the main grouping of sites around Fisherman Islands (ABGMPTY) whereas site S together with Q were considered anomalous (Section 5.3.2).

5.4.4 S-W Fisherman Islands and western side of the River

Formal scan counts were not made in the muddy cove within the block of mangroves in the south west of Fisherman Islands. However, feeding activity was quite intense at times in this cove with as many as 23 Sacred Ibis, 6 Black-winged Stilt, 5 Black-tailed Godwit, 20 Bar-tailed Godwit, 30 Red Knot, 50 Great Knot being recorded there on one occasion in October.

On the other side of the mangroves (Pelican Banks) some small gatherings of birds were noted including one large flock of Black-winged Stilts (see Appendix E). The mangroves themselves were not visited but birds were seen in the area from a distance and included flocks of roosting Sacred Ibis.

Feeding of waders on the western side of the Brisbane River was moderately intense around the foreshores of the entrance cove to Boggy Creek. At times reasonably large flocks in excess of 30 birds were seen moving around and included Sharp-tailed Sandpipers, Bar-tailed Godwits and Black-winged Stilts. A number of other species were noted in the area (see Appendix E) and Pied and Little Pied Cormorants were recorded loafing on the rock walls to the east of Bulwer Island.

6. GENERAL FEATURES OF THE WADER COMMUNITY

6.1 Movements

Fisherman Islands and the surrounding intertidal flats, are an integral and important part of a complex mosaic of bird habitat that includes areas around Luggage Point, Whyte Island, Lytton, Wynnum, and the western foreshore of the Brisbane River. It is possible that birds using Mud, St Helena and Green Islands also cross between here and Fisherman Islands but no movements were noted despite some careful observations. Movement between Mud, St Helena and Green Islands was apparent, especially between the latter two islands.

Perhaps the most significant regular movement to and from Fisherman Islands is of birds that feed around Luggage Point and roost on the northern end of Fisherman Islands. Flocks of Bar-tailed Godwits, Black-tailed Godwits and Great Knot can be regularly seen moving between these sites before and after high tide. Even though there is roosting behind the mangroves at Luggage Point, the favoured roost site for several species is Fisherman Islands.

Birds feeding to the south of the Boat Passage also seek out high tide roosts on Fisherman Islands. Flocks of Bar-tailed Godwit, Great Knot and Curlew Sandpiper were noted moving from the staging site on the south side of the Passage (site J) to Fisherman Islands (either the claypan or shoreline roost to the north). Birds from the same staging site were seen flying south to either the Lytton roost or beyond. That is, only a proportion of the birds that feed on the northern and eastern sides of Whyte Island, roost on Fisherman Islands. The Lytton roost appears to cater for birds that come in from the Wynnum foreshore as well as around Whyte Island. The Lytton roost is at times unsuitable for roosting either because of too little or too much water when, only the birds with longest legs (Godwits and Eastern Curlew) remain at the site. The only alternative at such times may be Fisherman Islands but more observations are needed around Lytton to clarify what movements are occurring.

Birds feeding around Fisherman Islands tend to roost on the Islands. Very little movement was seen away from these feeding areas to more distant roost sites. The most direct movement on and off feeding grounds was noted for Eastern Curlews which come straight off the claypan roost (south-west Fisherman Islands) across the mangroves into the "cove" as the tide falls. Similarly, Royal Spoonbills, Sacred Ibis and Egrets were making a similar short journey from roosts at the back of the cove.

6.2 Feeding densities

There is no attempt here to give absolute numbers to birds other than waders. A number of waterbirds were locally very abundant and reference should be made to Section 5.3.4. It is difficult to gauge how many of the waders roosting on Fisherman Islands are using the neighbouring feeding areas, rather than those at Luggage Point or Whyte Island. However, of all the species of wader observed, the Eastern Curlew is probably more often feeding and roosting in the vicinity of Fisherman Islands.

For scan counts taken out from Fisherman Islands in October (sites ABCDEFGHMPQRY, Figure 1) 119 Eastern Curlew were counted and this is undoubtedly an underestimate of the numbers feeding through the intertidal area to the east and south east of Fisherman Islands mainly because the deep water seagrass zone (CF) was not sampled fully and many Eastern Curlew were feeding there. At the time, there were over 200 birds on the claypan roosts (Section 5.1.4.1), therefore, 160 birds is chosen as a conservative estimate of the number of Eastern Curlew feeding around Fisherman Islands at the time.

For the combined scan counts from the same sites, Eastern Curlews represented 10% of feeding waders. Therefore, the total number of waders is estimated as 10 x 160, or 1,600 birds on the intertidal area to the east and south east of Fisherman Islands. Of this total the following species collectively represented about 13% or just over 200 birds: Pied Oystercatcher, Grey Plover, Lesser Golden Plover, Mongolian Plover, Large Sand Plover, Red-capped Plover, Black-winged Stilt, Ruddy Turnstone, Greenshank, Terek Sandpiper, Black-tailed Godwit, Red Knot, Great Knot, Red-necked Stint. Individually, these species were represented by up to 3% of the total, or about 50 birds. The more common species were: Eastern Curlew (160), Whimbrel (96), Grey-tailed Tattler (304), Bar-tailed Godwit (256), Sharp-tailed Sandpiper (496) and Curlew Sandpiper (80).

The numbers of birds are conservative estimates and pronounced seasonal changes in numbers occur (refer to Section 5.3.3). As noted above, the roost sites on Fisherman Islands are catering for greater numbers of birds that come in from other feeding areas. Furthermore, there is considerable spatial variation in the type of feeding area around Fisherman Islands.

6.3 Habitats

Three distinctly different zones are apparent and each caters for a different mix of species (see Section 5.3.2). The zones include an area towards the back of the large cove to the east of Fisherman Islands which is particularly muddy and lacks seagrass. On either side of this zone and extending right out beyond the south eastern corner of Fisherman Islands is the most widespread type of feeding area around Fisherman Islands which is mostly exposed at low tide and includes a mix of seagrass with smaller patches of sandier substrate. Finally, fringing this zone to the east and north are seagrass beds that are less often exposed at low tide but are nevertheless fed upon by larger species including Eastern Curlews.

The mangroves of Fisherman Islands are still quite extensive and not only offer protection for birds roosting behind them on claypans, but cater for a diverse forest bird fauna and act as roosts for a range of waders, waterbirds and seabirds.

The roost sites, the claypan where many birds feed, and to a lesser extent, the thickly grassed areas on Fisherman Islands, all represent significant resources that help to sustain a wide range of species and for some, a locally abundant population.

6.4 Significance of the area

The study area is of local and even regional significance to birdlife. In the most recent proposals for a Moreton Bay Strategy Plan (Qld Govt, 1991), the eastern part of Fisherman Islands and neighbouring seagrass areas are included in a "Habitat Protection" zone which is acknowledgement that the area has biological significance. This is explained in terms of seagrass beds and mangroves but no specific reference is made to the birdlife. The "Habitat Protection" zoning would not necessitate complete protection but rather suitable controls over recreational, commercial and extractive uses to prevent further habitat losses. Directly alongside this area and over the remainder of Fisherman Islands the primary activity is designated as "Port and Industrial".

The proximity of the proposed "Habitat Protection" and "Port and Industrial" zoning on Fisherman Islands raises special management issues. There is either direct overlap or little buffering between areas that are intensively used by birdlife and areas that are planned for Port facilities. There are many other management issues in relation to the study area but reconciling the current use of the Islands by birds with future developments is especially critical.

Appendix F gives a summary of work undertaken by Thompson and Kikkawa for the Dept of Heritage and Environment over the last few years documenting details of the use of Moreton Bay foreshores by waders. Their assessment of mainland roost sites led to speculation that the loss of roosting habitat through foreshore development has created fragmentation of what were once much larger roosts into smaller, scattered collections of birds that are more susceptible to disturbance (Thompson and Kikkawa 1988). It is likely that this progressive loss of amenity for roosting by birds has caused a decrease in the use of feeding grounds.

The bird roosts on Fisherman Islands cater for significant numbers of birds, as many as any site on the mainland foreshore of Moreton Bay. Thompson and Kikkawa (1988) list Deception Bay, Hay's Inlet, Nudgee, Luggage Point, Thornside, Oyster Point and Lytton as roosting areas for waders. At the time, they had no knowledge of the Fisherman Islands roost sites but my experience of these other areas is that they mostly cater for fewer birds than Fisherman Islands.

The species of wader that are common on the feeding grounds around Fisherman Islands are not necessarily common in other parts of Moreton Bay. Thompson and Kikkawa (1989) note that areas of very muddy substrates along the mainland shore are preferred by species that are much less common in central Moreton Bay. Species such as the Terek Sandpiper, Marsh Sandpiper, Sharp-tailed Sandpiper, Black-tailed Godwit, Black-winged Stilt and Lesser Golden Plover are absent or rarely seen in the North Stradbroke and Moreton Island feeding areas. The same species occurred regularly around Fisherman Islands. In particular, Marsh Sandpipers and Black-tailed Godwits are generally uncommon in Moreton Bay but were regularly recorded on or around Fisherman Islands. Furthermore, the high density of the Sharp-tailed Sandpiper at Fisherman Islands is unmatched elsewhere in the Bay. It was regularly recorded as one of the five most abundant species in scan counts yet in a survey of 13 sites throughout the mainland shore of Moreton Bay by a team of people over one weekend (Thompson 1990) only 121 Sharp-tailed Sandpipers were counted out of 16,895 birds. The Fisherman Islands area was not included in the count. The species does occur at Luggage Point in patches at reasonable density but Fisherman Islands appears to represent a major concentration of this particular migratory species.

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APPENDIX V

FISHERIES ADJACENT TO FISHERMAN ISLANDS

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EXECUTIVE SUMMARY

The Port of Brisbane Authority (PBA) has developed Whyte and Fisherman Islands as a major port facility at the mouth of the Brisbane River. Further expansion of port related facilities on the southern side of the mouth of the Brisbane River (north east of Fisherman Islands) is proposed by the PBA which may require disturbance of intertidal and subtidal lands on and near Fisherman Islands.

The PBA has commissioned WBM Oceanics to undertake the present study which provides information on commercial fishing operations and the fisheries importance of aquatic habitats present in the Fisherman Islands region. Elements of this report are to be incorporated into a port management and development strategy.

This report has been prepared taking into account information supplied by the Queensland Fish Management Authority (QFMA), Queensland Department of Primary Industries (QDPI; Fisheries Branch), Queensland Commercial Fishermen's Organisation (QCFO) and several commercial fishermen who regularly operate adjacent to Fisherman Islands.

Some of the information supplied by commercial fishermen is commercial in confidence and therefore has not been included in this publication.

Three main types of commercial fishing operations (excluding baitworm digging) occur in the study area; beam trawling, mesh (gill) netting and tunnel netting. Commercial baitworm collecting, undertaken on intertidal flats adjacent to Fisherman Islands on a substantial basis, is addressed in a separate report (WBM Oceanics 1991b). Each fishery is subject to regulations prescribing permitted fishing areas and techniques.

Net Fishing

Net fishing is the main fishery which occurs adjacent to Fisherman Islands and involves both tunnel netting (predominantly) and mesh netting. The study area is reported by commercial fishermen to be regularly fished by seven netting crews, each of which generally consist of one to four fishermen. When fish catches are large, or weather conditions are unsuitable in other areas of Moreton Bay, up to 14 crews may operate in the study area.

Virtually all of the study region is fished at some time by net fishermen. Fishing operations are conducted all year although fishing mainly occurs in the period November-August. The dominant species, whiting, butterfish, flathead, mullet and bream are taken year round with differing seasonal peak landing periods. Areas within mangrove forests are rarely fished and most fishing takes place on seagrass covered intertidal flats or areas fringing mangrove forests.

Areas to the north of Boat Passage are fished more frequently than areas towards Wynnum. The northern area, between the Boat Passage and Brisbane River shipping channel, produces significant mullet and flathead catches for most of the year. As a result, these two types of fish form the bulk of annual landings. Prime fishing locations occur along a ridge that runs eastward from northern Fisherman Islands towards St Helena Island and areas fringing the Boat Passage.

The intertidal flats and mangrove forests south of the Boat Passage are netted primarily for mullet, bream, flathead and butterfish. The relative importance of fish species differs from areas north of the Boat Passage in that less mullet and far more butterfish are taken. Areas adjacent to Crab Creek are reported by fishermen to be some of the most productive butterfish netting grounds in Moreton Bay and most netting south of the Boat Passage targets this species.

The areas fringing Fisherman Islands are of importance to Moreton Bay fisheries. No net catch statistics specific to the Fisherman Islands region are held by government agencies (QDPI, QFMA) or the QCFO.

It is difficult to estimate total landings for the study area given the varying interannual frequency of fishing effort, catch composition, total landings and market factors. Nevertheless, on the basis of information supplied by fishermen, it can be assumed that most fish are mullet, flathead, whiting, butterfish and tailor.

Net fishermen report that existing reclamation and other port related activities have adversely influenced their catches only to a minor degree. Some short-term (< 3 years) decreases in catches reportedly occurred as a result of silt laden water flowing eastwards onto the intertidal flats from bunded areas on Fisherman Islands approximately five years

ago. With the exception of works on the northern tip of Fisherman Islands (which fishermen claim significantly affected bream, mullet and jewfish catches in that area), no regularly used fishing grounds have been disturbed and no major long term adverse effects from port operations are reported. No data are available to quantify the adverse effects described by fishermen.

Crab Fishing

Net fishermen indicate that no commercial mud crabbers use the Fisherman Islands region on a regular basis although mud crabs (*Scylla serrata*) are taken as by-catch in netting operations. Sand crabs (*Portunus pelagicus*) are frequently taken by commercial fishermen. Net fishermen catch the crabs as by-catch in mesh/tunnel nets and occasionally set traps when crab abundance is high. One commercial sand crabber reportedly frequently fishes this area.

Beam Trawl

Beam trawl operations cannot legally occur on the intertidal flats south of the Brisbane River shipping entrance channel and are restricted to a small portion of the study area (the Brisbane River and northern fringes of the shipping channel).

Commercial fishermen advise that approximately 30 beam trawlers involving 40 fishermen (some fishermen have an assistant) work in the study area at least 50% of their fishing time. Of these, 17 beam trawlers are reported to be moored within and work exclusively in the Brisbane River, particularly the river mouth. The remaining 13 beam trawlers are moored elsewhere but rely heavily on the lower Brisbane River as a fishing ground.

The Brisbane River Greasyback prawn fishery is one of the major suppliers of bait prawns in Australia. The lower reaches of the river, including those within the study area are the most productive. Larger Greasyback prawns are sold for human consumption, although the majority of the catch is for bait. Baitprawns are sold throughout Queensland and exported mainly to N.S.W. and Western Australia. Banana prawns, taken in winter, are commonly large and are sold to the restaurant trade.

The abundance of prawns, and hence fishing operations, in various locations varies depending upon tidal state, water clarity/salinity, river flow and time of the year. In general, fishermen advise that the prime fishing grounds within the lower Brisbane River occur along the edges of the entrance channel to the Brisbane River, along the old bar cutting, and within the mouth of the Brisbane River (ie. within the study area).

Prawn species taken in the study area include Greasyback, King, Tiger and Banana prawns. Greasyback prawns form the bulk of catches and are taken mainly from November to May. King and Tiger prawns are taken in winter in some years, although considerable interannual variation occurs.

As for the net fisheries, no catch data specific to the Fisherman Islands region are held by Government authorities or the QCFO.

Beam trawlers report only minor concerns with PBA operations, generally in association with maintenance dredging. Maintenance dredging operations which leave the bottom in an uneven condition, render dredged areas unsuitable for beam trawling until natural processes level the seabed. The PBA bed levelling operations reduce this problem although fishermen believe levelling to a greater degree would significantly improve their catches. Maintenance dredging also creates turbidity plumes. Although not adversely affecting catches, the plumes are reported by fishermen to affect prawn distribution hence altering fishing areas but apparently not adversely affecting landings to a substantial degree.

Recreational Fishing

Most recreational fishermen do not use the extensive intertidal flats adjacent to Fisherman Islands for angling or crabbing for fear of their boats stranding/grounding. Shore based activities are limited to Wynnum and the verges of the Port of Brisbane Road at the Boat Passage as a result of the thick mangrove fringe and restricted road access.

The intertidal flats are mainly used by recreational fishermen seeking bait. Baitworm digging generally occurs near Wynnum and flats between the D'arcy light and Fisherman Island where access is easier. As noted previously, a separate report has been completed on baitworm collecting (WBM Oceanics 1991b).

Angling within the study area occurs mainly on the fringes of the main shipping channel, and areas within and adjacent to Boat Passage. Whiting fishermen consider the area south of the shipping channel (ie. east of Bishop Island) to be a prime fishing ground in spring months. Tailor, mackerel and other pelagic fish are also taken on a seasonal basis in the same area. Sand crabs are taken in reportedly large numbers from the area north east of Bishop Island (along the shipping channel).

The level of recreational fishing in Moreton Bay is increasing rapidly and is anticipated to double in the next decade. This will result in greater utilisation of areas near Fisherman Islands for angling and bait collecting.

FISHERIES IMPORTANCE OF WETLAND HABITATS ADJACENT TO FISHERMAN ISLANDS

The wetland areas adjacent to Fisherman Islands contain mangrove forests, seagrass beds and saltmarshes. Contrary to a generally held public perception, these habitats are not used as spawning grounds by species of fisheries value but provide valuable nursery and feeding habitat.

Mangroves produce large amounts of particulate organic material (detritus) derived from the decomposition of mangrove forest litter (ie. leaves, twigs, flowers) which forms the basis of most estuarine food chains. Mangroves provide food and shelter for juvenile fish and are important feeding grounds for many species of fisheries value.

One study of fish utilisation of mangrove areas in Moreton Bay (Morton 1990) concluded that the value of marketable fish within mangrove areas was $\$8380\ ha^{-1}$. This value only accounted for marketable species and did not include prawns or commercially important juvenile fish.

Seagrasses, which occur on intertidal and subtidal mudflats in the study area (see CSIRO seagrass report prepared for PBA), are important feeding areas for a variety of organisms. Turtles, dugong and some fishes (eg. garfish) feed directly on seagrasses whilst most other animals feed upon epiphytes, detritus, microfauna and the benthos associated with seagrass areas.

Research by the Queensland Department of Primary Industries on seagrass beds adjacent to Fisherman Islands indicate that seagrass beds are of substantial importance for fish and prawns. Post-larval and juvenile Greasyback, Tiger and King prawns are abundant in seagrass beds which serve as nursery areas. Larval Tiger prawns are unlikely to survive if they do not settle in seagrass areas. Many commercial fish species (eg. flathead, whiting) use seagrass beds as nursery areas. Seagrass beds also provide habitat for worms which form the basis of a major baitworm fishery in the study area.

OVERVIEW

The study region encompasses some of the more productive netting grounds in Moreton Bay and supplies a significant proportion of the mullet, flathead and butterfish market. Beam trawl operations at the mouth of the Brisbane River supply a major bait-prawn market. Bait prawns are both used locally and exported throughout Australia.

Additionally, areas fringing Fisherman and Whyte Islands contain large areas of mangroves and seagrasses. In common with other wetlands in Moreton Bay, these areas provide valuable nursery and feeding habitat for fish and prawn species of direct fisheries importance which are taken throughout Moreton Bay. The wetlands are of considerable regional significance as described in the Wetlands Report (WBM-Oceanics 1991a)1.0.

1.0 INTRODUCTION

The PBA has developed Whyte and Fisherman Islands as a major port facility at the mouth of the Brisbane River. The PBA has identified a long term need to expand the capacity of the Port to accommodate a future increase in Port traffic. Further expansion of Port related facilities on the southern side of the mouth of the Brisbane River (north east of Fisherman Islands) is proposed by the PBA. This may require disturbance of intertidal and subtidal lands on and near Fisherman Islands.

The draft Moreton Bay Strategic Plan, designed to ensure appropriate land use within Moreton Bay,confirms the future usage of lands adjacent to Fisherman Islands for port related activities (see Figure 1.1).

The present studies were to provide the PBA with information on commercial fishing operations and the fisheries importance of aquatic habitats present in the Fisherman Islands region for incorporation into a port management and development strategy.

Other separate studies have been completed (in conjunction with this report) which describe the wetlands and commercial bait worm digging operations (WBM Oceanics 1991 a,b) associated with the Fisherman Islands region.

2.0 SOURCES OF INFORMATION AND TERMINOLOGY

This report has been prepared on the basis of information supplied from a variety of sources.

The Queensland Department of Primary Industries (Fisheries Branch) provided information on fishing techniques. The Department maintains a logbook system where fishermen are required to complete daily records detailing catches and areas fished. The grid system used to identify areas fished divides Moreton Bay into two grid elements. It is impossible to identify catch locations within a grid and therefore no data is available that relates specifically to the Fisherman Islands area. As a result, the catch information presented in this report is based upon interviews and records held by fishermen.

The Queensland Commercial Fishermen's Organisation (QCFO) was requested to supply a statement on the importance of the Fishermans Island area. The QCFO provided a list of fishermen to contact who operate in the area however no written response has been received from the organisation to date.

The Queensland Fish Management Authority provided information on legislative aspects of the fishery (eg. number of licensed fishermen, closures etc.) and finfish landings in Moreton Bay.

Several commercial fishermen who regularly operate in the area were interviewed and provided information on fishery attributes. Mr J. Page (net fisherman), Mr G. Murphy and Mr M. Fennesy (beam trawl operators) were particularly helpful. Some of the information provided would be useful to other fishermen and the confidential nature of the information should be considered when referring to the findings of this report given the competitive nature of fishing operations.

The study region (study area) is shown on Figure 2.1. Emphasis was placed on those areas adjacent to Fisherman Islands and fishing activities on Mud Island and St Helena foreshores are not included in this report.

3.0 FISHERIES REGULATIONS

Commercial fishing operations are legislated under the Fisheries Act 1976-1984 and are administered by the Queensland Fish Management Authority. The Act prescribes gear types and permitted fishing grounds for various fishing techniques.

Three main types of commercial fishing operations (excluding baitworm digging) occur in the study area; tunnel netting, mesh (gill) netting and beam trawling. Regulations relevant to these operations are described below.

All commercial fishing operations are prohibited in Moreton Bay during weekends to minimise conflict with recreational fishermen.

It should be recognised that fisheries regulations (eg. closure boundaries) often change and that the regulations described in this report may need to be re-examined in the future.

Beam Trawling

Beam trawling is permitted within the Main and West (or Old Bar Cutting) Channels leading into the Brisbane River, and an area upstream of Juno Point bounded by the second green beacon in the West Channel, the western Coffee Pot beacon, the western Inner Bar beacon and the northern end of Bishop Island (see Figure 3.1). Operations may extend upstream (approx. 28 km) to the Victoria Bridge.

Beam trawls may not be towed by a vessel exceeding 9 m in length, have a net longer than 5 m, or a net mesh less than 25 mm.

Beam trawlers may extend their operations further offshore than the Coffee Pots (see Figure 3.1) although other trawl net regulations apply and fishermen must fit different mesh size nets. In other trawl areas, nets may not have a mesh smaller than 38 mm.

Regulations regarding permitted beam trawl operations near the Port of Brisbane are presently being reviewed by the QFMA and it is probable that beam trawling within major navigation channels will be restricted in the future.

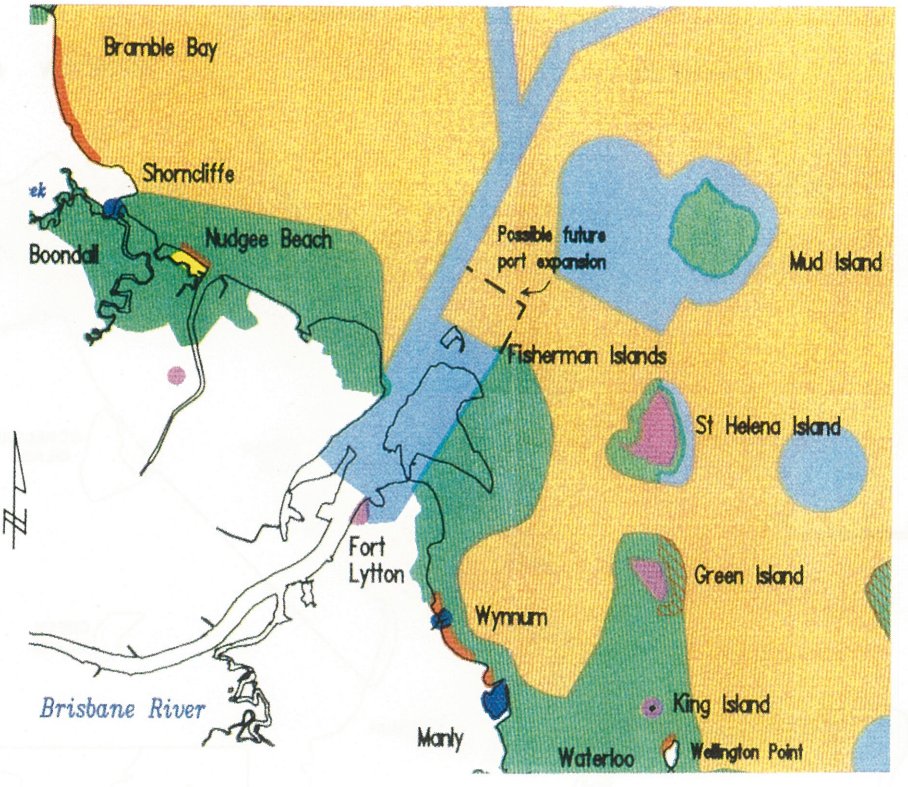
Mesh nets

Mesh netting is permitted on all foreshores within the study area.

Mesh nets cannot be longer than 800 m or have a mesh size less than 50 mm. A licensed fisherman must be at the net the whole time that it is in the water.

FIGURE 1.1

Extract from Draft Moreton Bay Strategic Plan



Preservation — to ensure outstanding biological communities are preserved.

Habitat protection — identifies important biological habitats.

General use — allows a wide range of uses with minimal environmental impact.

Port and industrial — for Port of Brisbane operations and other water-based industrial activities.

Marinas and harbours — for recreational boating, commercial water transport and associated onshore facilities.

Island residential — for low density, low impact residential and ancillary development.

Foreshore recreation — for public access and enjoyment of the the foreshore and adjacent waters.

Special management — where specific issues, uses or activities can be examined and controls applied.

0 2 4 6 8 10 Km

FIGURE 2.1

Study Area

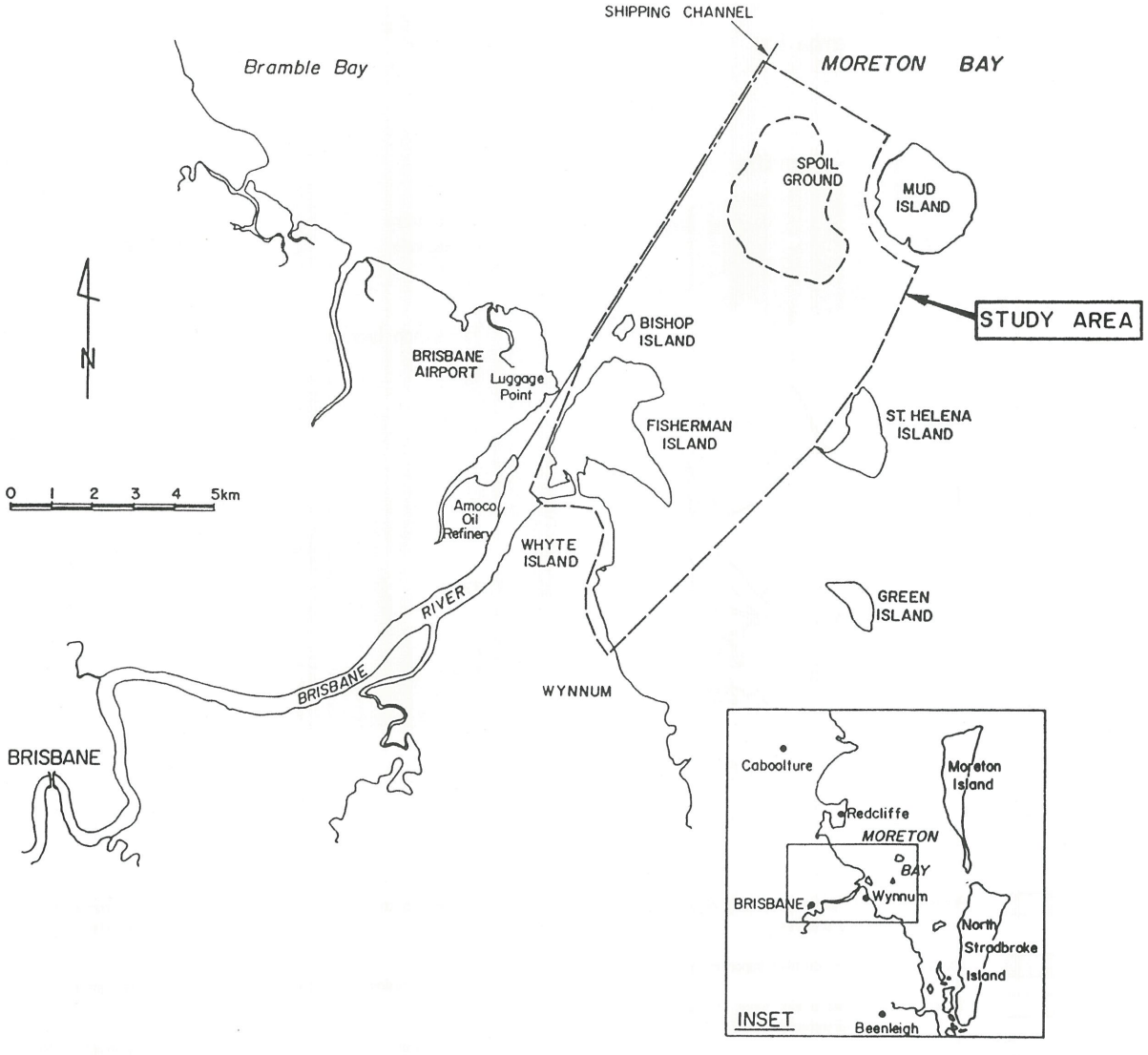
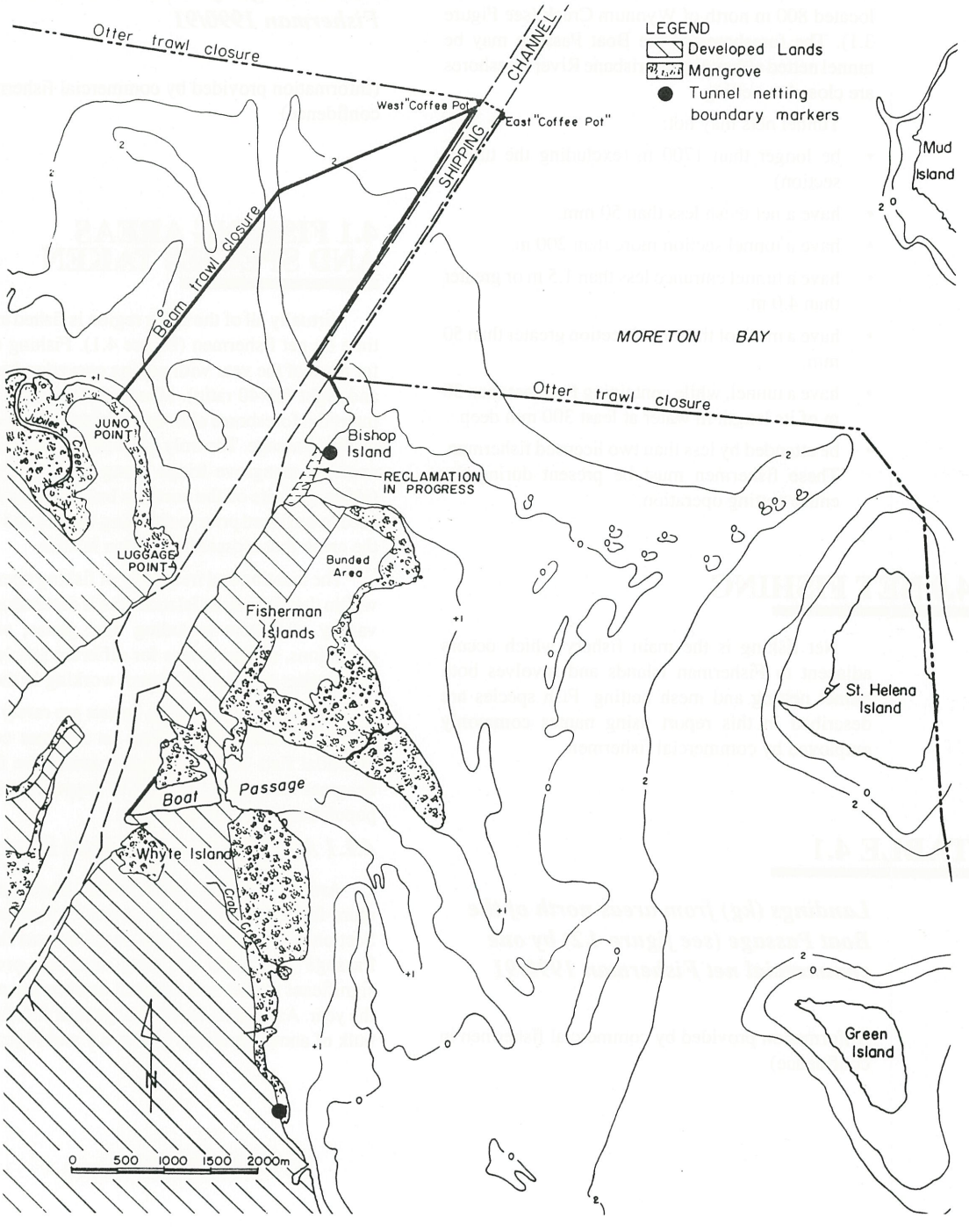


FIGURE 3.1

Closure Lines/Markers for Commercial Fishing



Tunnel netting

Tunnel netting may occur on foreshores between a marker (a board marked F-B) located on the southernmost end of Bishop Island and a marker located 800 m north of Wynnum Creek (see Figure 3.1). The foreshores of the Boat Passage may be tunnel netted although the Brisbane River foreshores are closed to netting.

Tunnel nets may not:

- be longer than 1700 m (excluding the tunnel section).
- have a net mesh less than 50 mm.
- have a tunnel section more than 200 m.
- have a tunnel entrance less than 1.5 m or greater than 4.0 m.
- have a mesh of the tunnel section greater than 50 mm.
- have a tunnel, while containing fish, less than 30 m of its length in water at least 300 mm deep.
- be attended by less than two licensed fisherman. These fishermen must be present during the entire netting operation.

4.0 NET FISHING

Net fishing is the main fishery which occurs adjacent to Fisherman Islands and involves both tunnel netting and mesh netting. Fish species are described in this report using names commonly employed by commercial fishermen.

TABLE 4.1

Landings (kg) from areas north of the Boat Passage (see figure 4.2) by one commercial net Fisherman 1990/91

(Information provided by commercial fishermen in confidence)

TABLE 4.2

Landings (kg) from areas south of the Boat Passage by one commercial net Fisherman 1990/91

(Information provided by commercial fishermen in confidence)

4.1 FISHING AREAS AND SPECIES TAKEN

Virtually all of the study region is fished at some time by net fishermen (Figure 4.1). Fishing occurs for most of the year with netting occurring both day and night (60:40 ratio). Most netting occurs on the intertidal foreshores although limited netting occurs in Boat Passage. The only areas rarely fished are the northern mangrove fringe along the Boat Passage (although a site on the northern bank near the bridge used to be fished prior to dredging works) and within the creek that crosses Fisherman Islands.

The location and frequency of fishing operations within the Fisherman Islands area is determined by a variety of factors including tidal phase, weather conditions, market prices for different species, and the number of other fishermen working in the area.

Areas within mangrove forests are rarely fished and most fishing takes place on seagrass covered intertidal flats or areas fringing mangrove forests. Seagrass flats are considered to support the largest populations of marketable fish.

4.1.1 Areas North of the Boat Passage

Areas to the north of the Boat Passage are fished more frequently than areas towards Wynnum (see Section 4.3.2). The northern area, between the Boat Passage and main shipping channel, produces significant mullet and flathead catches for most of the year. As a result, these two types of fish form the bulk of annual landings (Table 4.1 and Figure 4.2).

Commercial fishermen advise that whiting are mainly taken in spring whilst tailor are most common in autumn catches. Bream, butterfish, and black bream are rarely targeted but are taken frequently, generally as by-catch. Shark nets are occasionally set although catches are comparatively small.

Most fish reportedly travel on flooding tides into the fishing grounds from the northeast. A shallow sand ridge (with deeper water either side) extends eastwards from northern Fisherman Islands (see Figure 4.1). Fishermen report that fish move along this spit with the tide either feeding on benthos associated with the ridge or preying on bait fish that congregate along the sides of the ridge. In this regard, fishermen consider that the ridge attracts fish and makes it one of the better fishing locations (especially for tailor and whiting) near Fisherman Islands. They report that alterations to the ridge could affect their catches, not only from the ridge, but also in other areas, as fish supposedly use the spit as a "run" to move into intertidal areas near the mangroves on Fisherman Islands. Fishermen are concerned that modifications to the ridge could affect fish prey abundance and/or current directions, possibly adversely affecting the distribution of commercially targeted fish (eg. reduced fish utilisation of the Fisherman Islands area or fish congregating in areas unsuitable for netting).

A second ridge extends from the south-east corner of Fisherman Islands to D'Arcy Light (Figure 4.1) and is also an important fishing area. Mullet dominate catches although flathead and bream form a significant component of landings (Figure 4.2). Fishermen report that mullet move from the Brisbane River via the Boat Passage to congregate along the ridge. Fish distribution is commonly influenced by current strength and direction and fishermen believe that any alterations to current flows/directions that exist in the Boat Passage could alter mullet movement patterns and affect their catches. Such detrimental effects have reportedly occurred previously (see Section 4.6). Little information is available on the relationship between current flows and estuarine fish movements and thus quantifying the effects of man-induced current alterations is difficult.

4.1.2 Areas South of the Boat Passage

The intertidal flats and mangrove forests south of the Boat Passage are netted primarily for mullet, bream, flathead and butterfish. The relative importance of fish species (Table 4.3) differs from areas north of the Boat Passage in that less mullet and far more butterfish are taken (compare Figures 4.2 and 4.3).

Areas adjacent to Crab Creek support extensive areas of macroalgae (mainly *Ulva sp.*) which provide food for large populations of butterfish. The discharge of treated sewage into Crab Creek presumably results in elevated nutrient levels in waters and sediments near the creek providing conditions conducive to rapid algae growth. These areas are reported by Mr Page to be productive butterfish netting grounds, and most netting south of the Boat Passage targets this species.

4.2 CATCH VALUE AND REGIONAL CONTRIBUTION

(Information provided by commercial fishermen in confidence)

FIGURE 4.2

Summary catch data from one Commercial Netting Operation

(Information provided by commercial fishermen in confidence)

FIGURE 4.3

Summary catch data from one Commercial Netting Operation

(Information provided by commercial fishermen in confidence)

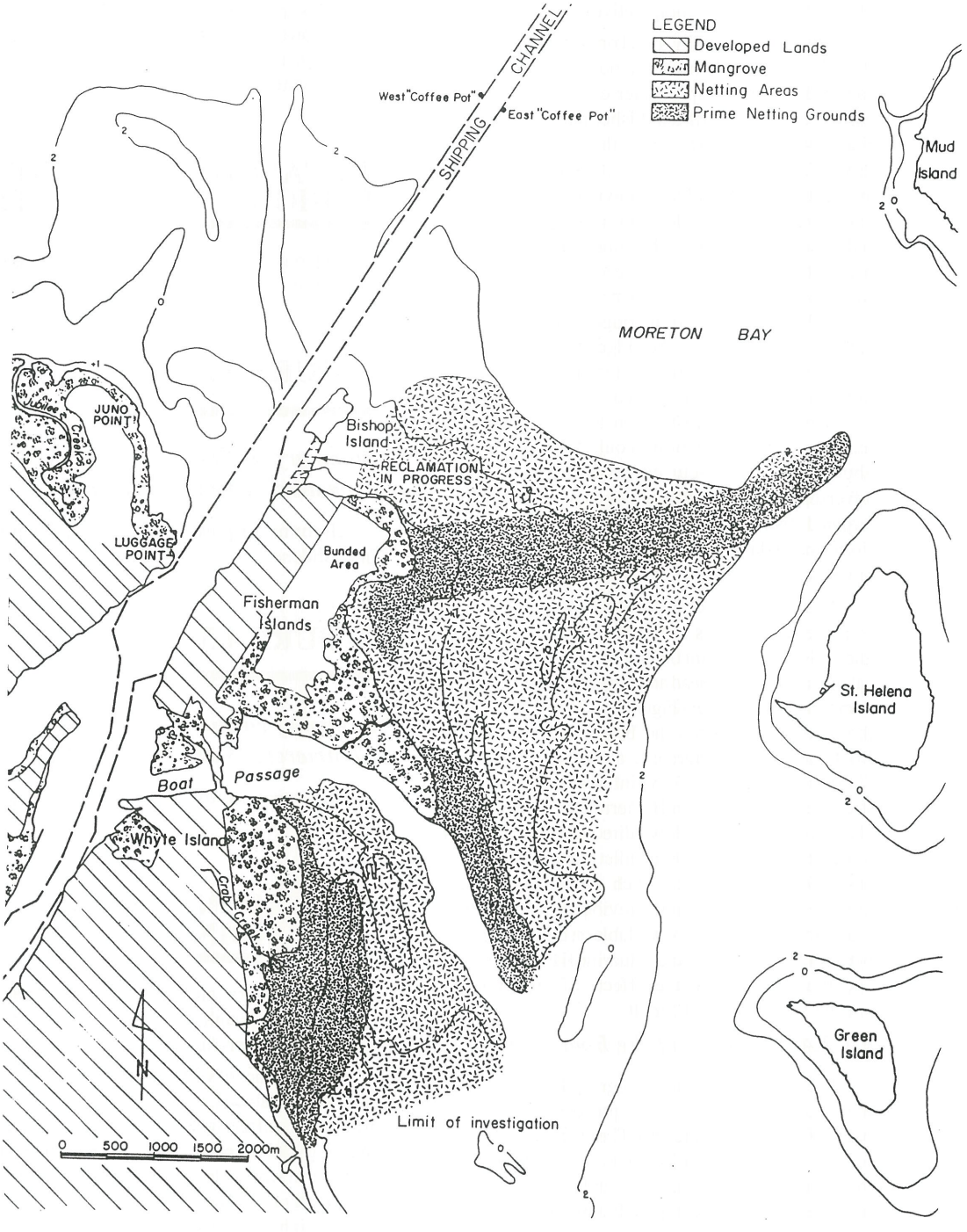
4.3 SEASONALITY OF LANDINGS

Fishing operations are conducted all year in the study area although fishing mainly occurs in the period November-August.

Peak catches of various species differ seasonally. Butterfish, flathead, mullet and bream are taken year round with differing seasonal peak landing periods. Whiting and tailor are taken mainly from June to September whilst black bream (luderick) are captured principally from October to March. This periodicity varies slightly from year to year.

FIGURE 4.1

Fisherman Islands Commercial Netting Areas



4.4 RECENT HISTORICAL CHANGES TO FISHING OPERATIONS

Fishermen report that catch rates and the species composition of catches has remained unchanged over the past 20 years for undisturbed regions of the study area. However, fishermen claim that recent works (< 10 yrs) in some areas of the Fisherman Islands region have changed the nature of fishing operations and reportedly decreased landings from some areas. The comments made by fishermen are presented below to demonstrate the importance of particular fishing grounds and effects of modifying works.

TABLE 4.4

Total 1989 Finfish landings for Moreton Bay (Excludes ocean beach fishery) provided by the QFMA

*Considered by QFMA to be an underestimate

FISH	TONNES
Mullet	765
Bream	161*
Black Bream	48
Dart	7
Flathead	30
School Mackerel	5
Other Mackerel	20
Shark	8
Tailor	138
Whiting	160*
TOTAL	1342

No data are available to support these statements, however they indicate the concerns of local fishermen in relation to port activities.

Boat Passage

The reclamation of lands over the last ten years on the south-west side of the Passage (Queensland Tugs and PBA depots) has reportedly affected mullet catches in areas near the eastern entrance of the Boat Passage. Prior to these works, mullet moving downstream in the Brisbane River used to enter the Boat Passage and moved eastwards through the passage onto the intertidal flats where they were susceptible to netting. Fishermen consider that the reclamation works have apparently formed an obstruction to the "normal" mullet movements and resulted in less fish entering the Boat Passage. Mullet reportedly remain in the Brisbane River to a greater extent than in the past, and consequently are less able to be netted thereby reducing commercial fish landings from the study area.

No data are available to confirm whether there has been a reduction in the number of mullet entering the Boat Passage or, if there has been a reduction, that this resulted from these reclamation activities.

Fisherman Islands Reclamation

Reclamation of Fisherman Islands has involved construction of bunds into which dredge spoil has been pumped. Approximately five years ago tailwaters from bunds located in central regions of Fisherman Islands (the Divide) overflowed onto the eastern intertidal flats. Fishermen claim that these waters contained very high levels of silt which smothered seagrass beds adjacent to mangroves and apparently raised the level of the flats. They believe that this markedly reduced fish catches in the affected area over a three year period until most seagrass beds recovered.

No information is available to confirm these reports although historical aerial photography indicate some silt input occurred. Photographic detail is insufficient to ascertain seagrass loss.

Fisherman Islands/Bishop Island Connection

The reclamation of subtidal lands between Fisherman Islands and Bishop Island filled in an area reputed to be an extremely productive fishing ground. This area consisted of undulating substrates and

several wrecks (used to construct Bishop Island) which provided shelter and food (eg. oysters on the wrecks) for bream and jewfish. The area is now mostly reclaimed. As a result of these works and associated habitat loss, commercial catches of these species have decreased from the northern Fisherman Islands region. Recreational fishermen also state that the reclaimed area was a productive fishing ground and that bream and jewfish catches near Bishop Island are less than they were prior to reclamation works. Reclamation of the subtidal lands between Fisherman Islands and Bishop Island also reportedly affected the movement of mullet from the river onto fishing grounds. Prior to the reclamation, mullet travelling downstream swam between the islands and reportedly congregated in shallow water near the northern tip of Fisherman Islands, where fishermen netted them. Fishermen believe that filling of the waterway between Fisherman Islands and Bishop Island has prevented fish from congregating near northern Fisherman Islands and mullet have since tended to remain within the main shipping channel before moving to other areas of the bay or onto the ocean surf beaches.

Commercial/recreational fishing organisations and State Government authorities do not hold site specific catch records and therefore the extent of decreased landings for the area cannot be quantified.

Overview

Overall, net fishermen consider that reclamation and other port related activities have adversely influenced their catches only to a minor degree.

Fishermen claim that approximately five years ago some localised short-term decreases in catches occurred because silt laden water flowed eastwards onto the intertidal flats from bunded areas on Fisherman Islands, leading to a short term loss of seagrass beds.

Fisherman advise that, with the exception of works on the northern tip of Fisherman Islands, no regularly used fishing grounds have been disturbed and no major long term adverse effects from port operations are experienced.

The general consensus amongst fishermen interviewed is that port related and fishing activities can be compatible in the long-term, providing port expansion strategies and techniques avoid disturbance of important fishing grounds.

4.5 OVERVIEW

There are 95 licensed netting operations in Moreton Bay. In 1989 Moreton Bay net fishermen landed 1342 tonnes of fish.

Fishermen advise that works by the PBA in the Fisherman Islands region have had relatively minor adverse effects on nearby commercial netting operations, other than in the area on the northern tip of Fisherman Islands.

5.0 CRAB FISHING

Net fishermen indicate that no commercial mud crabbers use the Fisherman Islands region on a regular basis. Mud crabs (*Scylla serrata*) are taken as by-catch in netting operations although landings are low relative to other areas of Moreton Bay. Most crabs sold are particularly large crabs destined for the restaurant trade.

Sand crabs (*Portunus pelagicus*) are frequently taken by commercial fishermen. Net fishermen catch the crabs as by-catch in mesh/tunnel nets and occasionally set traps when crab abundance is high. The principal sand crabbing ground is the ridge running eastwards from northern Fisherman Islands (described in Section 4.3.1) presumably because the ridge provides an attractive feeding for crabs. One commercial sand crabber reportedly frequently fishes this area. Attempts to locate this fisherman have proved unsuccessful.

6.0 BEAM TRAWL FISHING

Beam trawl operations cannot legally occur on the intertidal flats east of Fisherman Islands and are restricted to a small portion of the study area (the Brisbane River and northern fringes, see Section 3.0).

6.1 TRAWLING TECHNIQUES

Beam trawling involves towing a trawl net behind boat (generally 5-9 m in length), the mouth of the net being held open by a beam (maximum permitted width 5 m). This differs from otter trawling where the net is held open by otter boards or doors which act as spreading devices for the mouth of the net.

The beam trawl net is lowered over the stern of the vessel while it steams away, paying out the towing warp. The height of the skids and point of attachment of the warp to the beam is usually governed by the type of grounds and species of prawns which are being fished. Trawl time can vary from a few minutes to half an hour depending upon conditions.

6.2 NUMBER OF FISHERMEN

The QFMA advise that 77 commercial fishermen have an endorsement which permits beam trawling in the region between the N.S.W./QLD border and Double Island Point. Not all of these endorsements are used and in 1990, only 59 beam trawling operations were reported to the QFMA.

Approximately 30 beam trawlers involving 40 fishermen (some fishermen have an assistant) work in the study area at least 50% of their total fishing time (approximately 150 fishing days per year). Of these, 17 beam trawlers are moored within and work exclusively in the Brisbane River, particularly the river mouth. The remaining 13 beam trawlers are moored elsewhere but rely heavily on the Brisbane River as a fishing ground.

6.3 FISHING AREAS AND SPECIES TAKEN

The legally permitted beam trawl areas within the study region are shown in Figure 3.1. All grounds within the legal area are beam trawled. The abundance of prawns, and hence fishing operations, in various locations varies depending upon tidal state, water clarity/salinity river flow and time of the year.

Fishermen advise that fishing operations within the mouth of the Brisbane River, on any one fishing day, generally involve trawling in several areas throughout the region shown in Figure 6.1, which includes the study area. Prime fishing grounds generally occur within the study area along the edges of the entrance channel (Figure 6.1) along the old bar cutting, and within the mouth of the Brisbane River.

Prawn species taken in the study area include Greasyback (*Metapenaeus bennettae*), King (*Penaea plebjus*), Tiger (*Penaeus esculentus*) and Banana (*Penaeus merguiensis*) prawns. Greasyback prawns form the bulk of catches and are taken mainly from November to May. King and Tiger prawns form an important by-catch. Banana prawns are taken in winter in some years, although considerable interannual variation occurs.

6.4 CATCH VALUE

The Brisbane River Greasyback prawn fishery is one of the major suppliers of bait prawns in Australia. The lower reaches of the river, including those within the study area are the most productive. Bait prawns are sold throughout Queensland and exported mainly to N.S.W. and Western Australia. Larger Greasyback prawns are sold for human consumption, although the majority of the catch is for bait.

Banana prawns, taken in winter, are commonly large and are sold to the restaurant trade.

As for the net fisheries, no catch data specific to the Fisherman Islands are collected by Government authorities or the QCFO.

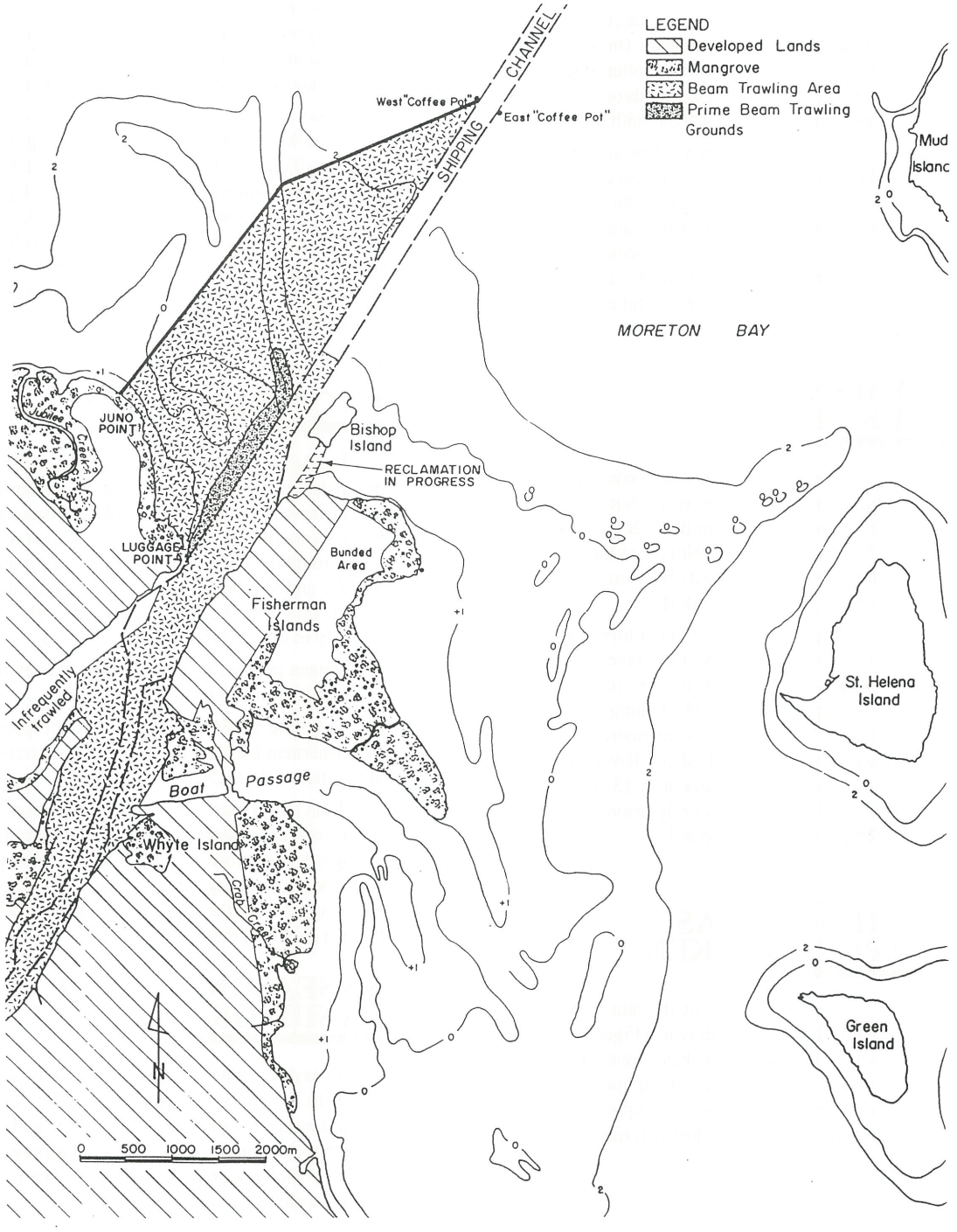
Beam trawl fishermen estimate that the beam trawl fishery operating within the study area involves (on average) 17 fishermen who work within the Brisbane River mouth, including the study area, 75-100% of their operating time. Thirteen fishermen reportedly operate in the area for half of their fishing time.

6.5 SEASONALITY OF LANDINGS

Greasyback prawns, the most commonly captured prawn in the study region, are generally taken in greatest numbers from November to May with peaks occurring in summer months. Banana prawns are taken in winter months although catches in some years are almost nil.

FIGURE 6.1

Main Beam Trawling Areas



6.6 INFLUENCE OF PORT OPERATIONS ON BEAM TRAWLING OPERATIONS

Beam trawlers report only minor concerns with PBA operations, generally in association with maintenance dredging.

Beam trawling requires a level seabed to work efficiently and prevent the skids/beam from "hooking up". Maintenance dredging operations which leave the bottom in an uneven condition render dredged areas unsuitable for beam trawling until natural processes level the seabed. The PBA bed levelling operations reduce this problem although fishermen believe levelling to a greater degree would significantly improve their catches.

Maintenance dredging also creates turbidity plumes. Although not adversely affecting catches, the plumes affect prawn distribution. Prawns move into shallower waters when conditions are turbid as a result of dredge plumes, perhaps because greater predator protection afforded by low clarity waters enables prawns to feed in otherwise "unavailable" shallow areas. In contrast, when waters are of high clarity, prawns tend to occur in deeper waters, including dredged areas such as main navigation channels. The influence of dredge plumes is reported by fishermen to alter fishing areas but not reduce landings to a substantial degree.

Dredging operations also provide benefits to beam trawling operations. The deepening of some areas of the river has created additional habitat favoured by Greasyback prawns. These deep areas have low light intensity, which may reduce prawn predation, and they serve to accumulate detritus which is used as a food resource by prawns.

Fishermen advise that the time of year when dredging is conducted is of little concern. However, on the basis of the seasonal nature of prawn landings (see Section 6.5), it would appear that the September/October period when catches are low would be the most preferable period for major dredging works. This would allow a greater time for dredged substrates to naturally level.

7.0 RECREATIONAL FISHING

No data are available on recreational catches or fishing levels for specific areas of Moreton Bay. The following information is based upon interviews with anglers who use the area.

Shore based angling locations are limited as a result of the thick mangrove fringe, muddy foreshores and restricted road access. However, those sites which are available are particularly popular with recreational fisherman because of their close proximity to residential centres of Brisbane. The most popular locations are the road bridge crossing at the Boat Passage for the Port of Brisbane Road, reclaimed foreshores along the Boat Passage and along the Wynnum North esplanade (at high water only). One boat ramp has recently been constructed in the Boat Passage. Other nearby boat ramps occur at Wynnum (Wynnum Creek) and Pinkenba.

Most recreational fishermen do not use the extensive offshore intertidal flats for angling or crabbing for fear of their boats stranding/grounding. The intertidal flats are mainly used by recreational fishermen seeking bait. Baitworm digging generally occurs near Wynnum and the flats between the D'arcy light and Fisherman Islands where access is easier. Baitworms are predominantly taken from areas close to the shore or from banks close to navigation channels (eg. Boat Passage).

Amateur baitworm digging also occurs amongst mangroves near Wynnum. These digging operations have extensively disturbed mangrove pneumatophores/seedlings and affected areas are visually unattractive (see Wetlands Study Report, WBM 1991a).

Angling within the study area occurs mainly on the fringes of the main shipping channel, and areas within and adjacent to the Boat Passage. Bream, jewfish, and luderick are captured mainly from shallow water adjacent to revetment walls near the tanker/cargo terminal and Bishop Island. More favoured fishing locations for these fish occur outside the study area at Luggage Point and the upstream BP river training wall.

Bream, whiting and flathead are commonly taken on the shallow flats south of the shipping channel and from the flats fringing the Boat Passage. Whiting fishermen consider the area south of the shipping channel (ie. east of Bishop Island) to be a prime fishing ground in spring months. On the opposing bank, the flats surrounding the seaward edge of the Old Bar cutting are also popular areas for anglers seeking whiting. Tailor, mackerel and other pelagic fish are also taken on a seasonal basis in these areas.

Crabbing is mostly restricted to sand crab trapping. Sand crabs are taken in reportedly large numbers from the area north east of Bishop Island (along the shipping channel), and the area west of St. Helena Island using pots and dillies.

The level of recreational fishing in Moreton Bay is increasing rapidly and is anticipated to double in the next decade. This will result in greater utilisation of areas near Fisherman Islands for angling and bait collecting.

8.0 FISHERIES IMPORTANCE OF WETLAND HABITATS ADJACENT TO FISHERMAN ISLANDS

The wetland areas adjacent to Fisherman Islands contain mangrove forests, seagrass beds and saltmarshes. Contrary to a generally held public perception, these habitats are not used as spawning grounds by species of fisheries value but provide valuable nursery and feeding habitat.

8.1 MANGROVES

Mangroves are highly productive ecosystems. The primary food source for aquatic organisms in most mangrove dominated estuaries occurs in the form of particulate organic material (detritus) derived from the decomposition of mangrove forest litter (ie. leaves, twigs, flowers). Estimates of litter fall (the most commonly measured component of net primary production) for *Avicennia marina*, the dominant species in the study area, range from 1.94 t/ha/yr to 6.42 t/ha/yr (Davie 1984) which were recorded at Mud Island. WBM Oceanics are presently undertaking leaf litter estimates at Fisherman Islands for the PBA (WBM Oceanics 1991a).

During decomposition, mangrove litter becomes a food source for a wide variety of filter, particulate, and deposit feeders such as molluscs, crabs, and polychaete worms. These primary consumers, which include representatives of most phyla, in turn form the food of a secondary consumer level which is usually dominated by small forage fish species and by the juveniles of the larger predatory species that form the third consumer level (Odum and Heald, 1972). In addition, there are important fishery species, which occupy both primary and secondary consumer levels. They feed directly on particulate organic detritus and also upon primary consumers.

Numerous studies have noted that fishes (particularly juveniles) are more abundant in mangrove dominated areas than in other nearshore habitats (Robertson and Duke 1987, Morton 1990). Possible explanations for this increase in fish abundance near mangroves include high availability of foods (Blaber and Blaber 1980, Morton 1990) and a high degree of structural heterogeneity (ie. shelter) in the form of prop roots, pneumatophores etc. (Robertson and Duke 1987). Many of the fishes present near mangrove areas of subtropical Queensland are of direct fisheries value (Morton, 1990).

Economic value

Morton (1990) concluded that mangrove forests at the mouth of Tingalpa Creek, (Moreton Bay) which are similar in structure to areas fringing Fisherman/Whyte Islands, provide important nursery and feeding habitat for fish of direct fisheries value. Study results indicated that:

- 46% of the fish species, 75% of the number of fishes and 94% of the biomass taken from mangrove forests and fringing waters were of direct importance to regional fisheries.
- the value of marketable fish taken from the mangrove study area was $8380 ha-1. This value only accounted for marketable species and does not include commercially important juveniles, fish or prawns.

8.2 SEAGRASSES

Seagrasses, which occur on intertidal and subtidal mudflats in the study area (see CSIRO seagrass report prepared for PBA), are important feeding areas for a variety of organisms. Turtles, dugongs and some fishes (eg. garfish) feed directly on

seagrasses whilst most other animals feed upon epiphytes, detritus, microfauna and the benthos associated with seagrass areas. Harlin (1980) reported that seagrass provides extensive surface area for large numbers of epiphytes which are grazed extensively by amphipods, gastropods etc. These animals are in turn eaten by larger animals.

Fish

Very few studies have been conducted specifically with regard to the fishes associated with seagrass beds in Queensland. Studies in N.S.W. have shown that seagrass beds support a large variety of fishes many of which are important to fisheries. Small epibenthic crustaceans were noted as a main part of the diet of juvenile fish in seagrass (Pollard 1984).

Recent studies by QDPI have involved beam trawling over seagrass beds fringing the northern banks of the Boat Passage monthly for a 15 month period. QDPI officers involved in the project have provided a list of fish species taken at Fisherman Islands. The detailed results of the QDPI studies, which are unavailable at present, are anticipated to be released in December 1991/January 1992.

The QDPI data indicate that the seagrass beds support a wide variety of small fish (40 species), many (approximately 16) of which are of fisheries importance. Beam trawling techniques are designed to capture prawns and principally catch only small, slow moving fish. Fast-swimming and pelagic fish (most of which are of direct fisheries importance) are generally under-represented in beam trawls. For this reason, the abundance of fish of direct economic importance (eg. mullet, whiting, flathead) contained in the beam trawl catches is low and does not reflect the nursery value of seagrass beds to fisheries.

Other research (ongoing) by the QDPI using different netting techniques (eg. stake netting) indicate that seagrass beds are valuable nursery habitat for flathead, whiting, mullet and bream (D. Cameron pers. comm.) whilst studies in N.S.W. have shown that patchy *Zostera* beds are an important feeding/shelter habitat for juvenile summer whiting, the most commercially important whiting species (Burchmore et al. 1988). Undoubtedly more detailed fish studies would reveal the dependence of many other fisheries species upon seagrass beds. Seagrass beds also provide habitat for worms which form the basis of a major baitworm fishery in the study area. As described in the Baitworm Report (WBM Oceanics 1991b), large populations of baitworms are only associated with seagrass beds.

Prawns

Seagrass also provide an important settlement area for the post-larval stage of several species of penaeid prawns (Young 1978). The post-larval stage is the stage which leaves the plankton to adopt a bottom dwelling (or demersal) lifestyle. Seagrass beds are considered valuable prawn nursery grounds, especially for the Tiger prawn, *Penaeus esculentus* (Young 1978, Staples et al. 1985, Coles and Lee Long 1985) and Endeavour prawns, *Metapenaeus endeavouri*, (Coles et al. 1987). Post larval and juvenile stages are found almost exclusively in seagrass beds. Within seagrass beds, Tiger prawns (*Penaeus esculentus*) fed on polychaetes, gastropods, algae and seagrass (*Zostera capricorni*) seedcases (Wassenberg and Hill 1987). It is probable that if larval Tiger or Endeavour prawns do not settle in an area of seagrass they will be unlikely to survive and will be lost to the fishery.

Greasyback prawns, the dominant prawn species caught in the study area (and Moreton Bay), spawn from October to May within Moreton Bay, no further than 16 km from river mouths (Dall 1958). Post-larval recruitment occurs mostly from March and June (Young and Carpenter 1977). Epibenthic post-larvae occur on a variety of substrates but are more abundant on seagrass beds than bare substrate and are more abundant in shallow than deeper water (Young and Carpenter 1977).

Beam trawl studies by QDPI (see Fish section above) at Fisherman Islands indicate that these seagrass beds:

- Mainly support large populations of juvenile Greasyback prawns, the dominant prawn taken in Brisbane River/Moreton Bay trawl (otter and beam) fisheries (see Section 6.0).
- Also support Tiger and King prawns but in lesser numbers.
- Contain greater abundances of juvenile prawns than in adjacent shallow subtidal areas.
- Have a comparable abundance of Greasyback prawns to another sample site located over seagrass beds at Deception Bay but contain greater numbers of King and Tiger prawns.

Economic Value

Unfortunately no data are available that can place an accurate estimate on the value to fisheries of specific seagrass areas such as those within the study area. Difficulties arise because:

(a) Prawns, fishes, etc. often move substantial distances between the juvenile and adult phase thus, at least on a local scale, attempts to locate nursery grounds for a particular stock are difficult. Tagging programs are useful in this context but require a large research input.

(b) Seagrass beds vary annually in terms of distribution and density of substrate cover.

(c) The "carrying capacity" of seagrass beds and fish/prawn recruitment levels to seagrass beds are likely to vary annually and between sites.

(d) Relatively little is known about the ecology of seagrass areas in Australia.

Whilst being extremely difficult to place a quantitative figure on the economic value of associated seagrass areas it is prudent to assume that large areas are of substantial importance to the fisheries of an area. Impacts due to the loss of small areas are difficult to assess given the often wide interannual variability in seagrass extent.

8.3 SALTMARSHES

Saltmarsh areas are limited in extent within the study area occurring only as small isolated patches (individually < 0.1 ha) in central Fisherman Islands (adjacent to the southern bund) and landward of Whyte Island mangroves. Saltmarshes occur in upper littoral regions. In Moreton Bay, approximately 15% of the high tides inundate this habitat annually. Studies of the fisheries value of saltmarshes in Moreton Bay (Morton et al. 1987, 1988) concluded that:

- fish species important to commercial fisheries do not directly utilise saltmarsh to a large extent. Of those that do, mullet and bream use tidal inlets to saltmarshes as feeding areas.
- the value of small areas of saltmarsh for maintenance of commercial fish populations is not critical however when considered in total, saltmarshes in Moreton Bay provide rich feeding grounds for certain types of fish.

8.4 OVERVIEW

The study region encompasses large areas of mangroves and seagrasses. In common with other wetlands in Moreton Bay, these areas provide valuable habitat for fish and prawn species of direct fisheries importance which are taken throughout Moreton Bay. The wetlands are of considerable regional significance as described in the Wetlands Report (WBM Oceanics 1991a).

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APPENDIX VI

THE FISHERMAN ISLANDS BAITWORM FISHERY

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EXECUTIVE SUMMARY

The Port of Brisbane Authority (PBA) has identified a longer term need to expand the capacity of the Port to accommodate a future increase in Port usage. This may require disturbance of intertidal and subtidal lands on and near Fisherman Islands.

The PBA, as part of Port management/ development strategies, has commissioned WBM Oceanics to undertake studies of the commercial baitworm fishery which operates on intertidal flats adjacent to Fisherman Islands.

The baitworm fishery provides a major bait supply for local anglers targeting estuarine fish such as bream, whiting and flathead. Worms are dug by hand (using a modified garden fork) on low tides amongst seagrass beds.

Fishermen construct bunds around the perimeter of a digging area (generally 8 m x 8 m) to prolong the period before flooding tides inundate the area. This process gives digging grounds a "checker board" appearance from the air. Commercial bait diggers are licensed and are required to replace seagrass removed from the bunded area in an upright position.

The area adjacent to Fisherman Islands is the largest (approximately 45 ha) and most productive baitworming area in Moreton Bay. Most digging operations are by commercial fishermen as amateurs generally dig closer to Wynnum where access is easier. Thirty to forty commercial bait collectors regularly work in the Fisherman Islands area.

The ecological effects of bait digging are largely unknown. Seagrass, if correctly replaced, regenerates after 3 - 5 years although raised areas (bund walls or spoil piles) may take longer to be revegetated. Results from studies examining digging impacts to intertidal fauna vary depending upon the species being considered. Estuarine benthic animals are resilient to changing environmental conditions and it is probable that baitworm digging results in mainly short term adverse impacts.

Baitworm digging occurs in areas used by net fishermen. Digging holes and construction of bunds creates an uneven substrate. When nets are set over such areas, the holes and ridges result in gaps being left under the net leadline which allow fish to escape thus reducing the catches of net fishermen. Conflicts between the two fishing groups are generally minor although occasional disputes occur. Some prawn trawl operators believe digging in seagrass areas destroys juvenile prawn habitat and thereby ultimately affects their catches. Conflicts arise between bait diggers generally due to disputes over digging techniques and "ownership" of digging areas.

The baitworm fishery is a viable fishery which appears to have a stable long term future. Management of digging operations (number of fishermen and techniques), the presence of large areas of seagrass and absence of major pollutant inputs are crucial to the productivity of the fishery.

1.0 INTRODUCTION

The PBA has developed Whyte and Fisherman Islands as a major Port facility at the mouth of the Brisbane River. The PBA has identified a longer term need to expand the capacity of the Port to accommodate a future increase in Port usage. Further expansion of Port related facilities on the southern side of the mouth of the Brisbane River (north east of Fisherman Islands) is proposed by the PBA. This may require disturbance of intertidal and subtidal lands on and near Fisherman Islands.

The draft Moreton Bay Strategic Plan, designed to ensure appropriate land use within Moreton Bay, confirms the future usage of lands adjacent to Fisherman Islands as Port related activities (see Figure 1.1).

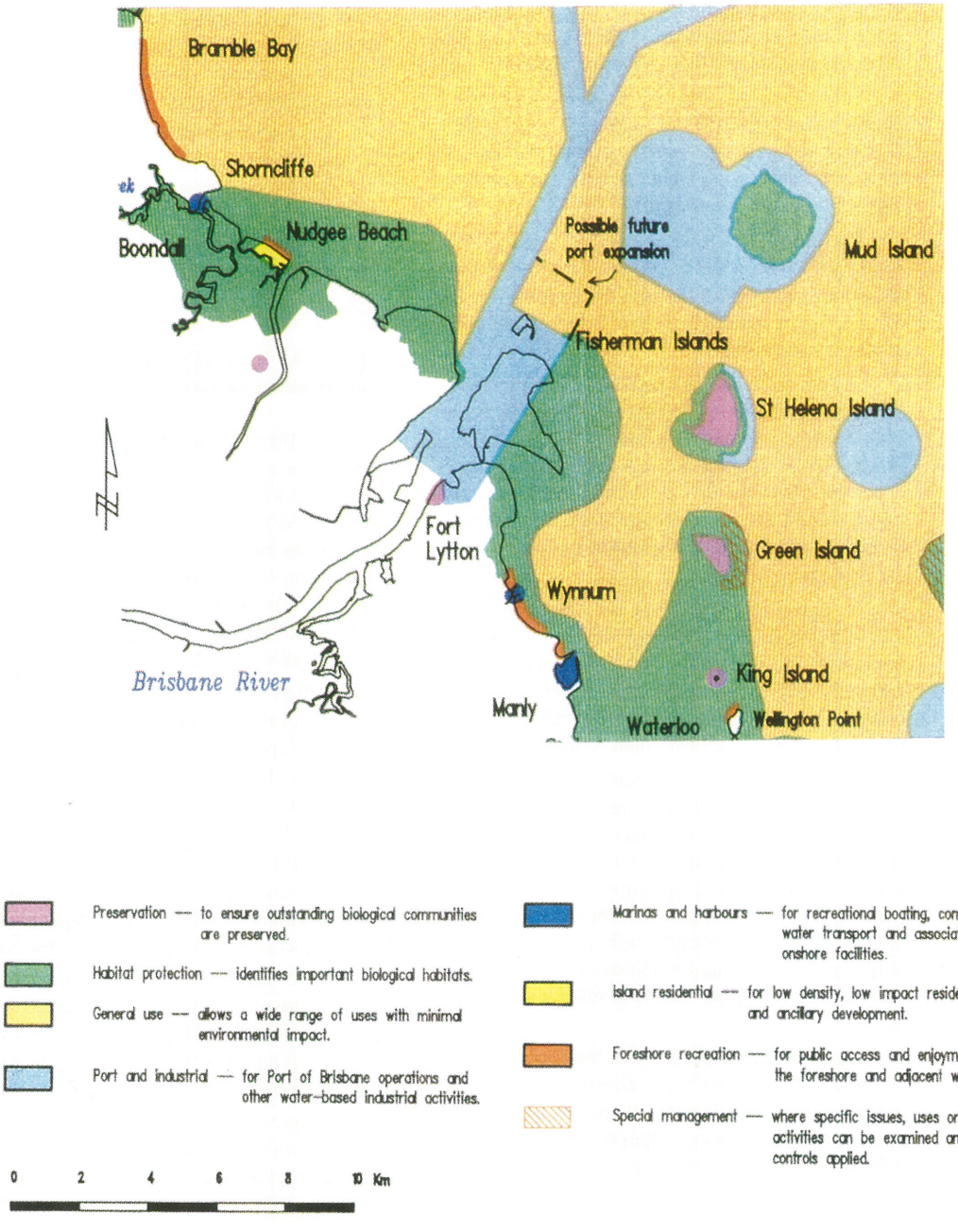
The PBA, as part of Port management strategies, has commissioned WBM - Oceanics to undertake several studies in relation to the ecological/fisheries importance of regions surrounding Fisherman Islands.

Some intertidal areas adjacent to Fisherman Islands are utilised by commercial and recreational baitworm diggers. The baitworm fishery provides a major bait supply for local anglers targeting estuarine fish such as bream, whiting and flathead.

The present study was undertaken to provide the PBA with information on baitworm digging operations to be incorporated into Port management and development strategies.

FIGURE 1.1

Extract from Draft Moreton Bay Strategic Plan



2.0 SCOPE OF THE STUDIES

The PBA has commissioned WBM - Oceanics Pty Ltd to:

- Map the major worm collecting areas in the region near Fisherman Islands.
- Describe the characteristics of the baitworm fishery operating near Fisherman Islands.
- Comment on the impact (short and long term) of present worm digging operations on seagrass beds and other areas of ecological importance.
- Assess the sustainability of existing collecting operations in the Fisherman Islands region.

3.0 FISHERIES REGULATIONS

A permit, issued by the Queensland Department of Primary Industries, is required to legally collect worms in Queensland. The permit system was initiated in 1987 in response to requests from the "better" commercial diggers for management of the fishery.

The permits are valid for one year and require that worms are dug by fork or by hand and that seagrass is replaced in an upright position. Digging is prohibited from occurring in Fish Habitat Reserves.

To obtain new permits to collect worms on a commercial basis, it is required that new collectors work under the supervision of an established permit-holder for one year prior to receiving an open collecting permit. This is to ensure that a new operator is adequately trained in digging methods which minimise disturbance to worm banks and seagrass.

4.0 SOURCES OF INFORMATION

In contrast to most other commercial fisheries in Moreton Bay which are managed by the Queensland Fish Management Authority, the baitworm fishery is managed by the Queensland Department of Primary Industries (QDPI).

A meeting was held with baitworm fishery managers from the QDPI who supplied some general information and baitworm operators to be contacted.

Mr B. Johnson, one of the major baitworm suppliers and employer of baitworm diggers in Moreton Bay, provided information on the fishery characteristics and viability.

Only one study (Forbes 1984) has been published on Moreton Bay baitworm fishery. The QDPI are presently involved in a long term study directed at assessing the impact of baitworm digging on seagrass beds (see Luck 1989). It is uncertain when the results of the study will be publically available.

5.0 THE BAITWORM FISHERY

5.1 The Worm Species

The commercial baitworm fishery adjacent to Fisherman Islands depends almost entirely on the eunicid polychaete *Marphysa sanguinea* (Montagu). The worm is most commonly known as the "mud-worm", "Cribb Island worm" or "bloodworm". It may attain a length of 40 - 50 cm (extended) and weigh up to 10 g. This species occurs in a wide variety of habitats from intertidal to waters 100 m deep (Pettibone 1963) and is globally widespread throughout warm oceanic waters (Fauchauld 1970). In Moreton Bay, it is most commonly found in seagrass beds at a sediment depth of 0.3 - 0.5m.

Mudworms are probably one of the most important regularly used baits for anglers in Moreton Bay. Anglers seeking bream, whiting and flathead (to a lesser extent) generally buy live worms, although "serious" or competition anglers often collect their own bait. In 1986, Moreton Bay was estimated to be used by 300,000 fishermen who spent 1.5 million fishing days per year in the Bay and spent an estimated $160 million each year on fishing activities (Neumann and Hundloe, 1986).

Other species of worms (beach, rock, wriggler) are commercially/ recreationally collected for bait although such collecting activities do not occur to a significant degree in the Fisherman Islands area.

5.2 Number of Fishermen

Information supplied by the QDPI indicate that 70 commercial baitworm diggers (mudworm only) operate in Moreton Bay, although the number varies annually from 60 to 80. Discussions with commercial fishermen indicate that 30 to 40 fishermen regularly

work the area adjacent to Fisherman Islands which is considered to be the most heavily utilised area in Moreton Bay. On some occasions, many unlicensed commercial operators are present in the area. Forbes (1984) recorded up to 33 diggers at Fisherman Island and concluded that about 15 was a typical number.

Fishermen form crews ranging in size from 2 - 20 fishermen to extend the period available for digging (see below).

Commercial fishermen report that relatively few amateur fishermen dig in their areas presumably because access is restricted (by boat only). Most amateur operations occur in more landward areas near Wynnum where access is easier (see Section 4.4).

5.3 Techniques

Digging operations are conducted using a four-pronged gardening-type fork. The fork is modified in that the prongs are angled upwards and the tips are flattened to aid digging.

Digging occurs on intertidal banks and thus the period when digging can occur is dependent upon tidal conditions. To reduce this dependence, fishermen form bunds (dykes) around the perimeter of a digging area. Diggers generally start forming a bund on the last stages of an ebbing tide.

Initially, the seagrass and top layer of substrate is removed from outside the proposed digging area and used to build the bund, leaving a trench around the bund. After the bund is complete, the fringing inner portions of the enclosed area are excavated to form a trench, with the spoil (seagrass and substrate) being added to the bund wall to further raise its height. Water that drains into the inner fringing trench is bailed out and the bunded area is thus drained and suitable for digging. Diggers then work as a team, excavating areas, bailing, placing the spoil in previously dug areas, and slowly spiralling towards the centre of the bunded area. Each forkful of spoil is carefully checked for worms which are placed in a collecting bucket. Digging continues until the tide overtops the bund and floods the enclosed area.

The site of the area bunded varies depending upon tidal conditions and the number of fishermen in the area. However, on average, bunds are 8m square.

Digging is an extremely labour intensive task and thus fishermen form teams (2 - 20 diggers) to enable a large area to be bunded and dug prior to incoming tides overtopping the bund. The amount of time available for catching worms is dependent upon the tidal conditions, seepage of water into the trench and endurance of diggers.

Some diggers take particular care with the seagrass because they believe it is important for the long-term maintenance of worm populations. These diggers remove the seagrass as a sod which is replaced after deeper layers are searched for worms. This is not possible for bund wall construction but may occur when inner drained portions are dug.

The worms are generally sorted into broken and unbroken individuals and delivered to a bait supplier. The worms may be held for up to 14 days in shallow water filled trays although the demand for worms is generally high and holding periods are rarely that long. Water within the trays is frequently replaced and some suppliers use additional treatments to ensure worm survivorship (eg. air conditioning, bactericides).

Digging generally occurs during the day although some diggers are equipped to work during the night (lights etc.) if the demand for bait is high.

5.4 Digging Areas

Discussions held with QDPI staff and commercial bait diggers indicate that the Fisherman Island area is the main worm digging area in Moreton Bay. Other commercial digging operations occur in Deception Bay although this is of lesser importance compared to Fisherman Islands.

Amateur diggers collect mudworms in many areas of Moreton Bay although the Wynnum - Lota foreshores are probably the most utilised area. Commercial diggers also operate in this area on occasions. Other significant amateur grounds occur in Deception Bay, along the Nundah and Redland Bay foreshores.

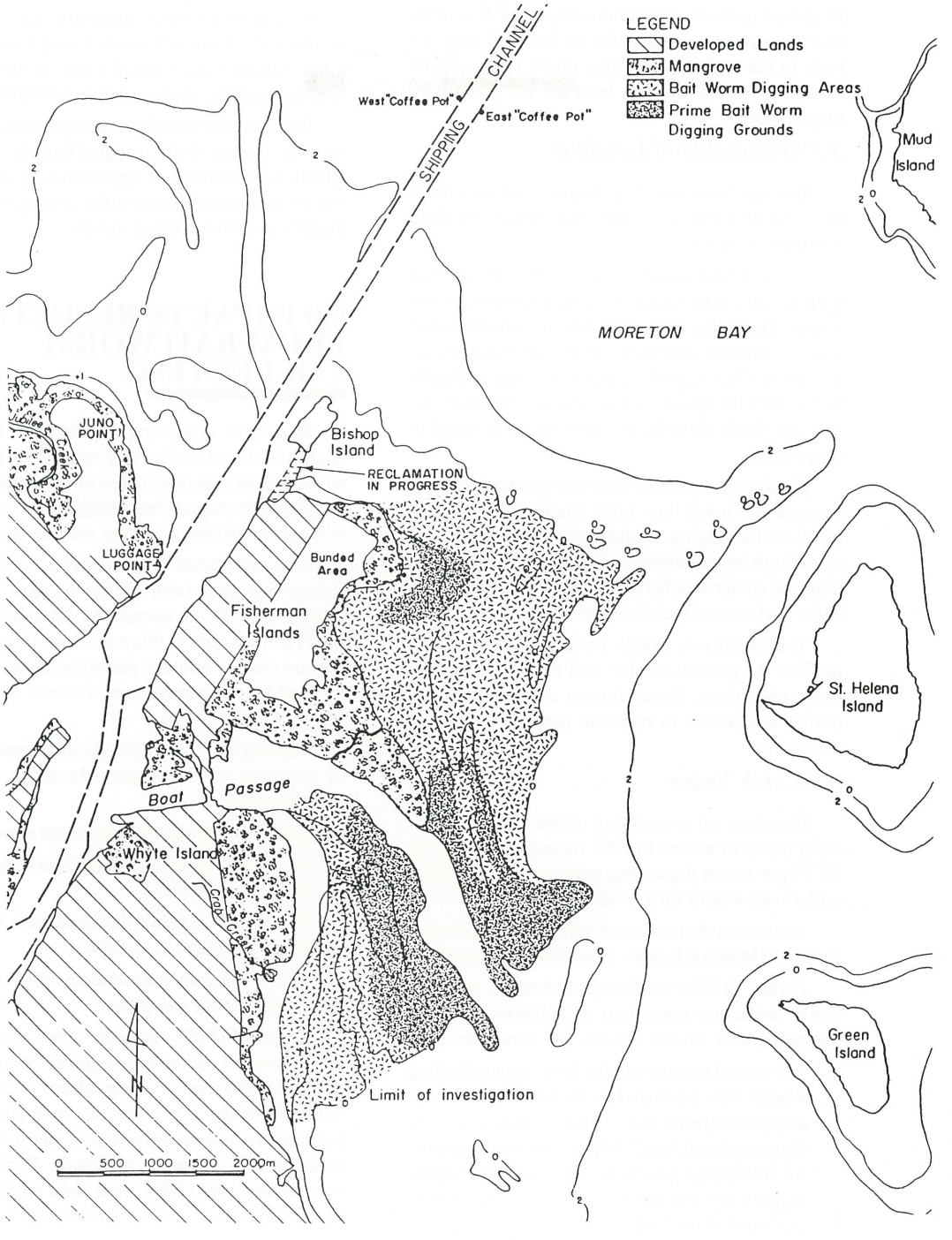
Fishermen generally only dig in seagrass areas to the low water spring tide mark. Although mudworms occur in unvegetated areas, worm abundance is greatest in seagrass areas and hence almost all digging occurs in such areas.

The main digging areas at Fisherman Islands cover approximately 180 ha and are shown on Figure 5.1. This area was determined on the basis of the regions in which seagrass has been disturbed by digging activities (CSIRO Cleveland supplied data) and WBM Oceanics field surveys.

Selection of a particular digging area is dependent upon individual digger preference, predicted tidal conditions and the number of fishermen in the crew. The repeated construction of bunds results in digging

FIGURE 5.1

Commercial Bait Worm Digging Areas



areas having a checkerboard appearance on aerial photography.

Forbes (1984) concluded that the Fisherman Islands digging area covered 1024 ha. Unfortunately he did not provide a map of digging areas. It appears that this value represented the total area of seagrass beds in the region at the time of his study and he assumed that all seagrass beds are (or potentially may be) dug.

5.5 Seasonality of Landings

Because baitworm digging occurs on intertidal flats, the tidal regime significantly affects the time available for digging.

Tides in Moreton Bay are unequal semidiurnal with greatest tidal ranges occurring in summer and winter. The higher of the high tides occurs during the day in summer and night in winter. Conversely, lower low tides occur during day in winter and night in summer. In spring and autumn, tidal ranges are less and day/night tides are approximately equal in magnitude.

Catches of worms are therefore greatest in winter because the lower low tides enable a larger time available for digging. Additionally, as worms tend to avoid high temperatures by burrowing deep into the mud, the cooler weather results in worms being close to the surface and therefore less digging is required.

The January to March period is considered to provide the poorest catches and many bait diggers cease operations. Some diggers continue to work during this period to maintain supplies to regular customers.

5.6 Catch Value

Enquiries at several bait shops indicated that retail prices of worms in 1991 ranged from $0.50 to $1.75 per worm depending upon size. Some retail outlets sell worms on a weight basis.

No data on the total catch value of the mudworm fishery in Moreton Bay are available from the QDPI.

Forbes (1984) conducted a detailed study of worm collecting operations at Fisherman Islands extending over several seasons and concluded that:

- The annual number of man days spent collecting worms was estimated to be 10,950. This was determined on the basis of the average number of diggers being 15 and 730 low tides being suitable for collecting operations. This estimate assumes diggers are present on every low tide and is probably an overestimate.
- Catch rates vary from 8.5 to 20.0 worms m-2 with an overall mean of 10.5 worms m-2.
- 2,312,400 worms are taken from the Fisherman Islands area each year.

Commercial diggers presently receive $30/100 worms on a wholesale basis. Using Forbes (1984) catch estimates the landed value of the baitworm fishery would be approximately $700,000.

Discussions with baitworm diggers in association with the present study, suggest that the Fisherman Islands region produces approximately $500,000 of worms taking into account the average number of diggers and their average income.

6.0 IMPACTS RESULTING FROM BAITWORM COLLECTING

Baitworm collecting adjacent to Fisherman Islands is almost exclusively carried out in seagrass areas because fishermen report that worm populations are greatest in seagrass beds. Digging and construction of bunds physically damages seagrass beds.

Some baitworm diggers carefully remove and replace seagrass from within bunded areas (see Section 5.3) in an attempt to minimise damage. QDPI permits require this procedure although not all diggers comply with the permit condition. Seagrass covered in the construction of bunds is smothered and dies.

Forbes (1984) qualitatively monitored recovery of seagrass at Fisherman Islands in 1980 and concluded that:

- Raised spoil heaps and bunds are slowly eroded.
- Recovery was more rapid in areas where seagrass had been replaced.
- Regrowth was slower in raised areas (spoil piles and bunds) than in hollows.
- Consolidation of the sediment in hollows had not occurred after two years.

Ongoing QDPI research notes that previous indiscriminate mudworm digging (mainly due to amateurs) has had a major affect in some areas between Sandgate and the Brisbane River mouth. Failure to replace seagrass sods has led to erosion and little, if any, seagrass regrowth. Replaced sods enhance recovery of dug areas and it is estimated that recovery generally occurs within three years (Luck

1989). QDPI monitoring programmes are underway to confirm this estimate.

The ecological effect of baitworm digging on benthic epifauna and infauna is largely unknown. Surface fauna (epifauna) is disturbed and buried under spoil piles or bund walls. It is probable that some buried epifauna would die. Burrowing fauna (infauna) would be affected to a lesser degree.

Casual observations of amateur baitworm digging operations by WBM Oceanics staff at Amity (North Stradbroke Island) over several years indicate the following short to long term impacts to benthic communities within baitworm digging grounds:

- Much of the impact to fauna, particularly epifauna, on the flats results from direct smothering and trampling during digging and bunding. The physical elevation and tidal drainage of worked areas is altered for many months or years. This results in more prolonged drying or inundation than previously experienced and for sedentary species such as bivalve molluscs apparently often results in death.
- Other epibenthic species such as soft corals, sea pens and anemones do not tolerate the disturbance of sediments at all well. Semi-mobile species such as anemones have been observed to relocate with the flooding tide following disturbance by digging.
- Often the freshly dug sediments bought to the surface by baitworm digging contain a significant quantity of organic detritus which has previously undergone anaerobic decay. Where this sulphurous material is deposited on the flats it appears to be avoided and is perhaps toxic to some forms of surface detrital feeders such as holothuroids (sea cucumbers).
- In the short-medium term, baitworm digging disturbs or removes the camouflage cover and food resources afforded by seagrass to benthic molluscs, crustaceans and polychaetes. These areas instantly become food foraging areas for the larger predators such as fish and seabirds.
- On the first flood tide following digging, fish such as bream, whiting and occasionally flathead move onto the diggings to actively feed upon exposed crustaceans, molluscs and polychaetes. Fish often school where the sediments have been heaped to form bunds and where wave/tide action actively erodes these mounds to expose new food sources.

Forbes (1984) examined the impacts of digging upon the most abundant burrowing fauna (an unidentified bivalve and the polychaete *Cirriformia tentaculata*) at Deception Bay (Moreton Bay) worm grounds and concluded that digging did not have a significant adverse impact on these organisms. Research in England demonstrated that digging for lugworms (*Arenicola marina*) and ragworms (*Nereis diversildor*) adversely affected catches of the edible cockle (*Cerastoderma edule*) as a result of burial (Jackson and James 1979). In contrast, McLusky et al. (1983) concluded that commercial digging for lugworms had little effect on two epibenthic species (*Hydrobia ulvae* and *Macoma balthica*). They suggested that many estuarine benthic animals are highly adaptable, able to cope with the variable ecological situations found in estuaries, and that this ecological resilience appears to render them largely unaffected by bait digging. A similar situation may occur on the Fisherman Islands digging areas.

Overall, it is probable that baitworm digging, if properly undertaken (eg. replacement of sods), results in mainly short term ecological impacts. Recovery of dug areas apparently occurs over several years (< five years).

7.0 CONFLICTS WITH OTHER FISHING OPERATIONS

Baitworm operations are conducted in areas used by net fishermen. The disturbance of the intertidal flats as a result of digging operations apparently provides both beneficial and detrimental impacts to net fishing operations.

Some net fishermen believe that baitworm digging in seagrass areas attracts fish because benthic invertebrates (eg. shells, crabs) are exposed and available for fish to feed upon. However, digging holes and construction of bunds produces an uneven substrate. When nets are set over such areas, the holes and ridges result in gaps being left under the net leadline which allow fish to escape. Conflicts mainly occur when diggers operate in a favoured netting location. Disputes are generally infrequent and minor although some instances have occurred where nets have been purposely damaged.

Some prawn trawl operators believe digging in seagrass areas destroys juvenile prawn habitat, ultimately affecting their catches. The prawn

fishermen state that disturbance/destruction of seagrass is an offence under the Fisheries Act and that government authorities are "turning a blind eye" to the damage done by baitworm fishermen (see Section 6.0 for impacts to seagrass).

Conflicts within the baitworm fishery are mainly between baitworm diggers themselves. Most problems arise because diggers who have a long-term commitment to the fishery try to manage their operations by:

- Replacing seagrass (as a sod) that has been disturbed to aid regeneration. QDPI baitworm permits require replacement of seagrass although the degree to which this is observed varies between diggers.
- Not digging upper (ie. landward) intertidal areas when lower areas are available.
- Leaving disturbed areas for a period before resuming digging.

Diggers who fail to effectively replace seagrass or work in "recovering" areas because it is easier to dig, are considered by long-term operators to delay the rehabilitation of disturbed areas to the ultimate detriment of the fishery.

Fishermen who operate year-round manage their digging areas to try to leave upper intertidal areas for digging when low tides are large and few intertidal banks are exposed (eg. day low tides in summer). Although diggers could dig these upper areas for an extended time period when low tides are small, this procedure would not leave any undisturbed digging areas for periods when the low tides are large. Conflicts occur when infrequent or short-term diggers work in areas that have been "reserved" for digging in the summer by the longer-term operators.

The present system where baitworm collectors are able to dig areas on an unrestricted basis inhibits efficient use of the baitworm grounds.

8.0 VIABILITY OF THE FISHERY

No information is available on the long-term future of the baitworm collecting fishery. The main concern expressed by baitworm fishermen in relation to Port activities, involves possible loss of baitworm digging areas as a result of reclamation or pollutant inputs.

Opinions expressed by QDPI and fishermen suggest that, providing the worm digging areas are not disturbed (eg. loss of seagrass, pollutant inputs, alterations to sediment characteristics) and the number of licensed worm diggers and digging techniques remain regulated, the fishery should be able to continue as a viable operation for the foreseeable future.

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