QUEENSLAND COASTAL WETLAND RESOURCE INVESTIGATION OF THE BOWEN REGION:

Cape Upstart to Gloucester Island

Christina Bruinsma
Karen Danaher
Paul Treloar
Rebecca Sheppard

Queensland Department of Primary Industries
Fisheries Group
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Danaher, K (1995) Coastal Wetlands Resources Investigation of the Burdekin Delta for Declaration as Fisheries Reserves: Report to Ocean Rescue 2000. Queensland Department of Primary Industries, Brisbane.

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Danaher, K and Stevens, T (1995) Resource Assessment of the Tidal Wetland Vegetation of Western Cape York Peninsula, North Queensland, Report to Ocean Rescue 2000. Queensland Department of Primary Industries, Brisbane

Treloar, P and Danaher, K (in progress) Coastal Wetland Vegetation Investigation of the Capricorn Region: Round Hill Head to Fitzroy River. Queensland Department of Primary Industries, Brisbane.

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EXECUTIVE SUMMARY

Protection of coastal wetland environments is an important prerequisite to effective and sustainable fisheries management and conservation of habitats for the use of future generations. Mangroves, saltmarshes and seagrasses directly support local and offshore fisheries through the provision of food, shelter, breeding and nursery grounds. As such, these vegetated wetland environments along with sandbars, intertidal flats and rocky foreshores, have significant economic value as well as their intrinsic aesthetic and ecological values.

Approximately two thirds of the wetland resources of the Queensland coastline have been mapped or are currently being mapped as a baseline dataset for Marine Protected Area investigation and particularly Fish Habitat Area (FHA) declaration, Ramsar site nomination and continued monitoring of these important fish habitats. This report summarises the results of the mapping undertaken in the Bowen region from the East Coast of Cape Upstart (Abbot Bay) to Gloucester Island (encompassing Edgecumbe Bay). The study was undertaken in order to:

1. document and map the coastal wetland communities within the Bowen region;
2. document levels of existing disturbance to and protection of the wetlands;
3. examine existing recreational and commercial fisheries in the region; and
4. evaluate the significance of the coastal wetlands in the region.

The general trend in the distribution of mangroves in the Bowen region is for Closed *Rhizophora* communities to establish along the foreshore and watercourses. Closed *Ceriops*, along with Closed *Avicennia* and Closed Mixed communities tend to dominate the landward fringe of the Closed *Rhizophora* communities. Extensive Saltpans generally occur between the mangrove communities and the upper tidal limit. These Saltpans range from totally unvegetated in the extremely hypersaline regions to samphire dominated in less saline areas. Small areas of Saline Grassland exist in the upper intertidal region. The area of each of the coastal wetland communities within the study region is displayed in Table 1.

TABLE 1 Total Area of Coastal Wetland Communities of the Bowen Region

COMMUNITY	AREA (hectares)
Closed *Rhizophora*	3015.6
Closed *Avicennia*	284.3
Open *Avicennia*	1.3
Closed *Ceriops*	1454.9
Open *Ceriops*	37.3
Closed *Avicennia* / *Ceriops*	153.3
Closed *Avicennia* / *Rhizophora*	77.3
Closed Mixed	75.6
Saltpan	5427.6
Saline Grasslands	7.7
Total	10 534.9

The coastal wetland communities of the Bowen region represent a diversity of environments that have value as both fisheries and waterbird habitat. The sheltered bays and exposed coastline exhibit intertidal flats, saline grasslands and saltmarshes along with numerous mangrove community types. Although the exact economic value of these wetlands is unknown, they contribute significantly to the local fisheries in providing food, shelter, and breeding and nursery grounds. Consequently, further investigation into the overall values of the wetlands of this region for gazettal of FHAs and Ramsar sites is suggested.

Recommendations

1. The consideration of the fisheries habitats from Adelaide Point to Cape Gloucester, including both the intertidal and offshore environments of Edgecumbe Bay, for inclusion in a FHA is strongly suggested. This area includes Emu, Yeates, Longford and Miralda Creeks and Gregory River coastal wetland systems. The protection of these systems in particular is urgently recommended, due to their relatively pristine status.

2. The coastal wetlands of Abbot Bay and the Don River Delta are less diverse than those of Edgecumbe Bay. However, these areas are important commercial and recreational fishing grounds and on this basis further investigation for FHA nomination may be warranted.

3. Continuation of coastal wetlands mapping to complete the remainder of the Queensland coast is strongly recommended, to:
    - provide baseline data for FHA declaration, review of current FHA boundaries and Ramsar site nomination;
    - to monitor spatial and compositional changes in communities on a local, bioregional and statewide basis; and
    - as a resource for incorporation into studies of the relationships of specific marine fauna to particular coastal wetland habitats.

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SECTION 1. INTRODUCTION

1.1 Project Scope

Marine, estuarine and freshwater systems in Queensland are managed under the provisions of the *Queensland Fisheries Act 1994* and *Fisheries Regulation 1995*. This legislation provides for the *'management, use, development and protection of fisheries resources and fish habitats'*. Under the legislation, marine vegetation communities (including seagrasses, mangroves and saltmarshes) are protected as marine plants by limiting the impacts of works able to be undertaken in these fish habitats and through the declaration of Fish Habitat Areas (FHAs). FHAs are part of the on-going management of fisheries resources within Queensland and are specifically declared to ensure continuation of productive recreational, indigenous and commercial fisheries in a region through habitat protection. Declaration publicly proclaims the value of the area from a fisheries viewpoint, and increases the statutory level of protection of the wetlands for community benefits. Appendix 1 displays the current distribution of declared FHAs of both Management A and B status in Queensland. Appendix 2 gives further details on FHA declaration and management.

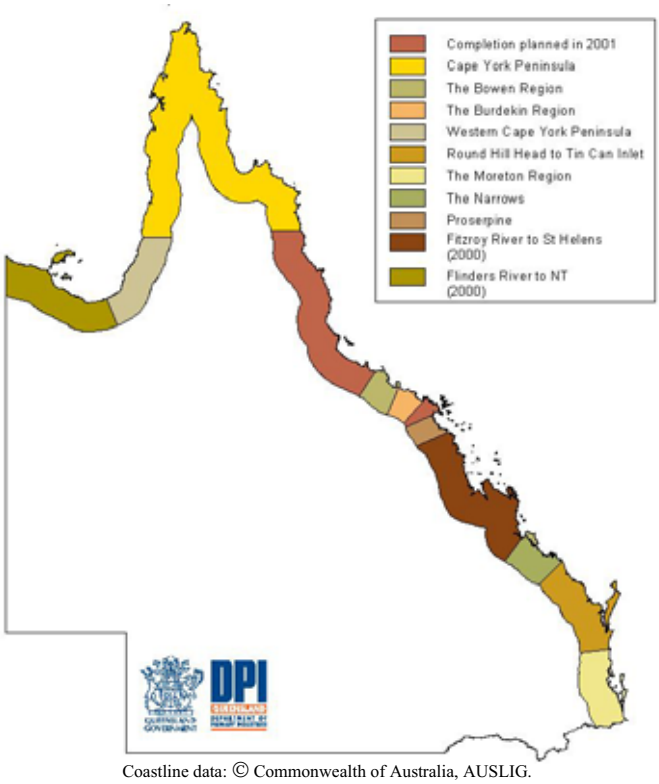
Further protection of significant wetland areas is achieved through the declaration of Ramsar sites. Formal listing of Ramsar sites was the result of the Convention on Wetlands of International Importance. Coastal wetland resources are an important consideration in the nomination of these Ramsar sites. In order for a site to be eligible for nomination as a Ramsar site at least one of the following four criteria must be met. These criteria are:

1. Criteria for representative or unique wetlands;
2. General criteria based on plants or animals;
3. Specific criteria based on waterfowl; and
4. Specific criteria based on fish.

Further details of these criteria can be found in Appendix 3. This study provides baseline information required for Ramsar site nomination.

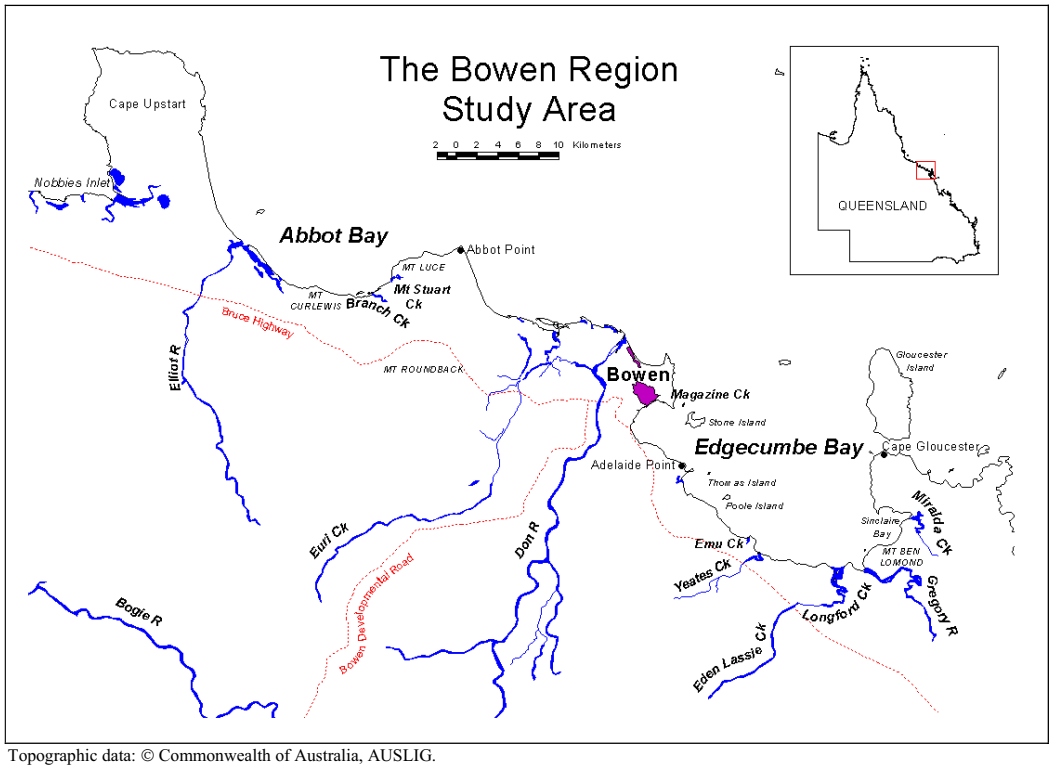
1.2 Current Progress of Queensland Coastal Wetlands Resource Mapping

Approximately two thirds of the Queensland coastal wetland resources have been mapped or are currently being mapped by the Queensland Department of Primary Industries Fisheries Group as a baseline resource for FHA declaration and continued monitoring of these important environments. The areas that have been completed or are currently being mapped are displayed in Figure 1.1. This work has resulted in additional FHAs being recommended for South East Gulf of Carpentaria, Cape York, the Burdekin, the Narrows and from Round Hill Head to Tin Can Inlet (Danaher 1995a; Danaher 1995b; Danaher and Stevens 1995; Treloar and Danaher, in progress, Bruinsma and Danaher 1999). Abbot Bay and Edgecumbe Bay support important fisheries however, the coastal wetland environments in this region have not previously been mapped in detail. This report summarises the results of the mapping undertaken in the Bowen Region (from Abbot Bay to Edgecumbe Bay) and outlines the recommendation for FHAs within this Region. The 1: 100 000 map sheets of the coastal wetland communities of the Bowen Region are presented in Appendix 4.



Coastline data: © Commonwealth of Australia, AUSLIG.

FIGURE 1.1 Queensland Coastal Wetlands Resource Mapping Projects



Topographic data: © Commonwealth of Australia, AUSLIG.

FIGURE 2.1 Locality Map of the Bowen Study Area

SECTION 2. BACKGROUND

2.1 The Study Area

The study area extends from the eastern side of Cape Upstart to the west of Cape Gloucester encompassing Abbot Bay, the Don River Delta and Edgecumbe Bay (Figure 2.1). Between these two mountainous Capes, is a lowland coastal system that comprises mainly gently to moderately undulating plains, and broad, near flat or very gently sloping alluvial plains associated with the more major drainage systems. These plains are periodically flooded and merge seawards into saltpans and tidal mangrove and mud flats. The region falls within the Lucinda – Mackay Coast Bioregion as defined in the Interim Marine and Coastal Regionalisation for Australia (IMCRA Technical Group 1998).

The major urban centre within the region is Bowen (20°01'00"S, 148 °15'00"E) with a population of approximately 9000 people (ABS 1996). Land use is predominantly rural with extensive cattle grazing occurring within the catchments. Other land uses include limited amounts of industry, including aquaculture, and growth of horticultural crops such as fruit, vegetables and sugarcane (Ludescher 1997; QDPI 1993).

The mean annual rainfall for the Bowen Region is 836mm for the area from Cape Upstart to Abbot Point and 1028mm for the area from the Don River Delta to Cape Gloucester (Table 2, Digby *et al.* 1999). The highest rainfall is recorded in the months from December to April with a large proportion of this occurring as major storms. Long-term temperature data for Bowen indicate that the average daily maximum in January is 31.5°C and 24.2°C in July (Sinclair Knight and Partners 1990).

The area is subject to high-frequency cyclonic activity (between 10 and 15 cyclones/decade: IMCRA Technical Group 1988), flooding and prolonged drought (Aldrick 1988). Salt concentrations within the coastal wetland environments fluctuate due to the seasonality of the rainfall. Large amounts of run-off occur in the wet season whereas the Don River and other smaller creeks often dry out by the mid year dry spell.

The extreme tidal range at Bowen is 3.4m with a mean spring tidal range of 2.2m (Bucher and Saenger 1989). The prevailing winds in the summer are from east to northeast and from the east to the southeast in winter (Aldrick 1988). The extreme tidal range of the main estuaries within the study area, along with hydrology and catchment details, included in Table 2, were compiled from information in the Australian Estuarine Database (Digby *et al.* 1999).

The Edgecumbe Bay area is one of mixed lithology. The coastal wetlands are characterised by sediments of Quaternary age. Mount Ben Lomond is composed of granites and Paleozoic shales and greywackes extend from Ben Lomond to Miralda Creek. Tertiary sandstones and conglomerates also exist within the area. General geology of the Abbot Bay region includes quaternary coastal sand dunes interspersed with older granitic and dioritic hills (Mt. Luce) (ANCA 1996).

The study area falls within Queensland's dry tropics. The predominant terrestrial vegetation type in the Bowen area is dry sclerophyll open woodland and grassland (Sinclair Knight and Partners 1990). The mangroves of the study area are characteristic of those coastal areas with

low, highly seasonal rainfall, and high evaporation rates throughout the year and thus have fairly extensive saltpan development adjacent to them (Saenger *et al*. 1977).

TABLE 2 Hydrology and Catchment Details for the Main Estuaries within the Study Area.

WETLAND	MEAN ANNUAL RAINFALL (mm)	RUNOFF COEFFICIENT	EXTREME TIDAL RANGE (m)	CATCHMENT AREA (km^2)
Elliot River	836	0.17	3.4	478
Branch / Mt Stuart Creeks	836	0.17	3.4	147
Euri / Saltwater Creeks	1028	0.14	3.4	414
Don River	1028	0.15	3.4	1230
Emu / Yeates Creeks	1028	0.49	3.4	91
Longford Creek	1028	0.49	3.4	325
Gregory River	1028	0.49	3.4	185
Miralda Creek	1028	0.49	3.4	57

Data compiled from the Australian Estuarine Database (Digby *et al.* 1999). Data for minor estuaries within the study area were not included in the database.

2.2 Fisheries of the Region

The Region from Abbot Bay to Edgecumbe Bay is an important area for both recreational and commercial fishers. Branch Creek, Elliot River and Euri Creek are important breeding and nursery grounds for many species of fish, prawn and crabs and thus play an important role in maintaining the fisheries resources of the Bowen area (Environment Science and Services Pty. Ltd. 1984). Additionally, the wetlands of the Don River catchment are recognised as important nursery areas for banana prawns, crabs and many fish species and are an important buffer zone between the land and marine environment (Glaister *et al.* 1993; Hill 1982; Robertson and Alongi 1992). Bucher and Saenger (1989) recognised that the estuaries of Yeates Creek, Longford Creek, Gregory River and Miralda Creek contribute significantly to the ecology of Edgecumbe Bay due to the extent of wetlands associated with these waterways. Yeates Creek, Longford Creek and Gregory River were identified as the most intensively fished estuaries in the area.

The total catch by 30-minute grid for the commercial net fishery in 1998 is displayed in Figure 2.2. The majority of the species targeted in the net fishery rely on coastal wetland environments for food sources and habitat requirements at some stage of their life cycle. Barramundi, blue and king threadfin, grey mackerel and shark dominate the tropical Queensland net fishery, from the Curtis Coast north. Species such as mullet, bream, whiting, tailor, gar and spotted and school mackerel represent the sub-tropical net fishery. The net fishery catch in the waters adjacent to the study area is relatively high.

Ludescher (1997) reported that there were 85 licensed commercial fishers holding membership of the Bowen branch of the Queensland Commercial Fishermen's Organisation (QCFO). Annual production from the inshore, foreshore and trawl fisheries in the Bowen Region typically has a wholesale market value of around $90 000, $350 000 and $2.4million respectively (pers. comm. Lew Williams 1999). The inshore fishery includes barramundi, blue and king threadfin and mud crab whereas the foreshore fishery includes shark and spotted and grey mackerel. Prawns and bugs are targeted in the trawl fishery.

Recreational catches in the Bowen Region include bream, flathead and tarpon (Saenger 1982) as well as banana prawns, barramundi, mangrove jack, salmon and lesser mackerel (Ludescher

1997). The public Bowen Wet Weekend Fishing Classic held in September has attracted approximately 2000 participants (Ludescher 1997).

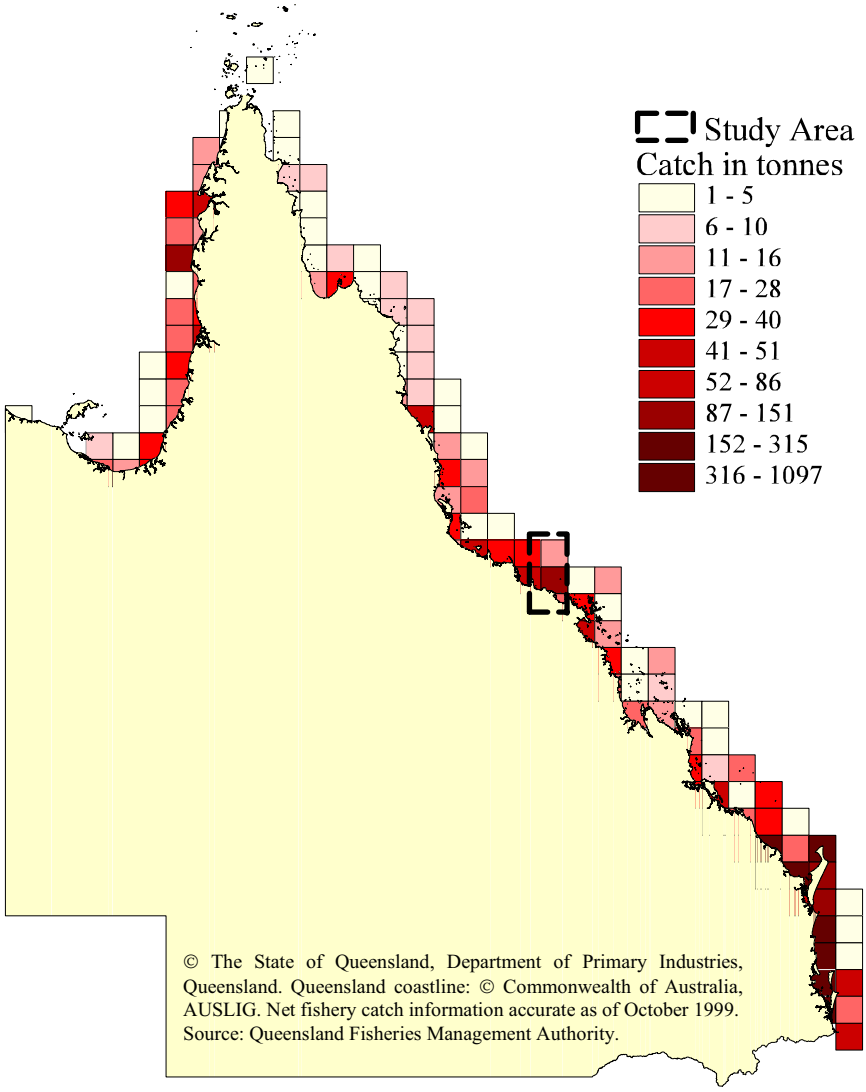


FIGURE 2.2 Queensland Net Fishery Catch by 30-minute Grid, 1998.

2.3 Coastal Wetland Environments

Mangrove and seagrass communities are recognised for their value to fisheries production. Both habitats directly support local inshore and offshore fisheries through the provision of food, shelter, breeding and nursery areas. Previous DPI research (Quinn 1992) has estimated that estuarine habitats provided by mangroves and seagrasses are critical to more than 75% of commercially and recreationally important fish and crustacean species during some stage of their life cycle (eg. prawns, mud and blue swimmer crabs, barramundi, whiting, flathead, bream and mullet). Mangrove and seagrass communities form only part of a range of coastal habitats (along with unvegetated to samphire-dominated saltpans, saline grasslands, intertidal flats, rocky foreshores and coral reefs) that all provide a diversity of environments maintaining

marine and estuarine ecosystems. However, mangrove communities are under continued pressure from coastal, urban and agricultural development (see Section 2.4 and 2.5).

For the purposes of this study, environments located between the highest astronomical tide contour and the low water mark (ie. the intertidal communities) are described collectively as coastal wetlands. The absence of a universally accepted definition of a mangrove community leads to many different interpretations of areal extents of "mangroves". Here, the term mangrove community refers to any community within the intertidal zone that is dominated by trees and shrubs. Saltmarshes are intertidal plant communities that are dominated by salt tolerant herbs and low shrubs, such as samphires and salt couches (Hopkins *et al.* 1998). Two subsets of this vegetation type are recognised in this study. Saltpans are those hypersaline areas that range from unvegetated claypans to areas dominated by samphire vegetation. Saline grasslands are those areas that are dominated by *Sporobolus virginicus* (salt couch).

Mangroves

Mangroves are a diverse group of predominantly tropical shrubs and trees growing in the marine tidal zone (Duke 1992). These marine plants serve a wide variety of functions including: - physical protection of the coastal fringe from erosion and flooding; sediment trapping; nutrient uptake and transformation; provision of a variety of plant and animal products; and provision of habitat for wildlife such as birds and crocodiles (Claridge and Burnett 1993, Ewel *et al.* 1998).

Mangrove species often have distinct distributional ranges at different geographic scales (Duke 1992). The physiological tolerance of each species to low temperature is the chief limiting factor to their latitudinal distribution (Duke *et al.* 1998). Consequently, species diversity generally decreases with increasing latitude.

Intertidal areas are subject to an extreme range of environmental parameters including salinity, soil type, frequency of inundation (both tidal and fresh) and wave action. As mangrove species are variable in their tolerance to these factors a pattern of species distribution known as zonation often occurs for these plants (Lovelock 1993). Mangrove zones in Queensland can vary from almost bare saltpans to dense forests more than 30 metres tall. By studying mangrove zonation at a particular location, indirect information can be derived on the extent of tidal inundation, and hence the direct utilisation by marine fauna. For example, Closed *Rhizophora* zones (or communities) which occur on the waters edge generally receive inundation with every high tide (twice a day for this region). In contrast Open or Closed *Ceriops* communities, which occur towards the landward mangrove edge, are generally only inundated on the spring tides that occur only once or twice per month.

The Bowen Region falls within the Lucinda – Mackay Coast Bioregion as defined in the Interim Marine and Coastal Regionalisation for Australia (IMCRA Technical Group 1998). The IMCRA Technical Group (1998) identified the Lucinda – Mackay Coast Bioregion wetlands as having less complex and diverse mangrove communities and lower littoral fauna diversity than those of regions to the north have. Thirty-six mangrove species have been identified in the Cape York Peninsula region whereas only 20 species are recorded to occur the Lucinda – Mackay Coast Bioregion. Additionally, the zonation of the mangrove communities is not as defined in this region compared to the wetter tropical areas.

The following twenty species are found within the Lucinda – Mackay Coast Bioregion.

- *Acanthus ilicifolius* L. — Holly Mangrove
- *Acrostichum speciosum* Willd. — Mangrove Fern
- *Aegialitis annulata* R. Br. — Club Mangrove
- *Aegiceras corniculatum* (L.) Blanco — River Mangrove
- *Avicennia marina* (Forsk) Vierh. — Grey Mangrove
- *Bruguiera gymnorrhiza* L. Lam. — Large-Leafed Orange Mangrove
- *Bruguiera parviflora* (Roxb.) Wight and Arn. Ex Griff. — Small-Leafed Orange Mangrove
- *Ceriops tagal* C. T. White — Yellow Mangrove
- *Crinum pedunculatum* R.Br. — Mangrove Lily
- *Cynometra iripa* Kostel — Wrinkle Pod Mangrove
- *Excoecaria agallocha* L. — Milky Mangrove
- *Heritiera littoralis* Ait. — Looking-Glass Mangrove
- *Hibiscus tiliaceus* L. — Native Hibiscus
- *Lumnitzera racemosa* Willd. — Black Mangrove
- *Osbornia octodonta* F. Muell. — Myrtle Mangrove
- *Sonneratia alba* Sm. — Mangrove Apple
- *Rhizophora apiculata* Bl. — Tall-Stilted Mangrove
- *Rhizophora stylosa* Griff. — Red Mangrove
- *Xylocarpus granatum* Koen — Cannonball Mangrove
- *Xylocarpus mekongensis* Pierre — Cedar Mangrove

In comparison, the Lucinda – Mackay Coast Bioregion contains a higher species diversity of mangroves than the Moreton Region in southeast Queensland in which only 9 species of mangroves have been identified (Duke 1992). The zonation of the wetlands in southeast Queensland generally is less pronounced than in the Bowen Region Lucinda – Mackay Coast Bioregion.

The primary production of mangroves varies between different communities. Factors affecting net primary productivity and forest growth include soil nutrient status and redox potential, salinity, temperature, light intensity, associated fauna and tidal flushing (Clough 1992, Amarasinghe and Balasubramaniam 1992). Economically important detrital marine food webs are supported by primary production from mangrove trees. Unfortunately, there is a lack of quantitative information regarding the direct benefits gained from the various mangrove forest community types.

Saltmarshes

Saltmarshes are intertidal plant communities that are dominated by salt tolerant herbs and low shrubs, such as samphires and salt couches (Hopkins *et al.* 1998). In these environments, interactions of the soil, water and air provide optimal environmental conditions, which under specific circumstances allow fisheries resources to feed, grow and reproduce to complete their lifestyle (Beumer *et al.* 1997). The Lucinda – Mackay IMCRA Region contains 8 saltmarsh species (IMCRA Technical Group 1998).

Seagrasses

Seagrasses are productive flowering plants, which are able to complete their life cycle completely submerged beneath marine waters (Mateer 1998). In order to establish a healthy community, seagrasses require minimum exposure to air, shelter from high-energy waves,

sufficient light penetration for photosynthesis and marine salinities. Consequently, coastal and surface topography, water depth and turbidity, and freshwater run-off all influence seagrass distribution and abundance patterns.

Coles *et al* (1992) report on the distribution of seagrasses in the Bowen Region. There are 8 species of seagrasses found in this Region compared to 13 species found in the Torres Strait (Poiner *et al* 1989) and 5 species in south east Queensland (Coles *et al* 1989).

Monitoring human induced change in seagrass communities through time is a difficult process as these communities are intrinsically dynamic. Natural variability in the species composition, density and biomass of seagrass communities over time results from the different responses of seagrasses to environmental parameters such as temperature, water turbidity, sediment stability and nutrient levels (English *et al.* 1994). For this reason, distribution patterns from previous studies can only be considered as "snapshots" of seagrass distribution in a window of time. However, as these regions have supported seagrass communities in the past, it is possible that they may do so in the future, providing the environmental conditions for establishment and maintenance of the meadows are favorable.

Freshwater Swamps

The contribution of freshwater swamps adjacent to coastal wetland systems to the productivity of fisheries habitats is relatively unstudied. However, the importance of freshwater input to mangrove communities has been recognised. Duke *et al.* (1998) report that areas of higher coastal rainfall and high riverine inputs of freshwater tend to support more diverse and taller mangrove forests. The influence of rainfall and freshwater seepage on mangals has also been presented as a unifying theme that helps to explain the distribution and diversity of mangroves at both a regional and local level (Semenuik 1983).

Other Habitats

Despite their minimal primary production, non-vegetated habitats such as rocky shores and intertidal flats are important fisheries habitats. Erftemeijer and Lewis (1999) recognised that intertidal mudflats constitute an important habitat that support a high biodiversity and biomass of benthic invertebrates, sustain productive fisheries and provide important feeding grounds for migratory shorebirds. Intertidal flats are defined as the zone exposed at low tide and submerged at high tide (Bird 1968), and may be unvegetated sand or mud or colonised by seagrass or algal beds.

2.4 Alterations to Coastal Wetland Environments

The coastal wetlands within the Bowen Region are predominantly in pristine or near pristine condition (Hegerl 1993a) (Table 6.2). However, some specific locations have undergone significant alterations. Major impacts to the mouth of the Magazine Creek estuary (also known as Saltwater Creek) east of Bowen have occurred due to the construction of a marina, causeway and pipeline across its wetlands as well as from dredging a channel through the tidal flats to the marina (Hegerl 1993a). Areas of mangrove have been cleared and changed tidal inundation patterns have resulted in mangrove mortality.

An area used for commercial salt extraction, the Bowen Saltponds, is located south of the town of Bowen. Reclamation of the coastal wetland vegetation for salt evaporation ponds has resulted in a considerable reduction of the original coastal wetland vegetation of the area. Changed tidal inundation patterns, due to the construction of bund walls, have resulted in

mangrove death. Additionally, construction of the highway and railroad yards has significantly altered the drainage of the upper estuary. Despite these alterations the remaining mangrove forest plays an important role in protecting the salt evaporation ponds from storm waves.

A levee has been constructed on the western side of Abbot Point and crosses from Mt. Stuart Creek to Branch Creek (Bucher and Saenger 1989). Mangroves on the landward side of this levee have been isolated from tidal waters and have therefore died. Although the tidal inundation patterns have changed, resulting in mangrove mortality, it is believed that the area behind the levee is still inundated by the highest king tides (pers. comm. John Martin, Abbot Point Port Authority 1999). The main purpose of the levee is an access route to creeks for recreational fishing. Additionally, bunds have been built on the eastern side of Abbot Point in the area of The Lake in order to isolate the lake from tidal influence from this side and to increase the depth of the water impounded for water bird habitat (ANCA 1996).

The development of an alumina refinery has been proposed by Comalco Limited approximately 6km south of Bowen and adjacent to the Adelaide Point wetland communities. The construction of a refinery could result in the loss of a small area of mangroves in the region. However, Hollingsworth Consultants (1984) expected that in the long term this loss would not have any significantly adverse physical or physico-chemical impacts on the marine biology or fisheries industries of Edgecumbe Bay.

2.5 Aquaculture Developments

A prawn aquaculture facility exists on the south side of Eden Lassie Creek and a second area is licensed for prawn farming north of Mt Curlewis adjacent to Abbot Bay. Pacific Aquaculture and Environment (1998) have identified regions adjacent to wetland areas in both Abbot and Edgecumbe Bay as optimal sites for future aquaculture development. This includes significant regions at Abbot Point, Adelaide Point and Sinclaire Bay. There have been preliminary inquiries to DPIQ concerning aquaculture developments from landholders and consultants in Abbot Bay. However, to date there have been no formal applications for aquaculture development in the study area.

2.6 Cultural Heritage Significance

The region extending from Cape Upstart to Abbot Point and including Mt Roundback forms a clan area of significance to the Juru people and the Wothan (Black Crow) clan. Wetlands, ocean and beach systems in the area formed major hunting and gathering habitats and beach scrubs along Abbot Beach were utilised for plants and fruits. The area is still used today by the Giru Dala people for hunting and gathering and as a spiritual and social centre (Natural Resource Assessments Pty Ltd 1997).

Prior to European settlement, the Bumbarra group of the Gia tribe inhabited the area from Bowen south to the headwaters of the Proserpine River (Hegerl 1993a). Hollingsworth Consultants (1984) stated that the lack of campsites and the absence of shell middens and other indications of occupation would suggest a history of sporadic occupation and passage through the area.

2.7 Conservation Values and Existing Conservation Measures

Sites at Abbot Point – Caley Valley (wetland reference BBN001QL) and Edgecumbe Bay (wetland reference CMC003QL) have been included in the National Directory of Important Wetlands. Abbot Point – Caley Valley is considered significant due to the impounded waters and its seasonal richness of the area as habitat for waterfowl and waterbirds (ANCA 1996). The extensive mangrove communities, including *Ceriops*, *Avicennia* and *Rhizophora* communities, are considered as notable flora within the area. The ecological features of the Edgecumbe Bay site were noted to include intertidal mudflats and mangrove communities.

The coastal wetlands associated with the Gregory River system have been assigned as 'key' Queensland coastal wetlands due to their high local as well as regional value. The wetlands are significant in that they represent a wetland type that is an intermediate between wetlands that experience higher rainfall immediately to the south and the drier Brigalow Belt Biogeographic Region wetlands to the north and south (Hegerl 1993b).

The Bowen Saltponds is listed as a nationally important site for the migratory bird, the Mongolian Plover (Watkins 1993).

Fish Habitat Areas have been declared throughout coastal Queensland to sustain existing and future fishing activities and to protect the habitats upon which fish and other aquatic fauna depend (QDPI 1997). Within the Lucinda – Mackay Coast region there are three FHAs of Management A status (Bowling Green Bay, Repulse and Sand Bay) and four FHAs of Management B status (Palm Creek, Cattle Creek, Bohle River and Midge). No FHAs exist in the Bowen region. The closest declared FHAs are the Bowling Green Bay FHA, Ayr, north of Abbot Bay, and the Repulse FHA, south of Edgecumbe Bay (Appendix 5). The major fish habitat types that are protected within the Bowling Green Bay FHA include Closed *Rhizophora* and Closed *Ceriops* mangrove stands with extensive areas of salt marsh, along with sparse seagrass beds within the bay (Beumer *et al.* 1997). A mangrove dominated floodplain with *Rhizophora* sp., *Acanthus ilicifolius*, *Acrostichum speciosum*, *Avicennia marina* and *Ceriops tagal* is protected within the Repulse FHA along with mangrove lined creeks, intertidal flats and seagrass beds around the mouth of Repulse Creek (Beumer *et al.* 1997).

Within Edgecumbe Bay, the coastal wetlands from Adelaide Point in the south to Cape Gloucester in the north lie within the Townsville to Whitsunday Marine Park (General Use Zones A and B). However, the majority of the study area is currently excluded from the Great Barrier Reef Marine Park.

SECTION 3. METHODS

3.1 Data

Maps of coastal wetland communities were produced from Landsat 5 Thematic Mapper (TM) satellite imagery. The eastern side of Cape Upstart to Abbot Point was mapped using a May 1994 Townsville TM (28/05/1994) scene which was rectified to the Australian Map Grid (AMG) with final radiometric correction and ground control points (GCP). A July 1995 Whitsunday TM scene (27/07/1995) with the same level of rectification and corrections was used to map the area from Abbot Point to Cape Gloucester. Landsat scenes of the same date were not used due to the limited availability of data. To minimise the potential problems associated with this discrepancy the study area was split into three geographic regions, (Abbot Bay, the Don River Delta and Edgecumbe Bay) which were then mapped from different images as described above. These three regions represent geographically separate units (bays and a delta) and were therefore considered as appropriate units for investigation.

The spatial resolution of Landsat TM data is 30m x 30m. The spectral characteristics of the data as well as details of the Landsat satellites are outlined in Appendix 6.

In addition to the satellite imagery, St. Lawrence to Townsville – Beach Protection Authority (BPA) colour, 1: 12 000 aerial photography flown in 1998 was used. The most current aerial photography available for the area was used in order to eliminate mapping errors due to changed conditions since the Landsat imagery was collected.

3.2 Mapping Methods

The satellite imagery was processed using ERDAS Imagine ® 8.3.1 on a MS Windows NT operating system. Six TM bands (excluding Band 6 – the thermal band) were contrast stretched using a linear stretch and breakpoints to highlight the intertidal regions. All water bodies were spectrally masked out using a TM band 4 (near infrared) image. In order to limit the area of the classification to the coastal wetland environment the terrestrial land features were masked out. The upper limit of the intertidal zone cannot be separated spectrally and so the boundary was interpreted manually using a false colour composite of TM bands 1, 4 and 5 (through blue, green and red colour guns, respectively) in conjunction with the colour aerial photography. This false colour composite is the best combination for identifying the intertidal zone and uses the most decorrelated bands (Sheffield 1985).

The remaining imagery, which included the intertidal zone and a small strip of adjacent coastal land, was processed using an unsupervised classification procedure. ERDAS Imagine uses the Iterative Self-Organising Data Analysis Technique (ISODATA) classification algorithm in order to create clusters of pixels that are spectrally similar. The ISODATA utility repeats the clustering of the image until either a maximum number of iterations have been performed, or a maximum percentage of unchanged pixels (convergence threshold) has been reached between two iterations (ERDAS 1997). A limit of thirty iterations or a convergence threshold of 99% was set in this classification. The resulting classes were labelled according to their dominant cover type with the aid of the aerial photography. Clumps of pixels less than 0.5 hectare were eliminated and the image was smoothed using a three by three pixel moving kernel.

The maps were converted from raster to vector format using ARC/INFO ® GIS software. To improve cartographic presentation of the data the jagged vector boundaries were splined and generalised and polygons with areas under 0.5 hectare were excluded. The vector coverages were overlaid on a Band 3 (visible red) Landsat TM layer (Map Sheets 1 – 3). Maps were produced using ARCVIEW ® GIS Version 3.1 at a scale of 1:100 000.

Coastal wetland communities were also overlaid on the Digital Cadastral Database (DCDB) to produce a 1: 250 000 map of tenure within the study region (Appendix 7).

3.3 Field Methods

The computer-based community classification was validated with fieldwork conducted during November 1997. At selected sites information on mangrove community floristics and structure was documented. At each site data recorded included the specific composition of mangroves, dominant genus, estimated density (Projective Foliage Cover - PFC) of each vegetation layer, composition and hardness of substrate, and presence/absence of seedlings, samphires, grasses, algae, leaf litter, roots, ferns, epiphytes, sedges and ponds.

The amount of fieldwork able to be done was limited by accessibility to the mangroves and by time and budget constraints. The information collected from the fieldwork was used to aid in the classification of the satellite image and the interpretation of the aerial photography. As the field sites were used to derive the final wetland classification they were not used in assessing its accuracy. Rather a set of random points was generated in order to assess the accuracy of the classification (Section 3.5).

3.4 Classification Details

Mangroves were classified to the community level on the basis of the dominant genus / genera present and relative densities. Generic level was selected as species within some genera can only be identified during the fruiting/flowering seasons (eg. *Rhizophora* and *Bruguiera* spp). The density of the community was determined by estimating the PFC. A canopy cover of greater than 50% was classified as closed, while less than 50% was identified as open.

The standard Specht (1987) vegetation categories of “forest” and “shrub”, which are based on height, were not included in this classification. This is due to the fact that community height cannot be determined from the Landsat TM data.

Only areas subject to tidal inundation were included in this mapping exercise. Excluded classes included permanent pools of water and elevated land containing terrestrial vegetation. Tidally exposed bare mud and sandbanks were also excluded.

3.5 Accuracy Assessment

A set of 120 random points was generated for accuracy assessment. The coastal wetland community present at each of these points was determined from the 1: 12 000 BPA aerial photography and this was compared to the class assigned on the maps. Some randomly assigned points (32) were beyond the limit of the aerial photography and thus could not be included in the accuracy assessment. An error matrix using this data was generated and the overall accuracy along with user’s and producer’s accuracy was calculated.

The overall classification accuracy is a measure of the number of correct pixels in the error matrix. User's accuracy is the probability that a pixel classified on the map actually represents that category on the ground and producer's accuracy calculates the probability of a reference pixel being correctly classified (how well a certain area can be classified) (Jensen 1996).

3.6 Intertidal Flats and Freshwater Swamps

The foreshore flats and swamps themes from the digital GEODATA TOPO-250K topographic map series (AUSLIG 1994) were used to create maps of intertidal flats and freshwater swamps (Appendix 8). The GEODATA product is primarily sourced from the 1: 250 000 scale National Topographic Map Series, which was completed in 1988. Foreshore flats and swamps from the Bowen, Ayr and Proserpine map sheets were utilised. Foreshore flats are defined as part of the seabed between mean high water and the line of low water. Swamps are defined as land that is so saturated with water that it is not suitable for agricultural or pastoral use and presents a barrier to free passage. It is often covered with characteristic grass and reed growths, and the degree of wetness may vary with season (AUSLIG 1994). Areas of intertidal flats and swamps have not been calculated from this data as this coverage is current only to 1988 and intertidal flats and swamps can be variable in distribution. The coverages are included to provide an indication of the extent of intertidal flats and freshwater swamps in the study area and should not be considered as an accurate present day distribution. Overlaying the foreshore flats coverage on the Landsat TM image gives an indication of where the spatial distribution of intertidal flats has changed since the coverage was created (1988).

3.7 Assessment of Coastal Wetlands for FHA Nomination

The suitability of various coastal wetland systems for nomination as candidate areas for FHA declaration is currently assessed on the basis of the following criteria:

1. Size
2. Diversity of or specific habitat features
3. Diversity of or specific marine fauna and flora
4. Level of existing and future disturbances
5. Unique features
6. Existing or potential fishing grounds
7. Protected species

The details of the methods of assessment of these criteria are included in Table 3.1.

TABLE 3.1 Details of the Methods of the Coastal Wetland Significance Assessment

CRITERIA	SUBCATEGORIES	DETAILS
Size		Area of mangrove and saltmarsh communities, calculated in hectares.
Diversity of or specific habitat features	Diversity of Mangrove and Saltmarsh Communities	**High (H)**: 11 – 14 mangrove and saltmarsh communities present
		Medium (M): 5 – 11 mangrove and saltmarsh communities present
		Low (L): 1 – 4 mangrove and saltmarsh communities present
		The number of mangrove and saltmarsh communities was calculated on the basis of the mapping conducted for this investigation. See Section 4.1 for the descriptions of these mapping units.
	Presence of Intertidal Flats	Comments on the extent of intertidal flats along the coastline were based on aerial photograph interpretation. See also Section 5.5.
	Presence of Rocky Foreshores	Comments on the location and extent of rocky foreshore features were based on 1: 100 000 topographic map details. Comments were not made for each individual coastal wetland, as interpretation of larger scale aerial photography or maps was not undertaken.
	Adjacent Freshwater Swamps	**Presence (Y)** or **absence (N)** of freshwater swamps adjacent to the coastal wetland communities. O indicates freshwater swamps nearby but not adjacent. The "swamp" coverage from the AUSLIG 1: 250 000 digital topographic series was used. See Appendix 8.
Diversity of or specific marine fauna and flora		Comprehensive surveys of species diversity for each wetland system were not conducted as part of this investigation. Specific, noteworthy marine flora communities have been described in Section 7.2 and are recorded as unique features (see below). Information concerning the diversity of fauna was not included in this evaluation.
Level of existing and future disturbances	Disturbance to Coastal Wetland Vegetation	**Pristine to Near pristine (P)** **Limited Alterations (LA)** – only a small part of the total wetland has been altered and natural drainage is considered to be essentially intact. **Moderate Alterations (MA)** – up to 20% of the wetland area is directly altered and / or the natural drainage within the wetland is considered to have been modified, but not drastically altered. **Extensive Alterations (EA)** - >20% of the wetland area is directly altered and / or natural drainage is considered to have been drastically modified. **N/A** – information not available for this wetland system. **Source** - Hegerl (1993a) Wetlands Database
	Disturbance to Adjacent Terrestrial Vegetation	**Near Pristine (NP)** : natural cover >90%
		Largely Unmodified (LU) : natural cover ~65 – 90%
		Modified (M) : natural cover ~35 – 65%
		Severely Impacted (SI) : natural cover <35%
		Adjacent terrestrial vegetation refers to the vegetation within 5km of the upper tidal limit.
Unique Features		**Presence (Y)** of unique features. The details of these features are included in Section 7.2.
Existing or potential fishing grounds	Significant / Important Fishing Grounds	**Significant (Y)** fishing grounds. Assessed from local knowledge of each coastal wetland system and / or from literature review. See section 2.2 for details.
Protected species	Not included in this evaluation.	All marine plants are protected under fisheries legislation. Other information on protected species was not collated as part of this exercise.

SECTION 4. RESULTS

4.1 Description of the Mapping Units

CLOSED *RHIZOPHORA*	**(Figure 4.1)**
Habitat	Occurs fringing waterways low in intertidal zone with roots submerged during high tides.
Canopy	Usually dominated by tall, mature *Rhizophora* spp. which form a dense canopy (approximately 5 - 6m) with a PFC greater than 50%. Other species that may occur in this community are *A. marina* (emergent), *Bruguiera spp.*, and *C. tagal*. A low *A. corniculatum* community sometimes forms a narrow fringe on the water's edge.
Shrub layer	Poorly developed or completely absent.
Ground cover	*Rhizophora* stilt roots with a sparse cover of *Rhizophora* seedlings.

CLOSED *AVICENNIA*	**(Figure 4.2)**
Habitat	A very diverse community that can be found in a range of intertidal environments from the seaward edge (as a pioneer), accretion banks (as a fringe) to the landward edge.
Canopy	*A. marina* with occasional *C. tagal* and *Rhizophora* spp. forming a dense canopy with a PFC of greater than 50%. Heights less than 10m, often around 5m.
Shrub layer	May have *A. corniculatum* and *C. tagal* forming an understorey.
Ground cover	*A. marina* pneumatophores and seedlings form a ground cover.

OPEN *AVICENNIA*	
Habitat	Found on the seaward edge as a pioneer and on the landward edge that is only inundated by the highest spring tide.
Canopy	*A. marina* plants form a canopy that has a PFC of less than 50%. Height varies, generally less than 1m in areas bordering on Saltpans and up to 10m in pioneering zones.
Shrub layer	Generally absent
Ground cover	Occasional presence of samphires (on the landward edge) and a sparse coverage of *A. marina* pneumatophores.

CLOSED *CERIOPS*	**(Figure 4.3)**
Habitat	Generally occur on upstream creek edges and towards the upper intertidal limit on land more elevated than Closed *Rhizophora* communities and landward of Closed *Rhizophora* communities. Only inundated by the spring tides.
Canopy	Dominated by *C. tagal* with occasional *A. marina*, *Bruguiera* spp. and *L. racemosa* forming a subdominant. Height of the canopy across sites varies (from approximately 1 – 4m) however at an individual site is remarkably uniform. PFC greater than 50%. Dead *C. tagal* trees and debris can often be found on the landward edge of these communities **(Figure 4.4)**.
Shrub layer	Generally absent
Ground cover	Consists of sparse seedlings and roots of the species present.

OPEN *CERIOPS*	
Habitat	Occurs on the landward edge of the intertidal zone and is inundated by only the high spring tides. This community is often surrounded by Saltpans and is rarely on the water's edge, except on eroding banks.
Canopy	A community dominated by *C. tagal* with occasional *A. marina* emergents. The PFC is less than 50%; height varies from less than 1m in the extremely saline areas to approximately 3m.
Shrub layer	Occasional presence of other species such as *A. corniculatum* and *A. marina.*
Ground cover	Consists of seedlings of the species present along with a sparse to open coverage of samphires and grasses.

CLOSED *AVICENNIA* / *CERIOPS*	**(Figure 4.5)**
Habitat	Commonly bordering Saltpans on the landward side of Closed *Ceriops* communities in areas only inundated during spring tides.
Canopy	A mixed community of *A. marina* and *C. tagal* forming a canopy with a PFC of greater than 50%.
Shrub layer	*A. annulata*, *A. corniculatum* and *L. racemosa* may be present.
Ground cover	Occasional presence of samphires and seedlings of the species present.

CLOSED *AVICENNIA* / *RHIZOPHORA*	**(Figure 4.6)**
Habitat	Generally occurring within Closed *Rhizophora* communities.
Canopy	A mixed community of *A. marina* and *Rhizophora* spp. together forming a closed canopy with a PFC of greater than 50%.
Shrub layer	The dense understorey may consist of *A. annulata*, *A. marina* and *Rhizophora* spp.
Ground cover	Roots and seedlings of the canopy species.

CLOSED MIXED	**(Figure 4.7)**
Habitat	Generally found on landward edges and in the upper tidal reaches of creeks and rivers.
Canopy	A Closed mix of species in which *A. corniculatum*, *A. marina*, *Bruguiera* spp., *C. tagal*, *E. agallocha*, *L. racemosa* and *Rhizophora* spp. may be present.
Shrub layer	A shrub layer consisting of juveniles of the various canopy species may be present.
Ground cover	Seedlings and roots of the various species along with sparse samphires and grasses.

SALTPAN	**(Figure 4.8)**
Habitat	Occurs along the landward edge of the intertidal zone in a hypersaline environment that is only inundated by the highest spring tides.
Canopy	Sparse stunted (0.2 – 0.8m) plants of *A. annulata, A. marina* and *C. tagal* may occur.
Shrub layer	Absent
Ground cover	Ranging from no vegetation to closed samphires (Figure 4.9) and algae, commonly an open coverage of samphires such *Halosarcia halocnemoides* and *H. indica.*

SALINE GRASSLAND	
Habitat	Occurs along the landward edge of the intertidal zone in a hypersaline environment that is only inundated by the highest spring tides. Sometimes extends past the upper tidal limit in open *Casuarina* sp. communities.
Canopy	Generally absent
Shrub layer	Absent
Ground cover	Ranging from sparse to dense coverage of salt couch (*Sporobolus virginicus*) within which a sparse coverage of samphires may also occur.

4.2 Classification Accuracy

The overall accuracy of the mapping was calculated to be 90%. The user's and producer's accuracies are displayed in Table 4.1.

The upper intertidal limit in this region was often difficult to interpret due to the extreme low relief of the terrain, as low relief allows seasonal variability in the actual tidal limit. In some areas, Saltpans and Saline Grasslands were therefore difficult to distinguish from terrestrial flats and grasslands. The final boundary of the coastal wetlands was decided upon using a mixture of satellite image analysis, aerial photograph interpretation, topographic map detail and fieldwork. Despite the difficulty encountered in this area, both the user's and producer's accuracies were 96% for the Saltpan category.

Some mangrove areas are not represented on the map due to the fact that they are smaller than the minimum mappable unit for this technique. Any area smaller than the satellite image pixel size can not be detected by this method. Additionally, polygons smaller than 0.5hectare are purposefully eliminated to improve cartographic representation. Mangrove communities that are narrow and linear are often excluded during the mapping process because of the limitations of the technique.

Due to the similar nature of their foliage, *Bruguiera* sp. communities and *Rhizophora* sp. communities are not spectrally separable using satellite image analysis or even from aerial photograph interpretation. Field observations confirmed that tidal and terrestrial communities sometimes overlap with no clear boundary.

TABLE 4.1 User's and Producer's Accuracy for the Coastal Wetlands Maps

COMMUNITY	USER'S ACCURACY (%)	PRODUCER'S ACCURACY (%)
Closed *Rhizophora*	92	100
Closed *Ceriops*	87	91
Saltpan	96	96
Other	85	79

FIGURE 4.1 A Closed *Rhizophora* community along a waterway near Bowen.

FIGURE 4.2 A Closed *Avicennia* community pioneering on a coastal sand flat near Bowen.

FIGURE 4.3 A Closed *Ceriops* community bordering on a saltpan at Miralda Creek.

FIGURE 4.4 Dead *Ceriops* near Bowen.

FIGURE 4.5 A Closed *Avicennia* / *Ceriops* community bordering on a Saltpan.

FIGURE 4.6 A Closed *Avicennia* / *Rhizophora* community near Bowen.

FIGURE 4.7 A Closed Mixed community consisting of *A. annulata*, *A. marina*, *C. tagal*, *O. octodonta* and *Rhizophora* sp.

FIGURE 4.8 An extensive Saltpan at Gregory River.

FIGURE 4.9 A Saltpan dominated by samphire vegetation near Bowen.

SECTION 5. DISTRIBUTION AND SIGNIFICANCE OF THE COASTAL WETLANDS

5.1 General Distribution

The general trend in the distribution of coastal wetland communities in the Bowen Region is for Closed *Rhizophora* dominated communities to establish along the foreshore and watercourses. Closed *Ceriops*, along with Closed *Avicennia* and Closed Mixed communities tend to dominate the landward fringe of the Closed *Rhizophora* communities. Extensive Saltpans generally occur between the mangrove communities and the upper tidal limit. These Saltpans range from totally unvegetated in the extremely hypersaline areas to samphire dominated in less saline areas. Small areas of Saline Grassland exist in the upper intertidal region.

The Bowen Region can be divided into three main coastal units: Abbot Bay, the Don River delta and Edgecumbe Bay. For the purposes of this study, Abbot Bay is defined as the region extending from Cape Upstart to Abbot Point. The Don River delta includes the coastline from Abbot Point to Cape Edgecumbe and Edgecumbe Bay extends from Cape Edgecumbe to Cape Gloucester. Further details of the coastal wetland communities within these areas are included in sections 5.2, 5.3 and 5.4 respectively. The distribution of coastal wetland communities within the Bowen Region is displayed in Appendix 4: Map Sheets 1 – 3.

TABLE 5.1.1 Total Area of Coastal Wetland Communities of the Bowen Region

COMMUNITY	AREA (hectares)
Closed *Rhizophora*	3015.6
Closed *Avicennia*	284.3
Open *Avicennia*	1.3
Closed *Ceriops*	1454.9
Open *Ceriops*	37.3
Closed *Avicennia* / *Ceriops*	153.3
Closed *Avicennia* / *Rhizophora*	77.3
Closed Mixed	75.6
Saltpan	5427.6
Saline Grass	7.7
Total	10 534.9

Alterations to the coastal wetland communities, details of land use in the catchments and notes concerning proposals for development and conservation measures are summarised in Table 6.1.

5.2 Abbot Bay

The eastern side of Abbot Bay, consisting of the Branch Creek and Mount Stuart Creek estuaries, is partially sheltered from prevailing easterly winds by Abbot Point and Mount Luce. The mangroves on the western side of the Bay are protected from wave action by sand banks upon which small Closed *Avicennia* / *Rhizophora* communities are pioneering.

Extensive Closed *Rhizophora* communities are associated with all three creek systems in this area (ie. Elliot River, Branch Creek and Mount Stuart Creek). Fringing the Closed *Rhizophora* on the landward side are narrow Closed *Ceriops* or Closed *Avicennia* / *Ceriops* communities. Extending from these are extensive Saltpans that range from samphire dominated to totally unvegetated. The terrain is of low relief and as such, the upper tidal limit is indistinct. Although the coastal wetland communities in Abbot Bay do not display a high degree of zonation, almost all of the mangrove communities mapped in this exercise are represented here.

TABLE 5.2 Areas of Coastal Wetland Communities of Abbot Bay

	AREA (hectares)			
	Elliot River	**Branch / Mt. Stuart Creeks**	**Abbot Bay Total**	**% of Abbot Bay Total**
Closed *Rhizophora*	545.7	312.2	857.9	18.7
Closed *Avicennia*	31.3	50.5	81.8	1.8
Open *Avicennia*	0	0	0	0
Closed *Ceriops*	108	166.2	274.2	6
Open *Ceriops*	3.8	3.9	7.7	0.2
Closed *Avicennia* / *Ceriops*	94	59.3	153.3	3.2
Closed *Avicennia* / *Rhizophora*	5.8	0	5.8	0.1
Closed Mixed	3.7	0	3.7	0.1
Saltpan	1071	2140.1	3211.1	69.9
Saline Grassland	0	0	0	0
Total	1863.3	2732.2	4595.5	

5.3 The Don River Delta

The development of sandbanks along the foreshore of this relatively exposed region of the coastline has allowed mangrove communities to establish. The wide extent and low relief of the Delta creates extensive habitat for mangrove communities to develop. Closed *Rhizophora* that is intermittently dissected by dune complexes that run parallel to the coastline dominates the seaward edge of the wetland. Again, Closed *Rhizophora* represents the greatest proportion of the mangrove communities in the area. The seaward edge of the wetland also has small patches of Closed *Avicennia* communities that have established on the sandbanks. A small Open *Avicennia* community is pioneering on a new sandbank at the mouth of the river. Within the Closed *Rhizophora* communities are some areas of Closed *Avicennia* / *Rhizophora*. The mangrove communities are generally low closed forest or closed scrub to 8m tall (Sinclair Knight and Partners 1990).

Behind the Closed *Rhizophora* communities is a mix of Closed *Ceriops* and Closed *Avicennia* communities with relatively distinct zonation. Landward of these areas are extensive Saltpans. The lack of freshwater input into the system in the winter months not only results in the Don River drying out but also the development of an extensive saline environment.

Further development of the Bowen Region may pose a threat to the coastal wetland communities of the Don River delta in the future. Agricultural fields already extend to the upper intertidal limit and further urban / tourism development for the Region has been proposed (the Whitsunday Springs Resort and Residential Community). Retention of riparian buffers would be appropriate to protect the wetlands.

TABLE 5.3 Areas of Coastal Wetland Communities of the Don River Delta

	AREA (hectares)			
	Euri / Saltwater Creeks	Don River	Don River delta Total	% of Don River delta Total
Closed *Rhizophora*	31.5	527.6	559.1	28.5
Closed *Avicennia*	8.7	109.2	117.9	6
Open *Avicennia*	0	1.3	1.3	0.1
Closed *Ceriops*	20.7	218.7	239.4	12.2
Open *Ceriops*	0	.7	.7	0.0
Closed *Avicennia* / *Ceriops*	0	0	0	0
Closed *Avicennia* / *Rhizophora*	13.2	55.9	69.1	3.5
Closed Mixed	0	0	0	0
Saltpan	211.8	762.9	974.7	49.7
Saline Grassland	0	0	0	0
Total	285.9	1676.3	1962.2	

5.4 Edgecumbe Bay

The estuaries of Edgecumbe Bay are well protected from the effects of wind and wave action by Cape Gloucester and Gloucester Island. The intertidal regions associated with Longford Creek, Gregory River and Miralda Creek (on the eastern side of the Bay) are particularly sheltered and thus support the largest mangrove communities in Edgecumbe Bay. Those wetlands on the western side of the Bay are generally a lot smaller and exhibit less distinct zonation than these eastern wetland communities.

The zonation within the mangroves on the eastern side of Edgecumbe Bay is clear, with Closed *Rhizophora* establishing on the shoreline and along rivers and Closed *Ceriops* communities behind. Small communities of Closed *Avicennia* are interspersed within the Closed *Rhizophora*. Saltpans are less prominent in this area than in Abbot Bay and the Don River Delta yet still form a major component of the wetlands. Closed Mixed communities occur in the upper tidal reaches of Gregory River and Rocky Creek.

Although a Closed *Rhizophora* community extends almost uninterrupted around the seaward edge of Mount Ben Lomond this community is smaller than the minimum mapping unit in many places. Only those areas larger than half a hectare and greater than one pixel (30m) wide could be mapped.

TABLE 5.4 Areas of Coastal Wetland Communities of Edgecumbe Bay

	Area (hectares)								
	Magazine Creek	**Bowen Saltponds**	**Stone Island**	**Adelaide Point**	**Emu / Yeates Creeks**	**Gregory River**	**Miralda Creek**	**Edgecumbe Bay Total**	**% of Edgecumbe Bay Total**
Closed *Rhizophora*	60.9	43.6	1.3	129.7	92.6	973.5	297.0	1598.6	40.2
Closed *Avicennia*	21	7.7	0	14.7	0	41.2	0	84.6	3.1
Open *Avicennia*	0	0	0	0	0	0	0	0	0
Closed *Ceriops*	32.7	38.9	0	28.5	82.6	650.4	108.2	941.3	23.7
Open *Ceriops*	13.3	0	0	0	11.2	1.8	2.6	28.9	0.7
Closed *Avicennia* / *Ceriops*	0	0	0	0	0	0	0	0	0
Closed *Avicennia* / *Rhizophora*	0	0	0	2.4	0	0	0	2.4	0.1
Closed Mixed	22.9	0	0	6.5	0	42.5	0	71.9	1.8
Saltpan	114.6	29.1	00	143.8	117.9	667.2	169.2	1241.8	31.2
Saline Grassland	0	0	0	0	0	7.7	0	7.7	0.2
Total	265.4	119.3	1.3	325.6	304.3	2384.3	577.0	3977.2	

5.5 Intertidal Flats, Rocky Foreshores and Freshwater Swamps

Intertidal Flats

Within the sheltered environment of Edgecumbe Bay intertidal flats are more prominent than in both Abbot Bay and the Don River Delta. Broad intertidal flats exist in particular between the Gregory River and Emu / Yeates Creek wetlands. Within Abbot Bay, intertidal flats exist at the mouths of both the Elliot River and the Branch / Mt Stuart Creek estuaries. However, the remainder of Abbot Bay is devoid of significant intertidal flats. Intertidal flats extend for approximately 14km along the coastline surrounding the Don River mouth.

Rocky Foreshores

Rocky foreshores exist within Edgecumbe Bay at the rocky headland of Cape Egdecumbe. Rock walls also exist following the coastline to the east and to the west of the Adelaide Point wetland and around some islands within the Bay.

Freshwater swamps

Freshwater swamps within the study area are limited in distribution to Abbot Bay. A large freshwater wetland to the north of the Elliot River mouth extends north for approximately 11.5km, following the coastline of Cape Upstart. A smaller wetland also exists to the south of the Elliot River wetland. Two small wetlands exist to the south west of the Branch / Mt Stuart Creek wetlands.

A large swamp environment exists to the south of Abbot Point. The salinity of this swamp area varies seasonally depending on the amount of freshwater input to the system. During the wet season the areas become brackish or mostly fresh. In the dry season, however, an absence of freshwater input and the occurrence of king tides create a saltpan environment. No freshwater wetlands exist within the Bowen Region south of this large Abbot Point wetland.

These freshwater wetland environments may contribute to the productivity of fisheries habitats in this Region (particularly as juvenile habitat for Barramundi) and are an important environment to consider for increased protection under Fisheries legislation.

SECTION 6. APPLICATION OF THE DATASET TO FHA PLANNING

6.1 Fish Habitat Area Declaration Process

FHAs are part of the on-going management of fisheries resources within Queensland and are declared with the specific intent to ensure continuation of productive recreational, indigenous and commercial fisheries in a region. The declaration of a FHA generally follows the process outlined below:

1. Nomination of an area as a candidate for declaration as a FHA.
2. Review of nomination and assessment of its priority for further investigation.
3. Site investigation / field habitat surveys, literature searches and reviews, assessment of fish catch records and preliminary discussions with user groups (eg. commercial fishers, recreational fishers, indigenous groups, local authority, other community groups, etc.) to determine if the nominated area meets FHA declaration criteria.
4. Preparation of an Area of Interest Plan and draft of known management issues.
5. Initial consultation with interested parties and relevant agencies.
6. Revision of information gathered during the initial consultation phase and preparation of a draft FHA Plan and a draft management strategy with recommendation of an appropriate management level (either 'A' or 'B', and use of a location-specific management plan).
7. Second round of consultation with interested parties and relevant agencies.
8. Revision of information gathered during the second round of consultation.
9. Preparation of a Declaration Plan of FHA Boundaries and submission of a proposal for declaration.
10. Provision of Plan and Submission to the Department of Primary Industries legal section.
11. Provision of Plan and Submission to the Minister for Primary Industries
12. Provision of Plan and Submission to the Governor in Council for declaration under the *Fisheries Regulation*.

The suitability of various coastal wetland systems for nomination as candidate areas for FHA declaration (ie. step 1) is currently assessed on the basis of the following criteria:

1. Size
2. Diversity of or specific habitat features
3. Diversity of or specific marine fauna and flora
4. Level of existing and future disturbances
5. Unique features
6. Existing or potential fishing grounds
7. Protected species

A summary of the assessment of the coastal wetlands from Cape Upstart to Gloucester Island, on the basis of these criteria, is included in Table 6.1. Details of the assessment methods and the category details are included in Table 3.1, Section 3.7.

Further details of the significance of specific coastal wetland communities are outlined in Section 8.2. This report concentrates on the identification of suitable areas for fisheries conservation from a coastal wetland community perspective.

Tenure of adjacent land is an important consideration in the FHA declaration process. Land tenure of the coastal strip from Cape Upstart to Gloucester Island, with the coastal wetland communities overlaid, is displayed in Appendix 7.

TABLE 6.1 Summary of Coastal Wetland Characteristics of the Bowen Region

WETLAND	AREA OF COASTAL WETLAND COMMUNITIES (ha)	DIVERSITY OF MANGROVE / SALTMARSH COMMUNITIES	INTERTIDAL FLATS	ROCKY FORESHORES	ADJACENT F / W SWAMPS	DISTURBANCE TO COASTAL WETLAND VEGETATION	DISTURBANCE TO ADJACENT TERRESTRIAL VEGETATION *	RECOGNISED / IMPORTANT FISHING GROUNDS	UNIQUE FEATURES
Abbot Bay	4595.5	M	At the mouths of the creeks and rivers.						
Elliot River	1863.3	M			Y	P	M	Y	Y
Branch / Mt Stuart Creeks	2732.2	M			Y	LA	M**	Y	Y
Don River Delta	1962.2	M	Extending for ~14km along the Don River mouth.						
Euri / Saltwater Creeks	285.9	M			Y	P	M	Y	
Don River	1676.3	M			N	N/A	SI	Y	Y
Edgecumbe Bay	3977.2	M	Broad intertidal flats within the sheltered bay environment.	See section 5.5					
Magazine Creek	265.4	M			N	EA	SI		
Bowen Saltponds	119.3	L			N	EA	SI		
Stone Island	1.3	L			N	P	M		
Adelaide Point	325.6	M			N	LA	LU		
Emu / Yeates Creeks	304.3	L			N	P	LU	Y	
Gregory River	2384.3	M			N	LA	M**	Y	Y
Miralda Creek	577.0	L			N	P	LU		Y

* See also catchment details Table 6.1

** The major impact to the terrestrial vegetation is through clearing or partial clearing for grazing. Grassland with open forest still exists in the majority of the area. There is little urban or agricultural development.

CRITERIA	CATEGORY DESCRIPTION (for further details see Table 3.1)
Diversity of Mangrove / Saltmarsh Communities	M – Medium L – Low
Adjacent Freshwater Swamps	Y – Yes N – No
Disturbance to Coastal Wetland Vegetation	P – Pristine / near pristine LA – Limited Alterations EA – Extensive Alterations N/ A – Information not available
Disturbance to Adjacent Terrestrial Vegetation	M – Modified SI – Severely Impacted LU – Largely Unmodified
Recognised Important Fishing Grounds	Y – Yes, see Section 2.2
Unique Features	Y – Yes, see Section 2.6, 2.7 and 8.2

TABLE 6.2 Alterations and Catchment Details of the Coastal Wetland Environments of the Bowen Region

WETLAND	ALTERATIONS	ALTERATION DETAILS	CATCHMENT DETAILS	NOTES
Elliot River	Pristine – near pristine		Mostly cleared or partially cleared	
Branch Creek / Mt Stuart Creek	Limited alterations	Levee crossing from Branch Creek to Mt Stuart Creek, Impounded water and bunds at the Abbot Point Port	Mostly cleared or partially cleared	
Euri Creek to Saltwater Creek	Pristine – near pristine		Mostly cleared with some agriculture and urban development close to the wetlands	Sinclair Knight and Partners (1990) - high conservation significance. Adjacent to proposed Whitsunday Springs Resort and Residential Community.
Don River	Information not available		Mostly cleared with some agriculture and urban development close to the wetlands	
Magazine Creek	Extensive alterations	Marina, causeway, pipeline, dredged channel	Mostly cleared	See Section 2.5
Bowen Saltponds	Extensive alterations	Much of original wetland reclaimed for salt evaporation ponds, bund wall construction	Mostly cleared, extensive forested areas on the west side, east mostly urban/industrial	See section 2.5
Stone Island	Pristine – near pristine	Freshwater drainage into wetland altered by construction of small dams in island gullies	Small patches of forest, mostly cleared	Townsville – Whitsunday Marine Park
Adelaide Point	Limited alterations	Several small dams preventing tidal inundation of drainage channels	Mostly cleared or partially cleared	Adjacent to proposed Comalco Limited Bowen Alumina Refinery (Hollingsworth Consultants 1984)
Thomas Island	Pristine – near pristine		Lowlying, uninhabited, predominantly grassland with scattered trees and shrubs	Townsville – Whitsunday Marine Park
Emu Creek	Pristine – near pristine		Mostly cleared or partially cleared	
Yeates Creek	Information not available		Cleared, partially cleared and forested land	Bucher and Saenger (1989) – ecologically significant area
Longford Creek / Gregory River	Limited alterations	Ponded pasture on Longford Creek	Mostly cleared or partially cleared for grazing. A few forested strips primarily along waterways.	Bucher and Saenger (1989) – ecologically significant area, Townsville – Whitsunday Marine Park
Miralda Creek	Pristine – near pristine		Trees, shrubs and grassland	

Source: compiled from Hegerl (1993a); Sinclair Knight and Partners (1990); Bucher and Saenger (1989); Hollingsworth Consultants (1984).

SECTION 7. RELATIONSHIP OF COASTAL WETLAND COMMUNITIES TO MARINE FAUNA

The importance of mangroves and seagrasses to marine fauna and fisheries productivity is well recognised. Robertson and Blaber (1992) have reviewed studies of the utilisation of mangrove communities by fish. Mangrove communities provide shelter from predators for juvenile fish and prawns through the structural complexity provided by prop roots, pneumatophores and fallen logs and branches. The increased turbidity in the adjacent waters also provides protection from predators. Mangrove communities are also important feeding sites for fish and increase the supply of food available to juvenile fish through primary production. The food provided may not be directly from the mangroves but through associated and dependent plankton or epibenthos.

Although the ecological background to the claim that mangroves are important for fisheries productivity is well documented, rigorously quantified relationships are surprisingly few (Baran in press). In Australia, Staples *et al.* (1985) found a correlation between the extent of mangrove-lined rivers and the annual catch of banana prawns. Pauly and Ingles (1986) reported that the most important part of the variance of the maximum sustainable yield of penaeids (53% of the variance) could be explained by a combination of area of mangrove habitats and latitude. However, these studies do not conclusively prove the relationship unless the real dependency of fisheries resources on the mangrove environment is examined. For example, is the mangrove zone essential for a given species; what are its trophic or reproductive relationships with this zone; are there alternative areas for its development (Baran in press)? Beumer and Halliday (1994) were able to demonstrate different feeding patterns exhibited by different species of fish. However, the extent to which these patterns reflect the dependence of the species on different intertidal zones was unclear.

Fringe and riverine forests are considered particularly important as habitat for juvenile and adult fish due to their accessibility and the level of nutrient export (Ewel *et al.* 1998). Portions of basin forests where tidal channels provide access are also considered important for the same reasons. Beumer and Halliday (1994) reported that the direct use of subtropical *R. stylosa* mangrove forest by fish in Tin Can Inlet is less than that recorded for other types of mangrove forests elsewhere in Australia. The low catch rates in these forests were attributed to a reluctancy or inability of fish to enter and use the available forest due to the root structure of *R. stylosa* which is not as open and unrestricted as *A. marina* forests. A study undertaken in Townsville (Robertson and Duke 1990) recorded a higher density of fish in tropical mangrove communities than in subtropical mangrove communities. The fish species were of little direct economic importance in Australia but they contribute as prey species to the production of economic species in adjacent open water. Table 7.1 is a comparison of fish density and standing crop (weight) for studies of fish within mangrove communities along the East Coast of Australia.

TABLE 7.1 Comparison of Fish Density (number per m^2) and Standing Crop (grams per m^2) for Studies of Fish within Mangrove Forests along the East Coast of Australia.

MANGROVE FOREST TYPE OR COMPLEX	NET TYPE	AREA SAMPLED (M^2)	DENSITY ($no.m^{-2}$) (% ECONOMIC)	STANDING CROP ($g.m^2$) (% ECONOMIC)	LOCATION	SOURCE
R. stylosa **(subtropical)**	Block	1000	0.05 ± 0.01 **(61)**	2.01 ± 0.30 **(80)**	Tin Can Bay	Beumer and Halliday (1994)
A. marina **(temperate)**	Block	~1000	~0.094 **(38)**	~6.4 **(32)**	Botany Bay	Bell *et al.* (1984)
A. marina **(subtropical)**	Block	3340	0.27 ± 0.14 **(75)**	25.3 ± 20.4 **(94)**	Moreton Bay	Morton (1990)
R. stylosa, C. tagal, A. marina **(tropical)**	Trap		3.5 ± 2.4[a] **(<6)**	10.9 ± 4.5[b] **(<36)**	Townsville	Robertson and Duke (1990)

Source: Beumer and Halliday (1994)
a = $no.m^{-3}$ as water depth varied greatly in this study
b = $g.\ m^{-3}$ as water depth varied greatly in this study

Ewel *et al.* (1998) recognised that different kinds of mangrove forest provide different goods and services. In the study, coastal wetland systems are divided into three extremes based on dominant physical processes. Tide-dominated mangroves are referred to as fringe mangroves, river-dominated mangroves as riverine mangroves and interior mangroves as basin mangroves. Productivity (generally measured by litterfall in these forests) is closely related to water turnover, with riverine >fringe >basin. Higher productivity and relatively shorter residence times of litter in riverine and fringe mangroves, both associated with higher frequency of inundation, make them particularly important, except where basin zones are much larger. Amarasinghe and Balasubramaniam (1992) found that the annual rate of Net Primary Production (NPP) in the waterfront zones of the mangrove stands (that is, estuarine and fringing stands) was greater than that of the backwater mangrove zones. Variations were once again attributed to differences in tidal flushing and influence of freshwater in the different localities.

Table 7.2 compares studies determining the primary production (through leaf litter) of different mangrove communities. Robertson and Daniel (1989) found that in tropical *C. tagal* forests, much of the leaf litter is removed by crabs (71%) with a microbial turnover being very low (<1% yr^{-1}). Less *A. marina* leaf litter is consumed by crabs (33%) with microbial turnover being much higher (32%) and tides exporting approximately 21% of the annual production. The leaves of *R. stylosa* and *C. tagal* have low initial nitrogen concentration, high C: N ratios and very high tannin concentrations. This results in decay rates slower than that of *A. marina* leaves which have high initial nitrogen concentrations, low C: N ratio and low tannin content (Robertson 1988). Although leaf litter production of *R. stylosa* mangroves is similar to that of *A. marina*, the greater export of its leaves and their relatively slower release of carbon and nitrogen, suggests that *R. stylosa* may be of less importance for primary production within communities than are *A. marina* mangroves (Beumer and Halliday 1994).

Despite the data concerning the different rates of primary production and nutrient export there is still not enough quantitative information to rank the fisheries value of different communities (or habitats) in importance against one another. Considerable variation in measuring mangrove leaf litter (Hutchings and Saenger 1987), along with the temporal nature of some habitats (eg. seagrass beds (Mellors *et al.* 1993, Poiner *et al.* 1989)) make quantification of the relative values of different species / densities difficult. Additionally, the assumption that dense communities (both mangroves and seagrasses) are more important than less dense communities does not always hold true. Beumer and Halliday (1994) found that shallow water habitats do not have to be continually covered with seagrass to be of value to fisheries. In terms of fish production, intertidal areas like those found in Tin Can Inlet can be as productive as adjacent mangrove areas.

As noted previously, the crab fauna is a significant contributor to leaf litter decomposition and hence is an integral component in nutrient cycling in these mangrove systems. The substrate in which the mangroves are growing (eg. sand, mud, and rocky rubble) could significantly effect the potential abundance of crustacean fauna, thus the nutrient cycling process itself.

TABLE 7.2 Comparison of studies determining the primary production of mangroves as leaf litter.

MANGROVE SPECIES	PRIMARY PRODUCTION ($g.\ m^{-2}.yr^{-1}$)	SOURCE
***R. stylosa* (tropical)**	556	Robertson (1986)
***R. mucronata* (tropical)**	441	Amarasinghe and Balasubramaniam (1992)
***A. marina* (tropical)**	519	Robertson and Daniel (1989)
***A. marina* (tropical)**	374	Amarasinghe and Balasubramaniam (1992)
***A. marina* (subtropical)**	580	Goulter and Allaway (1979)
***C. tagal* (tropical)**	822	Robertson and Daniel (1989)

Further Investigation

There is a need to identify and map fisheries habitat for the management and conservation of the resource, as well as a requirement for conducting further research into the interactions between fauna and the habitat. Studies combining data on mangrove forest primary productivity, fish species associated with these mangrove stands and feeding strategies of these fish species will contribute to a better understanding of the value of particular habitats to fisheries productivity. Continuation of the mapping of the coastal wetland communities of the Queensland coastline will provide quantitative data for incorporation into these studies. Additionally, it provides the base information required for monitoring short and long term changes in coastal wetland habitats.

SECTION 8. DISCUSSION

8.1 Regional Significance of the Bowen Coastal Wetlands

The Bowen Region experiences a relatively low annual precipitation level with most rain falling in the summer. The rainfall regime in the Region has facilitated the development of extensive Saltpans that become brackish to fresh in periods of high rainfall. Mangrove communities do not establish in this hypersaline environment due to the lack of freshwater input in the dry season. Wetlands to the north (Innisfail to Cairns) and to the south (Proserpine to Mackay) experience a higher rainfall that enables mangrove communities to establish further into the intertidal zone and limits the extent of the Saltpans. The extensive Saltpans associated with the Bowen Region wetlands are characteristic of the drier environment that occurs here.

Although expansive Saltpans have established in most of the Bowen Region, the mangrove communities, in particular Closed *Rhizophora*, are also relatively extensive. The higher run-off coefficient within Edgecumbe Bay compared to Abbot Bay and the Don River Delta indicates a larger amount of freshwater availability within these coastal wetland systems (see Table 2). The increased freshwater input in this area lowers the salinity of the upper intertidal zone, allowing mangroves to colonise and limiting the development of more extensive Saltpans. The distinct zonation of the wetlands associated with the Gregory River can be attributed to the higher freshwater input as well as the greater degree of terrain relief compared to Abbot Bay and the Don River Delta.

8.2 Significant Features of the Coastal Wetland Systems in the Bowen Region

Abbot Bay and the Don River Delta

The coastal wetland systems of Abbot Bay and the Don River Delta have been reported as significant for specific fisheries in the Region. The fisheries habitats associated with Branch Creek and Elliot River are important breeding and nursery grounds for many species of fish, prawn and crabs and thus play an important role in maintaining the fisheries resources of the Bowen area (Environment Science and Services Pty. Ltd. 1984). The wetlands of the Don River catchment are recognised as important nursery areas for banana prawns, crabs and many fish species and are an important buffer zone between the land and marine environment (Glaister *et al.* 1993; Hill 1982; Robertson and Alongi 1992). Additionally, Euri Creek has been recognised as an important breeding and nursery ground for many species of fish, prawns and crabs.

Abbot Bay and the Don River Delta have a lower diversity of fisheries habitats than the area of Edgecumbe Bay, further south. No extensive rocky foreshores were identified in Abbot Bay and the Don River Delta. Additionally, the intertidal flats within this area are limited in their distribution to the mouths of the creeks and rivers. A medium diversity of mangrove and saltmarsh communities was identified in this area. The extensive Saltpans that are present in this region are characteristic of the dry environment.

Freshwater swamps adjacent to coastal wetland systems may contribute to fisheries productivity in periods of significant freshwater flow. Large areas of Saltpans, particularly behind Abbot Point, are subject to freshwater inundation in periods of high rainfall. During the wet season the areas become brackish or mostly fresh depending on the amount of fresh water

entering the system. In the dry season, however, an absence of freshwater input and the occurrence of king tides create a Saltpan environment.

The tidal inundation patterns behind Abbot Point have been altered through the building of bunds and levees. Restoration of the mangrove communities that have died as a result of these alterations is an issue that needs to be considered as part of any investigation for a FHA in this area.

Edgecumbe Bay

At present, the mangroves at Adelaide Point along with the wetlands associated with Emu, Yeates, Longford and Miralda Creeks and Gregory River are considered to be near pristine or have limited alterations (Hegerl 1993a). Moreover, Yeates Creek, Longford Creek, Gregory River and Miralda Creek are considered to be important systems contributing to fisheries productivity. Consequently, the protection of the coastal wetland habitats within Edgecumbe Bay for ensuring longterm fisheries production should be considered urgently.

Although Edgecumbe Bay exhibits only a low to medium diversity of mangrove and saltmarsh communities, intertidal flats and rocky foreshores add to the diversity of fisheries habitats represented in this area.

Both the Magazine Creek and Bowen Saltponds wetlands have been altered extensively. The proximity of these wetlands to the city of Bowen suggests that expansion of Bowen may result in further alterations to these wetlands. Development also poses a small threat to the mangroves at Adelaide Point due to the Comalco Alumina refinery proposed for this area. However, such a development is expected to have little impact on the viability of the area from a fisheries perspective (Hollingsworth Consultants 1984).

The Longford Creek, Gregory River and Miralda Creek wetlands to the east are unique in this area in that they experience a higher proportion of freshwater availability than the majority of the other wetland communities in the Bowen Region. This is reflected in the comparatively less extensive Saltpans associated with these communities.

A *Phytophthora*-related mangrove dieback within *A. marina* communities along Hay Creek, near Adelaide Point has been reported (Hollingsworth Consultants 1984). The distribution, possible causes and effect that this disease has on the productivity of these mangroves is an important issue for further investigation.

8.3 Recommendations

1. The consideration of the fisheries habitats from Adelaide Point to Cape Gloucester, (including both the intertidal and offshore environments of Edgecumbe Bay) for inclusion in a FHA is strongly suggested. This area includes Emu, Yeates, Longford and Miralda Creeks and Gregory River coastal wetland systems. The protection of these systems in particular is urgently recommended, due to their relatively pristine status.

2. The coastal wetlands of Abbot Bay and the Don River Delta are less diverse than those of Edgecumbe Bay. However, these areas are important commercial and recreational fishing grounds and on this basis further investigation for FHA nomination may be warranted.

3. Continuation of coastal wetlands mapping to complete the remainder of the Queensland coast is strongly recommended, to:
   - provide baseline data for FHA declaration, review of current FHA boundaries and Ramsar site nomination;
   - to monitor spatial and compositional changes in communities on a local, bioregional and statewide basis; and
   - as a resource for incorporation into studies of the relationships of specific marine fauna to particular coastal wetland habitats.

8.4 FHA Declaration in the Bowen Region

The coastal wetland vegetation communities of the Bowen Region represent a diversity of environments that have value as both fisheries and waterbird habitats ranging from sheltered bays and exposed coastlines with mudflats, sandflats and saltmarshes to numerous mangrove community types. Although the exact economic value of these wetlands is unknown, they contribute significantly to the local fisheries due to the food, shelter, breeding and nursery grounds that they supply.

Knowledge of the coastal wetland environments in the Bowen Region is critical for fisheries management. Coastal wetland resource information will be integrated with data on adjacent land use, tenure and other relevant coastal management issues. This knowledge base, along with community consultation and support, will be required in order to define the relative fish habitat values and to determine suitable boundaries for area of interest plans for FHA declaration in the Bowen Region. Investigations for FHA declaration in the Bowen Region by regional DPIQ Fisheries officers are scheduled to commence in the year 2000.

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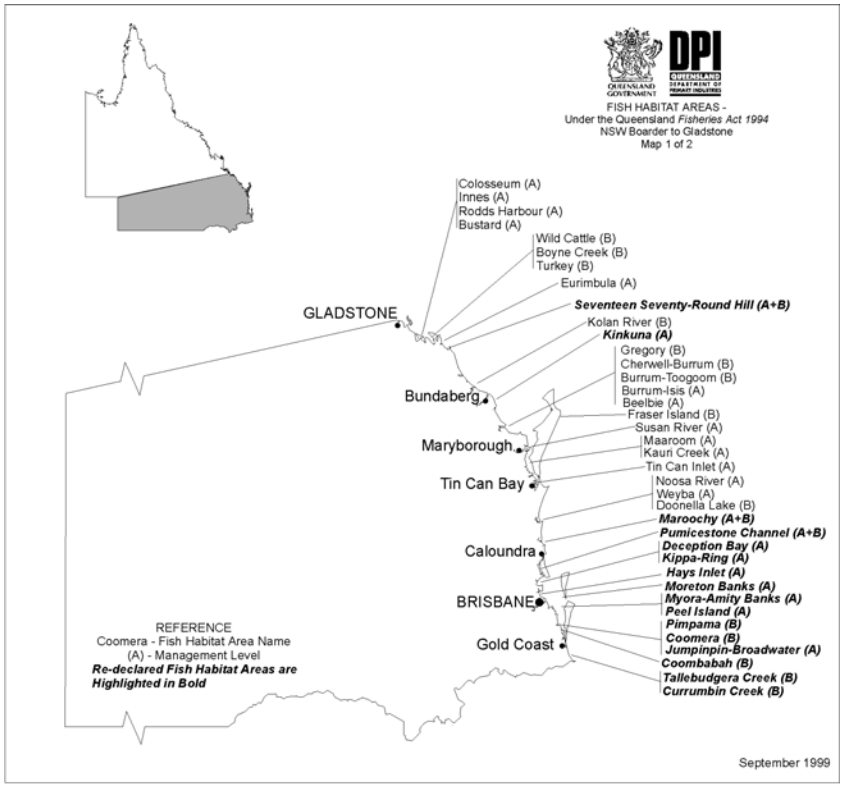
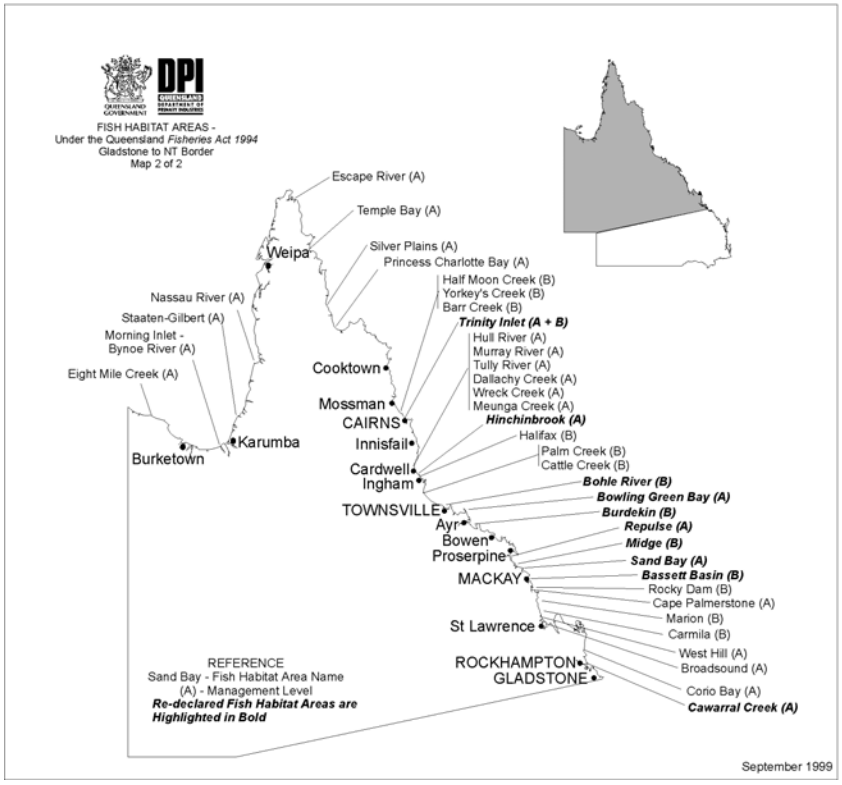
APPENDIX 1: DECLARED FHAS IN QUEENSLAND





Fisheries Information Leaflet

FISH HABITAT AREA

DECLARATION PROCESS AND MANAGEMENT OPTIONS

What is a Fish Habitat Area

Fish Habitat Areas form an important component of the ongoing protection and management of fisheries resources and wetland habitats in Queensland. The Areas are declared with the specific intent of ensuring the continuation of productive recreational, commercial and traditional fisheries in a region.

A Fish Habitat Area may be declared in both marine and freshwater environments to protect important juvenile and adult fish habitats. These habitats include sand bars, shallow water areas, undercut banks, snags, rocky outcrops, pools, riffles, seagrass beds, mangrove stands, yabby banks etc.

Declaration of a Fish Habitat Area complements the existing and more general fisheries habitat management (e.g. protection of all marine plants) by:
providing additional statutory protection to critical freshwater and unvegetated marine habitats,
publicising the fisheries value of the area, and
providing guidelines on fish habitat management to other management groups and members of the community proposing works within or adjacent to the Declared Area.

Fish Habitat Areas are declared and managed under the *Fisheries Act 1994* and the *Fisheries Regulation 1995* by the Department of Primary Industries. Management provides for community use and enjoyment of the area (e.g. commercial, recreational and traditional fishing, boating etc.) whilst restricting activities which may have negative impacts on the fisheries and habitat values of the area (e.g. dredging, reclamation, discharging/drainage etc.).

While an individual Fish Habitat Area (FHA) is nominated and declared on the basis of its specific habitat and fisheries values, each FHA extends the statewide network of Fish Habitat Areas. These Areas combine to help protect the regional viability of Queensland's fish and crustacean stocks by supporting adjacent and offshore fishing grounds (via primary production inputs, protection of nursery areas and feeding grounds, and protection of spawning locations).

Why is it important to protect fish habitat?

Considerable research has been undertaken during the last 20 years to investigate the associations and interrelationships between fish stocks and coastal and freshwater habitats. This research has documented that many species of fish and crustaceans have specific habitat requirements and that these habitat requirements often change as the individual moves through its life cycle. Studies estimate that approximately 75% (by weight) of all seafood landed commercially in Queensland is from species dependent on estuarine habitats during part of their life cycle. Similarly, a high proportion of species targeted by the recreational fishing sector and indigenous fishers is also dependent on estuarine and freshwater habitats during part or all of their life cycles.

Ever increasing pressure for both coastal and inland industrial, residential and agricultural development has and continues to have a major impact on Queensland's freshwater and inshore fisheries habitats. The permanent losses and/or alterations of these fisheries habitats have led to effects on fisheries productivity. For example, CSIRO researchers (Staples D.J., Vance D.J. and Heales D.S. 1984), in relation to commercial prawn fisheries in northern Queensland, concluded that "Any changes

QUEENSLAND DPI QUEENSLAND EDFISH The Wetlands Education Project

to the nursery habitat will have a corresponding effect on the offshore catch." The nursery habitats referred to include seagrass flats, algal beds and mud-banks immediately adjacent to the mangrove fringe.

The following examples taken from research data again illustrate the degree of habitat disturbance in recent times:

- during the period 1974 to 1987, 8.4% of the mangrove habitat and 10.5% of the saltmarsh-claypan habitat between Coolangatta and Caloundra have been lost to development (Hyland S.J. and Butler C.T. 1988)
- during the period 1951 to 1992, 60% of the wetlands (including both freshwater and marine wetlands) within the Johnstone River Catchment have been lost (Russell D.J. and Hales P.W. 1993)
- during the period 1941 to 1989, 2.5% (approx. 650ha) of the mangrove forest and 5.5% (approx. 990ha) of coastal saltflats along the Curtis Coast have been lost (QDEH, 1994)

Given the degree of existing development impacts on fisheries habitat and the likely pressures for future impacts on these habitats, it is clear that management and protection of the most significant of these habitats are essential/necessary. Declaring these areas as Fish Habitat Areas, is an important measure in sustaining important and valuable* commercial, recreational and traditional fisheries stocks.

* At a wholesale level the product value of the Queensland commercial fishing industry in 1996 was estimated to be $300 million. The recreational fishing industry value has been estimated to be at least equal to that of the commercial industry.

Who owns a Fish Habitat Area?

In Tidal Areas

Fish Habitat Areas in tidal areas are generally declared over Unallocated State Land (USL). The areas are not declared over tenured land (e.g. freehold or leasehold) unless a specific agreement is reached between the DPI and the holder of the tenure. A Fish Habitat Area is a fisheries habitat management measure for protection of habitat, not a form of tenure.

As the majority of land over which a Fish Habitat Area is usually declared is State Land, **community** use and enjoyment of these areas is a primary consideration in their management. It should be noted however, that if tenured land is included in a Fish Habitat Area, through specific agreement, the **rights of the tenure holder** is a primary management consideration and community use of the tenured portion of the Fish Habitat Area may be severely restricted. Protection of and the use of the habitat by fish in these lands is the key management concern.

In Freshwater Areas

As with tidal areas, freshwater Fish Habitat Areas are not a tenure but a Fisheries management measure. They can be declared over USL and, may be declared over tenured land if a specific agreement is reached between the DPI and the holder of the tenure. Given the nature of landuse and tenure arrangements around freshwater rivers and streams throughout Queensland, it is likely that freshwater Fish Habitat Area proposals may involve more tenured land than those in tidal areas.

It is envisaged that freshwater Fish Habitat Areas will focus on critical areas of fisheries habitat within a catchment and that these areas will complement existing and future whole of catchment management initiatives.

What criteria are used to determine if an area is suitable for declaration as a Fish Habitat Area?

An area may be proposed for declaration as a Fish Habitat Area by a range of interested parties or individuals. A number of recent proposals have been submitted by community groups, recreational and commercial fishing groups, local authorities and by staff from within the Department of Primary Industries.

Selection criteria currently used by DPI to assess the suitability of an area to be declared as a Fish Habitat Area are outlined below:

- size (larger areas being seen as more viable in the long-term)
- existing or potential fishing grounds
- diversity of or specific fish habitat features
- diversity of or specific marine flora and fauna
- level of existing and likely future disturbances
- unique features
- protected species

Management categories

A Fish Habitat Area may be declared under either **Management 'A'** (the highest level of protection) or **Management 'B'**. These two management categories have associated management frameworks.

In general terms, a Fish Habitat Area 'A' is declared over areas that contain fish habitats that are **critical** for fisheries productivity and sustainable fishing in the short and long term and to maintain the ecological character and integrity of undisturbed fisheries habitats. This management level does not impact on the normal day to day uses of the area by the community (e.g. boating and fishing), but does severely restrict development related disturbances.

A Fish Habitat Area 'B' is declared over areas that contain fish habitats that are **important** for productive and sustainable fishing in the short and long term and to minimise the impacts of non-fisheries related disturbance to important fisheries habitat. Declaration of an area as a Fish Habitat Area 'B' is often proposed to act as a buffer between a Fish Habitat Area 'A' and existing or future disturbances (e.g. residential or industrial development). This management level allows for Permits to be granted for construction of certain private and public facilities subject to minimal impacts on the habitats.

(A guide to management policies for activities within Fish Habitat Area 'A' and 'B' is provided on page 4-5 of this document).

Additional management may occur through a location-specific management plan, once the Fish Habitat Area has been declared. This management may be most suitable in freshwater areas, which are likely to have specific management issues (e.g. extractive industry).

A decision regarding the most appropriate management category is usually made following the first round of community consultation, at which time all relevant issues should be available for consideration.

The declaration process

The declaration of a Fish Habitat Area generally follows the process outlined below:

1. Nomination of an area as a candidate for declaration as a Fish Habitat Area.
2. Review of nomination and assessment of its priority for further investigation *[Period of time between Stage 2 and 3 will be determined by the prioritisation process]*
3. Site investigation/field habitat surveys, literature searches and reviews, assessment of fish catch records and preliminary discussions with user groups (e.g. commercial fishers, recreational fishers, indigenous groups, local authority, other community groups etc.) to determine if the nominated area meets Fish Habitat Area declaration criteria.
4. Preparation of an Area of Interest Plan and draft of known management issues.
5. Initial consultation with interested parties and relevant agencies.
6. Revision of information gathered during the initial consultation phase, preparation of a draft Fish Habitat Area Plan and a draft management strategy with recommendation of an appropriate management level (either 'A' or 'B', and use of a location-specific management plan).
7. Second round of consultation with interested parties and relevant agencies.
8. Revision of information gathered during the second round of consultation.
9. Preparation of a Declaration Plan of Fish Habitat Area Boundaries and a submission of proposal for declaration
10. Provision of Plan and submission to the Department of Primary Industries legal section.
11. Provision of Plan and submission to the Minister for Primary Industries.
12. Provision of Plan and submission to the Governor in Council for declaration under *Fisheries Regulation*.

It is expected that the declaration process from Step 4 to the final declaration should take a period of approximately 12 months to complete, however this will depend on the complexity of the issues associated with the individual area.

What are the restrictions to the user groups/adjoining land holders of the declaration of an area as a Fish Habitat Area ?

It should be noted that the management guidelines for Fish Habitat Areas 'A' and 'B' outlined below have been developed from the legislative powers and provisions of the Fisheries Act 1994 and Fisheries Regulation 1995.

Any works within a Fish Habitat Area require approval under the Fisheries Act. Each application is assessed on its individual merits and the manner in which it complies with current fisheries legislation and management policies.

ACTIVITY	FHA 'A'	FHA 'B'
Community access	✓	✓
Boating	✓	✓
Commercial and recreational fishing by lawful line or net	✓	✓
Commercial and recreational crabbing by lawful dilly or pot	✓	✓
Traditional Fishing	✓	✓
Yabby pumping	✓	✓
Worm digging	✗	✗
Collection of molluscs	✗	◆
Public works for fisheries infrastructure benefit (e.g. public jetty, public boat ramp), where there is an existing need	✓✪	✓✪
Minimal impact public works for community infrastructure benefit, with full restoration of habitat (e.g. fully buried water, power or sewerage lines)	✓✪	✓✪
Major impact public works for community infrastructure benefit (e.g. road bridge, rail bridge etc.)	✗	✗
Maintenance of existing structures	✓✪	✓✪
General placement of mooring piles or blocks	✗	✗
Placement of mooring piles or blocks directly adjacent to proponents tenured property	✗	✓✪
Construction of private access facilities for fisheries purposes into FHA from proponents tenured property (e.g. jetty, pontoon, boat ramp)	✗	✓✪
Construction of new private access facilities for other than fisheries purposes (e.g. ferry loading / boarding facilities)	✗	✗
Placement of structures for the restoration of fish habitat or of natural processes (e.g. placement of baffles or booms to revegetated marine plants)	✗	✓✪
Construction of residential canal estates	✗	✗
Mining (including sand mining)	✗	✗
Minimal impact exploratory surveys of potential mineral deposits	✗	✓✪
Extractive industry operations (including gravel dredging)	✗	✗
Dredging tidal lands for a private purpose (including channel dredging)	✗	✗
Disposal of dredge spoil	✗	✗
Revetment works where there is visible proof of bank erosion or slumping	✗	✓✪
Revetment works where there is no visible proof of bank erosion or slumping	✗	✗
Beach replenishment to control erosion for community fisheries purposes	✓✪	✓✪
Beach replenishment to control erosion for other than fisheries purposes	✗	✓✪
Reclamation of any land (e.g. for car parks, vessel trailer parks, restaurants, airport runways etc.)	✗	✗
Construction of tidal gates, weirs and baffles	✗	✗
Drainage or flood mitigation works affecting natural water flows	✗	✗
Reclamation of any land within the FHA for aquaculture purposes (including for pond construction and/or cage culture)	✗	✗
Dredging of a aquaculture water intake or outlet channel	✗	✗
Placement of underground aquaculture inlet and outlet pipes or elephant trunk systems	✗	✓✪
New facilities for discharge of sewage effluent or unfiltered stormwater	✗	✗
Collection of dead wood	✗	✗
Any proposal having only minor benefit in terms of management, public use and enjoyment of any declared Fish Habitat Area for fisheries purposes not justifying the impacts	✗	✗

Key to Symbols

✓ Unrestricted Activity

✓✪ Activity considered compatible with FHA declaration, subject to DPI Permit consideration

✗ Activity considered incompatible with FHA declaration

◆ Under review

How does community infrastructure requirements (e.g. road, rail bridges) relate to the management of a Fish Habitat Area?

Infrastructure for community benefit (e.g. bridge pylons, powerline support structures), permanently alters the natural fisheries habitat values of the localized area, without offering fisheries management benefits to the area. Therefore, these structures are not seen as compatible with the intent of Fish Habitat Area declaration. In addition, any impacts on intertidal habitats as a result of regular maintenance of these structures to ensure community and structural safety may require statutory approvals from the DPI.

For the reasons outlined above DPI management seeks to exclude present and planned community infrastructure from Fish Habitat Areas. This is generally achieved through prior negotiation with the individual government agencies to incorporate strategically located community infrastructure corridors through the Fish Habitat Area. These corridors are not part of the Fish Habitat Area and not subject to its management.

It should be noted that public jetties and public boat ramps providing boat access to fisheries resources are considered compatible with the intent of Fish Habitat Area declaration, therefore these facilities are generally not excluded from the declared Areas.

The Revocation Process

The declaration of a Fish Habitat Area is seen as long-term management of an area of important fisheries habitats. It is recognised when adopting this style of management that with time, community needs may change and additional community infrastructure (e.g. a road / rail bridge duplication) may be required. A whole-of-government and community approach to acceptance of these needs may then require removal of part of a declared Fish Habitat Area for the agreed purpose. Excision of an area of habitat from within a declared Fish Habitat Area requires formal revocation.

Details of the process for revocation are available from the DPI Fisheries Group. The process is structured and open to public scrutiny and includes such elements as a requirement for the submission of a 'Revocation Support Study' and an appropriate amendment of the Fisheries Regulation by Governor-in-Council.

For further information please contact:

Southern Fisheries Centre
PO Box 76 (13 Beach Road)
DECEPTION BAY Q 4508
telephone- (07) 3817 9500

Northern Fisheries Centre
PO Box 5396 (38-40 Tingira Street, Portsmith)
CAIRNS Q 4870
telephone (07) 4035 0126

References

Hyland, S.J. and Butler, C.T. (1988). *The Distribution and Modification of Mangroves and Saltmarsh - Claypans in Southern Queensland*, Queensland Department of Primary Industries Information Series, Brisbane, 74pp.

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APPENDIX 3: CRITERIA FOR RAMSAR SITE NOMINATION
LISTING WETLANDS OF INTERNATIONAL IMPORTANCE

(Source: http://www.fws.gov/r9dia/global/Ramsarfr.html, accessed 1st Sep 1999)

The text of the Ramsar Convention (Article 2.2) states that:

> *"Wetlands should be selected for the List [of Wetlands of International Importance] on account of their international significance in terms of ecology, botany, zoology, limnology or hydrology"* and indicates that *"in the first instance, wetlands of international importance to waterfowl at any season should be included."*

To facilitate the implementation of this provision, the Conference of the Parties has adopted the following four clusters of criteria for the identification of wetlands of international importance:

1. Criteria for representative or unique wetlands
   A wetland should be considered internationally important if:

   (a) it is a particularly good representative example of a natural or near-natural wetland, characteristic of the appropriate biogeographical region; or
   (b) it is a particularly good representative example of a natural or near-natural wetland, common to more than one biogeographical region; or
   (c) it is a particularly good representative example of a wetland which plays a substantial hydrological, biological or ecological role in the natural functioning of a major river basin or coastal system, especially where it is located in a transborder position; or
   (d) it is an example of a specific type of wetland, rare or unusual in the appropriate biogeographical region.

2. General criteria based on plants or animals
   A wetland should be considered internationally important if:

   (a) it supports an appreciable assemblage of rare, vulnerable or endangered species or subspecies of plant or animal, or an appreciable number of individuals of any one or more of these species; or
   (b) it is of special value for maintaining the genetic and ecological diversity of a region because of the quality and peculiarities of its flora and fauna; or
   (c) it is of special value as the habitat of plants or animals at a critical stage of their biological cycle; or
   (d) it is of special value for one or more endemic plant or animal species or communities.

3. Criteria based on waterfowl
   A wetland should be considered internationally important if:

   (a) it regularly supports 20,000 waterfowl; or
   (b) it regularly supports substantial numbers of individuals from particular groups of waterfowl, indicative of wetland values, productivity or diversity; or
   (c) where data on populations are available, it regularly supports 1% of the individuals in a population of one species or subspecies of waterfowl.

4. Criteria based on fish
   A wetland should be considered internationally important if:

(a) it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity; or
(b) it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetlands or elsewhere, depend.

Each cluster of criteria is supplemented by guidelines for its application. The guidelines can be obtained from the Ramsar Bureau or on the Ramsar Web site.

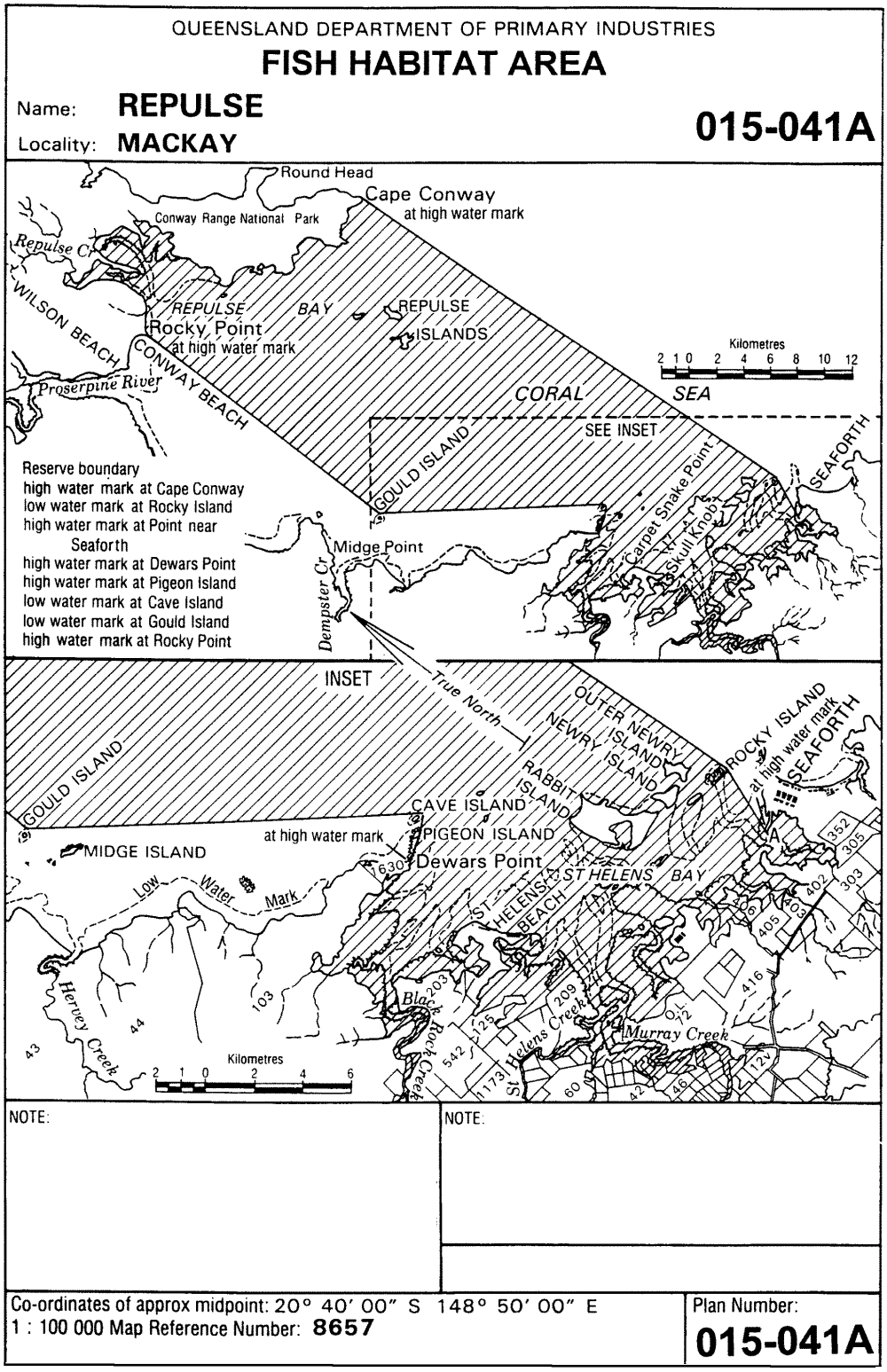
APPENDIX 4: COASTAL WETLAND COMMUNITIES OF THE BOWEN REGION

Sheet 1: Abbot Bay
Sheet 2: The Don River Delta
Sheet 3: Edgecumbe Bay

APPENDIX 5: DECLARED FISH HABITAT AREAS ADJACENT TO THE BOWEN REGION

REPULSE FISH HABITAT AREA	
Management Status	A
Plan No.	015-041A
Date of Declaration	10 May 1986
Approximate Midpoint	20 40'00"S, 148 50'00"E
Locality	Repulse Bay and tidal lands to Cape Conway and Seaforth in the east and to Rocky Point and Gould Island in the west
Map Reference	Proserpine 1:100 000 (8657)
Size (ha)	71 000
Local Authority	Whitsunday Shire Council
Proximity to major centre	40 km south-east from Proserpine
Management Features	Habitat conservation for fish stocks; conservation of commercial and recreational fishing grounds; protection of dugong, prawn and turtle habitat
Fisheries Values	Barramundi, blue salmon, bream, estuary cod, flathead, grey mackerel, grunter, mangrove jack, queenfish, school mackerel, whiting, banana prawns
Major Habitat Types	Mangrove dominated floodplain with *Rhizophora*, *Acanthus*, *Acrostichum*, *Avicennia* and *Ceriops* being common; mangrove lined creeks; intertidal flats; seagrass beds around the mouth of Repulse Creek
Note	The Repulse Fish Habitat Area covers the tidal land and the waters covering the land of Repulse Bay, St Helens Bay and Coral Sea as indicated and all the creeks and tributaries thereof to the limit of tidal action.

BOWLING GREEN BAY FISH HABITAT AREA	
Management Status	A
Plan No.	015-050A
Date of Declaration	25 November 1989
Approximate Midpoint	19 20'00"S, 147 15'00"E
Locality	Part of Bowling Green Bay
Map Reference	Bowling Green Bay 1: 100 000 (8359)
Size (ha)	68 600
Local Authority	Burdekin Shire Council
Proximity to major centre	27km north-north-east of Giru
Management Features	Conservation of commercial and recreational fishing grounds and resources; area identified as important to the food chain of offshore billfish fishery; major barramundi nursery habitat; important dugong and loggerhead turtle habitat
Fisheries Values	Barramundi, blue salmon, bream, estuary cod, flathead, grey mackerel, grunter, mangrove jack, queenfish, school mackerel, whiting, tiger prawns, banana prawns
Major Habitat Types	Closed *Rhizophora* and *Ceriops* dominated stands with extensive areas of saltmarsh; sparse seagrass beds within the Bay; exposed banks and freshwater lagoons
Note	The Bowling Green Bay Fish Habitat Area covers all tidal land and the waters covering the land of the mainland foreshores, inlets, rivers, creeks, tributaries, and contiguous wetlands of Bowling Green Bay indicated between Cape Cleveland and Cape Bowling Green.


QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES
FISH HABITAT AREA
Name: REPULSE
Locality: MACKAY
015-041A
Round Head
Cape Conway
at high water mark
Conway Range National Park
Repulse Cr
WILSON BEACH
REPULSE BAY
REPULSE ISLANDS
Rocky Point
at high water mark
CONWAY BEACH
Proserpine River
CORAL SEA
Kilometres
2 1 0 2 4 6 8 10 12
SEE INSET
GOULD ISLAND
SEAFORTH
Carpet Snake Point
Skull Knob
Reserve boundary
high water mark at Cape Conway
low water mark at Rocky Island
high water mark at Point near Seaforth
high water mark at Dewars Point
high water mark at Pigeon Island
low water mark at Cave Island
low water mark at Gould Island
high water mark at Rocky Point
Midge Point
Dempster Cr
INSET
True North
OUTER NEWRY ISLAND
NEWRY ISLAND
RABBIT ISLAND
ROCKY ISLAND
at high water mark
SEAFORTH
GOULD ISLAND
CAVE ISLAND
PIGEON ISLAND
at high water mark
MIDGE ISLAND
Dewars Point
Low Water Mark
ST HELENS BEACH
ST HELENS BAY
Hervey Creek
Helens Creek
Murray Creek
Kilometres
2 1 0 2 4 6
NOTE:
NOTE:
Co-ordinates of approx midpoint: 20° 40′ 00″ S 148° 50′ 00″ E
1 : 100 000 Map Reference Number: 8657
Plan Number:
015-041A

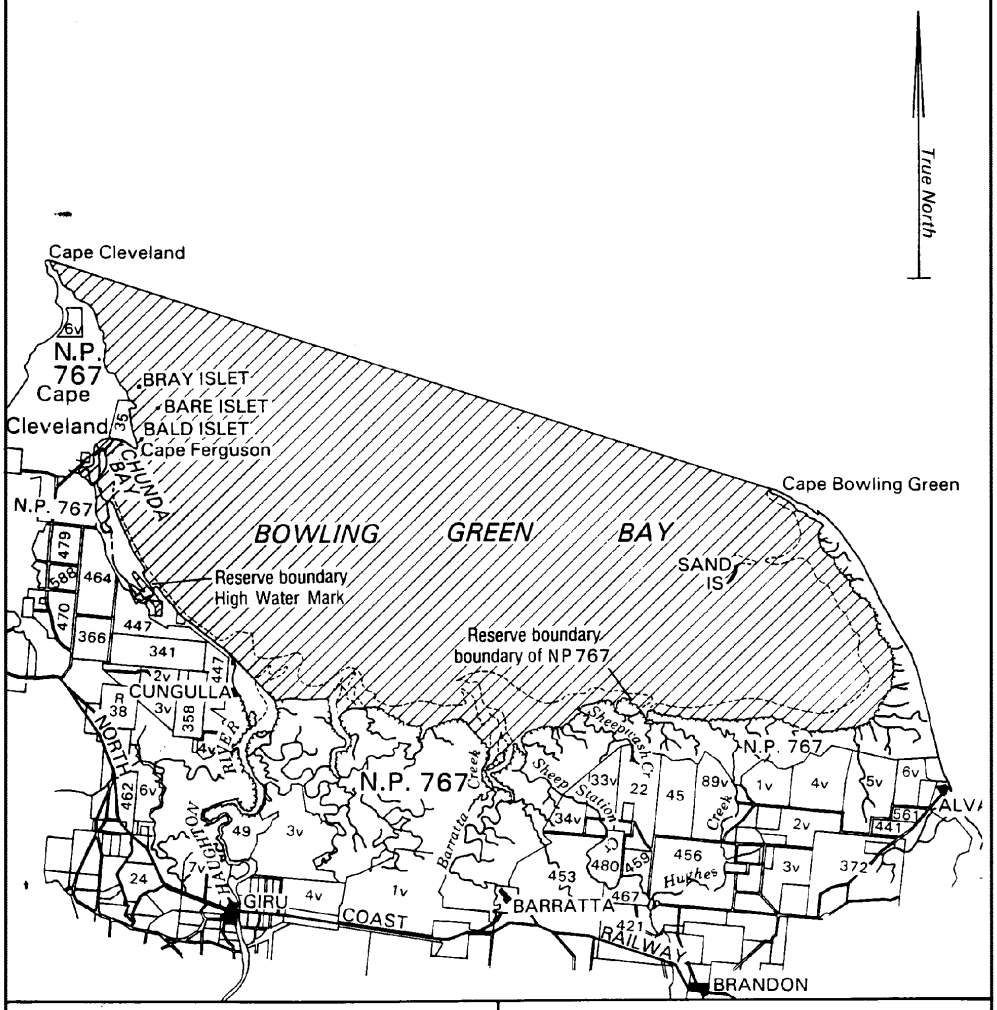
QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES

FISH HABITAT AREA

Name: **BOWLING GREEN BAY**

Locality: **AYR**

015-050A



NOTE.

NOTE

Kilometres 2 0 2 4 6 8 10 12 14 Kilometres

Co-ordinates of approx midpoint: 19°20′00″S. 147°15′00″E.

1 : 100 000 Map Reference Number **8359**

Plan Number

015-050A

The Landsat 5 satellite, launched by the US government, orbits at 705km above the earth's surface and takes 16 days to sense the whole of the earth's surface. Its instrument, the Thematic Mapper (TM), digitally scans "scenes" which are 185 x 185 km. The scanned scenes are made up of digital values recorded from the amount of light reflected from the Instantaneous Field of View (IFOV) or pixel. TM pixels represent an area of 30 x 30 m on the ground thus objects of interest must be at least this size in order to be detected by the sensor. For every pixel the Landsat TM sensor records light in seven different wavebands. These bands and some general applications for their use are outlined in Table 2.

TABLE 1 Landsat Thematic Mapper Sensor System Characteristics (Jensen 1996)

SENSOR CHARACTERISTIC	DETAILS
IFOV (Instantaneous Field of View) at nadir	30 x 30 m for bands 1 to 5, 7 120 x 120 m for band 6
Data rate	85 MB/s
Quantization levels	8 bits, 256 levels
Earth coverage	16 days Landsat 4 and 5
Altitude	705 km
Swath width	185 km
Inclination	98.2^{o}

TABLE 2 Characteristics of Landsat Thematic Mapper Bands (Acres 1989)

TM BAND	MICROMETERS	GENERALISED APPLICATION
1 (blue)	0.45 – 0.52	Coastal water mapping, soil / vegetation differentiation
2 (green)	0.52 – 0.60	Green reflectance by healthy vegetation
3 (red)	0.63 – 0.69	Chlorophyll absorption for plant species differentiation
4 (reflective infrared)	0.76 – 0.90	Biomass surveys, water body delineation
5 (mid-infrared)	1.55 – 1.75	Vegetation moisture measurement
6 (thermal infrared)	10.40 – 12.5	Plant heat stress mapping, sea surface temperatures
7 (mid-infrared)	2.08 – 2.35	Hydrothermal mapping

APPENDIX 7: LAND TENURE OF THE BOWEN REGION

APPENDIX 8: INTERTIDAL FLATS & FRESHWATER SWAMPS OF THE BOWEN REGION