



Australian Government



Queensland Government

WETLAND MANAGEMENT PROFILE

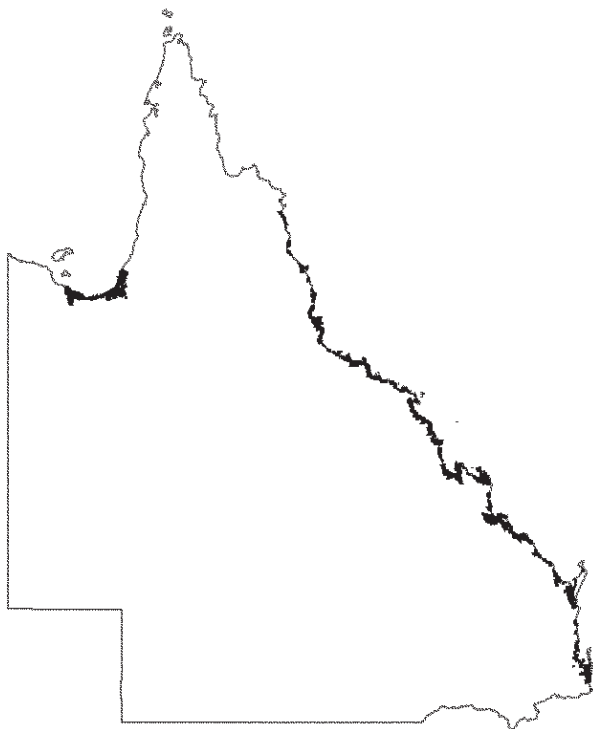
MANGROVE WETLANDS

Mangrove wetlands are characterised by trees that are uniquely adapted to tolerate daily or intermittent inundation by the sea. Distinctive animals are nurtured in their sheltered waters and mazes of exposed mangrove roots; others live in the underlying mud. A familiar sight on the coast throughout Queensland, mangrove wetlands provide frontline defence against storm damage, enhance reef water quality and sustain fishing and tourism industries. These habitat assets can be preserved and loss and degradation (through pollution and changed water flows) averted by raising awareness of the benefits of mangrove wetlands and by implementing integrated plans for land and resource use in the coastal zone.

Description

Mangroves are woody plants, usually trees (woodland to forest) but also shrubs, growing in the intertidal zone and able to withstand periods of inundation by seawater each day. In this profile, the term "mangrove wetland" is used to refer to wetlands that are characterised by dominance of mangroves. "Mangrove associates" are non-woody plants that mainly or commonly occur in mangrove wetlands. The terms "mangrove forest" and "mangrove swamp" are sometimes used in regard to particular types of mangrove wetland or to mangrove wetland in general.

MANGROVE wetlands are characterised by the dominance of mangroves — woody plants growing in the intertidal zone and able to withstand periods of inundation by seawater each day.



Map showing mangrove wetlands in Queensland.
Map: EPA

Situated in land zone 1, mangrove wetlands are invariably in the intertidal zone and sometimes extend narrowly for many kilometres inland along tidal rivers, also around some near-shore islands. Accordingly, they are below the level of Highest Astronomical Tide (HAT) and typically are in the lower, most frequently and deeply inundated parts of the intertidal zone. Along most of Queensland's east coast, mangrove wetlands endure twice-daily high tides that vary in amplitude from 1–2m in the south and north to over 7m in parts of central Queensland such as Broad Sound. On the Gulf of Carpentaria coast, high tide occurs only once each day (the cycle is about 25 hours), generally reaching up to 2–4m in height.

The substrate on which mangroves occur is mostly marine or estuarine sediments, being fine dark clay (silt) that is highly saline and deprived of oxygen (anaerobic) — a hostile environment for plant growth. Mangroves can also grow on sandy or rocky coast or on carbonate reef sediments but tend not to reach the height, density or extent of mangroves on marine clay.

Where the sediments are gently sloped and/or the tidal range is low, the mangrove wetlands may not be as deeply or extensively dissected by tidal channels as on steeper coast, where tidal range is high and/or where there are numerous inflowing streams from the inland. The spatial pattern of mangrove wetlands therefore is diverse. They can be linear along simple coastlines, branching where there are many tidal creeks such as those penetrating broad salt flats behind the coastline or block-like around major deltas of rivers or in the shelter of near shore islands (for example the Hinchinbrook area).



Mangrove wetlands along a tidal creek.
Photo: Roger Jaensch, Wetlands International

Mangrove wetlands frequently merge with saltmarsh wetlands that can be tens of kilometres wide at greatest extent (for example the southern Gulf of Carpentaria; refer to the *Saltmarsh wetlands* management profile for further information www.epa.qld.gov.au/nature_conservation/habitats/wetlands/wetland_management_profiles/) and may adjoin or be components of estuaries and tidal inlets. They sometimes also directly adjoin other wooded but non-tidal wetlands such as coastal melaleuca swamp wetlands (refer to the *Coastal melaleuca swamp wetlands* management profile for further information www.epa.qld.gov.au/nature_conservation/habitats/wetlands/wetland_management_profiles/) and palm-dominated wetlands (in the Wet Tropics bioregion); see *Palm swamp wetlands* management profile www.epa.qld.gov.au/nature_conservation/habitats/wetlands/wetland_management_profiles/.

The salinity of water in mangrove wetlands varies with location and position. Mangroves at the seaward margins would be inundated by water of similar quality to that of the open sea, around 35 parts per thousand of dissolved sodium chloride. However, mangroves at the landward edge of broad mangrove blocks or many kilometres from the ocean along minor tidal channels on salt flats may experience much higher salinities. Furthermore, mangroves along major estuary channels, and especially those that occur far upriver near the tidal limits, experience lower salinities.

The structure of mangrove wetlands varies under the influences of substrate, position and salinity. Mangroves can be shrub-like or form closed forest over 30m tall and many mangrove wetlands show distinct zonation (see Ecological values section). These variations have contributed to the classifying and mapping of five or more regional ecosystems (REs; including sub-REs) in some bioregions (see Appendix 1).

The plant diversity of mangrove wetlands is low but a high diversity of marine fauna occurs, dominated by invertebrates (crustaceans, worms and other benthic animals) and fishes. Due to high salinity and limited access to dry ground, shallows and open space, mammals, frogs, reptiles and waterbirds are poorly represented in mangrove wetlands, compared to non-tidal wetlands, although there is a suite of mangrove forest birds. Many animals use mangroves at certain stages of the life cycle, season or day. Details of typical flora and fauna are given under Ecological values (below).

Since mangrove wetlands are defined by the presence of particular salt-tolerant trees/shrubs and the limits of tidal inundation, recognition of the boundaries of this wetland type can often be straightforward. Recognition can be more difficult where mangroves merge with riverine forest or coastal rainforest. Mangroves commonly occur sparsely as isolated trees/shrubs on saltmarshes but ecotones are usually narrow, limited to the margins of tidal creeks.

Management of mangroves will always require an integrated approach that considers the impacts of management actions on or in surrounding marine areas, freshwater wetlands and dryland ecosystems including catchments of streams with runoff that enters the mangrove wetlands.

Distribution

Apart from stretches of coast dominated by sand masses or steep rocky shore and lacking tidal creeks and rivers (for example much of the Cooloola to Fraser Island coast; parts of western Cape York Peninsula), mangrove wetlands occur along most of Queensland's coastline. They form extensive stands in both southern and northern, wetter and drier regions. The most complex examples, with tallest forest, most well developed zonation and greatest number of mangrove species, tend to be along the coast with high, year-round rainfall (for example the Wet Tropics). Where saltmarsh wetlands — especially the bare salt pans — are most extensive, the adjoining mangrove wetlands tend to be relatively small in extent.

THE total area of mangrove wetlands along the coast bordering the Great Barrier Reef system is estimated as 207,000ha and the total area in Queensland has been estimated as 460,000ha.

Mangrove wetlands are widespread in the Gulf of Carpentaria and in parts of central Queensland (for example Shoalwater Bay) and south-east Queensland (for example Pumicestone Passage), where mangroves grow narrowly along most of the tidal creeks that are prolific along low gradient sections of coast. However, the largest (non-linear) blocks of mangrove wetland in Queensland are reported to be at Newcastle Bay (20,000ha) on northern Cape York Peninsula and Hinchinbrook Channel (16,400ha) in the Wet Tropics. The total area of mangrove wetlands along the coast bordering the Great Barrier Reef system is estimated as 207,000ha and the total area in Queensland has been estimated as 460,000ha.

Queensland conservation status

There are 19 regional ecosystems (REs), or units within regional ecosystems, that contain mangrove wetlands in Queensland (see Appendix 1). Three of these (REs 3.1.2, 3.1.4 and 3.2.30 have been assigned as "of concern" under the Queensland *Vegetation Management Act 1999* (VM Act) and by the Environmental Protection Agency (EPA) (Biodiversity Status, see www.epa.qld.gov.au/nature_conservation/biodiversity/regional_ecosystems/ and Appendix 1).

These REs are principally in land zone 1 but may penetrate land zone 3 as un-mapped narrow fringes along tidal reaches of rivers. RE 3.2.30 is on islands within the lagoon of the Great Barrier Reef. Mangrove wetlands occur in all coastal bioregions of Queensland. Within bioregions they have been classified and mapped as one RE or, in some bioregions, separated or subdivided according to tree/shrub structure, species composition and zonation, or occurrence in relation to tidal and freshwater regimes. Because of their tidal inundation and distinctive vegetation features, they are not easily confused with other REs except at some margins where they may merge seamlessly with adjoining coastal or riverine forest.

A number of protected areas in Queensland contain substantial areas of mangrove wetlands (see Appendix 1), for example Cape Melville, Jardine River, Endeavour River, Daintree, Edmund Kennedy, Hinchinbrook Island, Halifax Bay Wetlands and Lakefield National Parks and a number of island national parks in the north; Byfield, West Hill, Conway, Cape Upstart and Bowling Green Bay National Parks in central Queensland; and Bribie Island, Burrum Coast, Eurimbula and Southern Moreton Bay Islands National Parks in south-east Queensland. Many areas of mangroves along the east coast of Queensland are protected under Management Areas within the State Great Barrier Reef Coast Marine Park, Woongarra Marine Park, Hervey Bay Marine Park and Moreton Bay Marine Park. Each park is subject to different management zones with specific zoning plans. The Commonwealth Great Barrier Reef Marine Park covers subtidal areas (that is seaward of low water mark) along the length of Queensland's coastline and therefore does not generally encompass mangrove communities.



Mangroves *Ceriops* sp. in Bowling Green Bay National Park. Photo: Karen Danaher, DPI&F

Mangrove wetlands are represented in 55 nationally important wetlands listed in *A Directory of Important Wetlands in Australia* (2005) (see Appendix 3). There are a number of pieces of legislation such as the Queensland *Integrated Planning Act 1997* that include planning, assessment and permit requirements relating to wetlands listed in the Directory. Any activities that may impact on Directory wetlands (and potentially wetlands in general) must be consistent with this legislation.

FISH habitats are managed by DPI&F under the Queensland *Fisheries Act 1994* and *Fisheries Regulation 1995* which protect and manage marine plants, including mangroves and mangrove associates.

Fish habitats are managed under the Queensland *Fisheries Act 1994* and *Fisheries Regulation 1995* by the Department of Primary Industries and Fisheries (DPI&F). This Act protects and manages all marine plants in Queensland, including mangroves and mangrove associates. Highly important areas of fish habitat, including mangrove wetlands, are also protected within declared Fish Habitat Areas (FHAs) under this Act. FHAs provide considerable protection to mangrove wetlands from development-related disturbances, for example, the Hinchinbrook Fish Habitat Area includes 6000ha of mangrove wetland and Trinity Inlet Fish Habitat Area includes over 3200ha of mangrove wetland. In the Tweed-Moreton bioregion more than 57 percent of mangroves are protected within the FHA program (McKinnon *et al.*, 2003).

The *State Coastal Management Plan — Queensland's Coastal Policy* (2001) and regional coastal management plans provide direction for conserving, protecting and managing coastal wetlands, including mangrove wetlands. These plans are statutory documents under the Queensland *Coastal Protection and Management Act 1995* which guide activities undertaken in coastal areas of the state.

The Queensland *Environmental Protection Act 1994* establishes a general environmental duty upon landowners to take all reasonable and practical measures to prevent or minimise harm to wetlands and their environmental values, having considered such things as the sensitivity of the wetland, recommended practices and financial implications.

Mangrove wetlands have a range of environmental values related to ecological health, public amenity and safety. Some of these values are described in the Cultural heritage values and Ecological values sections below.

National conservation status

The Moreton Bay, Shoalwater and Corio Bays, Great Sandy Strait and Bowling Green Bay Ramsar sites (Wetlands of International Importance under the Ramsar Convention) contain mangrove wetlands. The Fraser Island, Great Barrier Reef and Wet Tropics World Heritage Areas (WHAs) as defined in the World Heritage List maintained by the World Heritage Convention, also include areas of mangrove wetland. (Note that the alignment of the boundary of the Great Barrier Reef WHA is such that only five percent of the adjoining coastal mangrove wetlands are inside the WHA.) The Shoalwater Bay Military Training Area (Byfield) and the Wide Bay Military Training Reserve (Tin Can Bay) are Commonwealth heritage places under the Commonwealth Heritage List, and include mangrove wetlands. Cowley Beach Training Area, another Commonwealth property also includes substantial areas of mangrove wetlands and it is also included in the Wet Tropics World Heritage Area. There are also migratory shorebirds that inhabit mangrove wetlands in Queensland, and which are listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (that is, they are listed under the Japan-Australia and China-Australia Migratory Bird Agreements (JAMBA/CAMBA respectively) and/or the Bonn Convention) (see Species of conservation significance and Appendix 2). Eleven animals and two plants that inhabit mangrove wetlands in Queensland are listed as threatened under the EPBC Act and/or the Queensland *Nature Conservation Act 1992* (NC Act) and/or the IUCN Red List (see Species of conservation significance and Appendices 2 and 3).

Ramsar wetlands, World Heritage properties, Commonwealth heritage places, listed migratory species and threatened species are matters of national environmental significance under the EPBC Act and, as such, are afforded protection under the Act. Any action that will, or is likely to, have a significant impact on a declared Ramsar wetland, World Heritage property, Commonwealth heritage place, listed migratory species or threatened species will be subject to an environmental assessment and approval regime under the EPBC Act.

For each of these World Heritage and Ramsar sites, management plans or equivalent are in place; in some instances they may not apply to the entire Ramsar site.

Cultural heritage values

All wetland ecosystems are of material and cultural importance to Indigenous people and many will have profound cultural significance and values. More than 270 Indigenous cultural heritage sites have been recorded within mangrove wetlands in Queensland, most dating from the mid Holocene, being less than 4000 years old. Most mangrove wetlands have not been systematically surveyed or assessed for cultural heritage significance.

There is a high likelihood of encountering cultural heritage sites within and adjacent to mangrove wetlands. Evidence of traditional occupation and use recorded within mangrove wetlands include painted rock art, burials, stone and earth arrangements, hearths, middens, stone artefacts and scatters, fish traps, food and fibre resources and historic contact sites. Some mangrove wetlands have particular significance as landscape features, story places and as sites for cultural activities.

MANGROVE wetlands are sources of traditional food and fibre providing a diverse and plentiful range of animal and plant species that were used in many ways including to manufacture wooden implements, and for food, shelter, medicines and fish poisons.

The most commonly recorded sites associated with mangrove wetlands are shell middens and stone artefact scatters associated with open camp occupation sites. These sites are likely to be found in areas of higher ground within or adjacent to mangrove wetlands. Mangrove wetlands are very productive traditional food and fibre resource areas providing a diverse and plentiful range of animal and plant species. Mangrove species were used in many ways including the manufacture of wooden implements, food, shelter, medicines and fish poisons.

Archaeological evidence of cultural sites, such as stone artefacts and shells, are often concentrated along ecotones around the margins of mangrove wetlands, and in association with neighbouring regional ecosystems such as coastal melaleuca swamps, wet heath/sedgeland and saltmarsh wetlands. The clustering of sites along ecotones reflects the concentration of traditional occupation and use within areas of greatest biodiversity.

Some mangrove wetlands also have non-Indigenous (historic) cultural heritage significance, although most have not been surveyed or assessed for historic heritage values. The EPA has recorded five historic sites associated with mangrove wetlands. The historic heritage values of mangrove wetlands demonstrate evidence of very limited past occupation and use associated with timber and forestry industries and maritime transport, such as log dumps, loading ramps and tramways. In some areas mangrove forests were exploited for timber for boat building — particularly grey mangrove *Avicennia marina*; for oyster racks — principally river mangrove *Aegiceras corniculatum*; and for the manufacture of charcoal. The bark of most species was used to extract tannins used in the tanning industry. It is important to note that evidence of Aboriginal occupation is often encountered at historic sites.

Refer to the *Coastal fringe wetlands — cultural heritage* profile www.epa.qld.gov.au/cultural-heritage/ for more information on identifying, assessing and managing cultural heritage values associated with mangrove wetlands.

Ecological values — introduction

Mangrove wetlands are key components of the landscape of the intertidal zone and provide ecosystem services that include:

- provisioning services, such as sustenance for humans in the form of finfish and shellfish;
- regulating services, such as sequestering of carbon (CO₂) and net oxygen production;
- cultural services, such as opportunities for nature observation; and
- supporting services, such as cycling of nutrients to adjoining marine lagoons and reefs.

MANGROVE leaves and roots, both live and decaying, provide carbon and nutrients that are broken down by organisms such as fungi, bacteria and crabs and the nutrients released to support plankton.

The mangrove trees are the key and prominent ecological component of mangrove wetlands. The roots and trunks of mangroves reduce the speed of water currents and trap water-borne sediments, which reduces siltation in other marine wetlands.

Mangrove leaves and roots, both live and decaying, provide carbon and nutrients that are used by other organisms. Fungi, bacteria and crabs (see below) break down the leaves and the released nutrients support plankton; one teaspoon of mangrove mud may contain millions of bacteria. Small organic particles (detritus) are covered with a protein-rich bacterial coating; this detritus is food for marine snails, crustaceans and fish, which in turn sustain larger animals. Furthermore, agricultural chemicals and other nutrients carried to the coast by rivers can be trapped and recycled by mangroves. These functions may be provided for many decades because individual trees can live for 100 years.

Ecological values — flora

Thirty-three mangrove tree species, two additional natural hybrids and two common mangrove associates comprise the 37 types of mangrove found in Queensland (www.aims.gov.au/pages/reflib/fg-mangroves/pages/fgm-qld-15.html). Some mangrove wetlands in north-east Queensland estuaries include as many as 28 mangrove species whereas there are less than 20 mangrove species on the Gulf of Carpentaria coast. The number of species tends to decrease with increasing latitude south, suggesting that temperature influences diversity. But highest species diversity occurs where rainfall is highest and in estuaries of the largest river catchments.

The 37 species/hybrids (there are only 69 species worldwide) are from 19 plant families, of which the Rhizophoraceae is dominant with three genera: *Bruguiera* (five spp.), *Ceriops* (three spp.) and *Rhizophora* (three spp. and one hybrid). Grey mangrove *Avicennia marina* is the most widely encountered mangrove tree in Queensland and it occurs in both tropical and temperate regions of Australia, often as the sole or dominant species. *A. marina* has three varieties, two of which are found along the foreshores of Queensland. *A. marina* var. *australasica* extends south from Rockhampton to the NSW border and *A. marina* var. *eucalyptifolia* extends from Mackay north to Cape York Peninsula, across the Gulf of Carpentaria and to Darwin. The palm *Nypa fruticans* is a mangrove associate that occurs only in the far north (but forms extensive stands in New Guinea and south-east Asia) and prefers low salinity regimes such as edges of tidal rivers. Its fronds may be nine metres tall and its fruit is often beach-washed.

Many of these plants occur only in mangrove wetlands though some, such as the fern *Acrostichum speciosum*, may also occur as minor elements of wetland or dryland forest, or riverine forest, in the coastal zone.



The grey mangrove *Avicennia marina* is the most common mangrove species in Queensland.
Photo: Roger Jaensch, Wetlands International

One hybrid, *Lumnitzera x rosea*, is considered endemic to Queensland and within Australia, the mangroves *Dolichandrone spathacea* and mangrove apple *Sonneratia caseolaris* are found only in Queensland mangrove wetlands. Endemics are few because mangroves are widespread in Australia and are dispersed by floating seed capsules.



Mangrove apple *Sonneratia* spp., Hinchinbrook Island. Photo: Karen Danaher, DPI&F

A PROMINENT feature of many mangrove wetlands is zonation, where the position of a particular mangrove species is determined by wave energy, salinity, access to nutrients and/or soil oxygen levels.

A prominent feature of many mangrove wetlands is zonation, which is especially evident from aerial views, and this may be recognised by mapping as separate REs or sub-REs. Position of particular mangrove species is determined by wave energy, salinity, access to nutrients and/or soil oxygen levels. Forest, woodland or scattered clumps of pure *Avicennia marina* (with pale grey-green foliage), or sometimes *Sonneratia alba*, often constitutes the exposed seaward margins of mangrove wetlands; *Avicennia* may also dominate across the wetland in less diverse southern examples. In more sheltered sites, such as immediately landward of the frontal *Avicennia* but still low in the intertidal zone, and also along seaward reaches of estuaries, tall forest (up to 30m) dominated by *Rhizophora* and *Bruguiera* species such as red (spotted) mangrove *R. stylosa* and large-leafed orange mangrove *B. gymnorhiza* (with dark green foliage) provides a second zone. Especially in tropical regions, the landward margins of mangrove wetlands may be dominated by dense low woodland or thickets of *Ceriops* species and black mangrove *Lumnitzera racemosa*, blind-your-eye (milky) mangrove *Excoecaria agallocha* and *Avicennia marina* may also be common; this hypersaline zone can be broad in width where the upper intertidal flats (including saltmarsh) are extensive, for example in low/seasonal rainfall areas. A fourth zone, comprising a mix of tree species found in adjoining zones, may be present between the landward and outer zones. Further upstream along tidal creeks and larger estuaries, and in narrow landward zones that sometimes occur as an ecotone in wetter regions, mangrove wetlands usually comprise a mix of the above-mentioned trees and/or most of the remaining mangrove species. Mangroves that are principally found in this river-side zone include river mangrove *Aegiceras corniculatum* and club mangrove *Aegialitis annulata*. One mangrove RE (3.2.30) occurs only on low islands of the Great Barrier Reef and is dominated by low forest/shrubland of *Pemphis acidula*.

The floor of seaward zones in mangrove wetlands is generally bare of understorey vegetation, except where seedlings are colonising adjoining mudflat. Seedlings and shrubs of less conspicuous mangrove plants may be present in the central and landward zones. Landward zones also tend to harbour samphires such as *Suaeda* spp., *Tecticornia australasica* and *Sarcocornia* sp. and saltwater couch *Sporobolus virginicus* (also known as sand or marine couch).

A feature of the floor of mangrove wetlands is the roots (pneumatophores) of mangroves, which appear above the mud substrate. These have (collectively) a large surface area, with spongy tissue and many pores, to allow oxygen to pass to roots in the mud. Oxygen is generally limited in mangrove wetlands due to tidal inundation and the oxygen-depleted (anaerobic) mud. Membranes in surface cells of the roots exclude up to 90 percent of the salt in seawater although some enters and is secreted via the leaves, or stored in the bark and older leaves — sometimes at high concentration — until they fall. (Mangrove leaves are well adapted to reduce loss of precious fresh water, some being succulent, having thick waxy skins or variable pore openings.) The roots provide habitat for fish, crabs, molluscs, other invertebrates and birds and their form varies among mangrove species or may occur in combination: peg or snorkel roots for *Avicennia* and *Sonneratia* spp., stilt or prop roots for *Rhizophora* spp., knobby/knee roots for *Bruguiera* spp., and buttress, plank or ribbon roots for cannonball mangrove *Xylocarpus granatum* (see box). Mangrove roots also provide support in soft, unstable mud.



Prop roots of *Rhizophora* spp..

Photo: Roger Jaensch, Wetlands International



Knobby roots of *Bruguiera* spp..

Photo: Roger Jaensch, Wetlands International



Buttress roots of the cannonball mangrove *Xylocarpus granatum*. Photo: Roger Jaensch, Wetlands International

To reproduce in the harsh seawater regime, many mangrove seeds germinate before leaving the parent tree. The seedling grows out through the fruit (for example *Rhizophora* and *Ceriops* spp.) or within the fruit (*Avicennia* and *Aegiceras* spp.) as a propagule, ready to develop into an independent plant. On falling into the water the floating propagule becomes dormant and disperses with currents and wind, until lodging in substrate and starting to grow. However, some mangroves (for example *Lumnitzera* spp.) reproduce in the same way as most other trees.



Fruit of the grey mangrove *Avicennia marina*.

Photo: Sarah Young, EPA

The canopies and upper branches of mangroves sometimes support mistletoes for example *Amyema mackayense*, orchids such as the endangered mangrove orchid *Dendrobium mirbelianum* (NC Act) and other epiphytes (see ant plant information in the Species of conservation significance section). The latter may be abundant in the most humid climatic zones. Lichens such as *Bulbothrix apophysata*, *Bulbothrix microscopica* and *Relicina terricrocodila* grow on the red mangrove and are restricted to Moreton Bay, Tin Can Bay and Portland Roads on Cape York Peninsula respectively. Ferns such as the mangrove fern *Acrostichum speciosum* and mushrooms may also grow on the mangrove trunks and branches.

CANNONBALL MANGROVE

The cannonball mangrove *Xylocarpus granatum* has a combination of features that is unique among Queensland mangroves. Its mottled, flaky, pale pink-orange trunk is supported by buttress roots that often extend outwards dramatically as thin vertical planks and/or networks of above-ground ribbons. The title “cannonball mangrove” is derived from the large round fruit, golden-brown when ripe, that comprises 12 to 18 seeds tightly packed inside a hard case (hence the name “monkey-puzzle nuts”). North Queensland beaches may be littered with these seeds. This mangrove tree may stand up to 25m high, especially beside rivers through mangrove wetlands of the Wet Tropics. In some Pacific Island countries its pale timber is highly prized for carving of wooden artefacts. The related cedar mangrove *X. mekongensis* has quite different roots, bark and fruit.



The distinctive fruit of the cannonball mangrove *Xylocarpus granatum* can be as large as 20cm in diameter, containing up to 18 tightly-packed seeds. The fruit explodes on ripening and the seeds disperse with the tide. Image: EPA

MANGROVE wetlands are ecologically linked to other marine wetlands — many of the animals that occur in mangrove wetlands also occur in adjoining intertidal flats, open marine waters, saltmarshes, estuaries and/or freshwater wetlands.

Ecological values — fauna

Mangrove wetlands are ecologically linked to other marine wetlands. Many of the animals that occur in mangrove wetlands also occur in adjoining intertidal flats, open marine waters, saltmarshes, estuaries and/or freshwater wetlands. Much exchange of individuals occurs, in many cases according to life stage, and the nutrients that are exported from mangrove communities enrich the seagrass beds, lagoons and inshore reefs that are key habitats for other marine animals.

Fishes are highly mobile inhabitants of mangrove wetlands, coming and going with the rise and fall of tide, especially in the most landward parts of the wetland. Mudskippers *Periophthalmus* spp., however, are mangrove fishes that can stay behind after the water retreats, being able to burrow in mud, and to move across wet mud and climb roots using special pectoral fins. Mangrove wetlands are particularly important as fish nurseries: their myriad of exposed roots and tree trunks provide shelter for juveniles of estuarine, nearshore and ocean-going fishes and food is abundant.

Stocks of fishes such as mangrove jack *Lutjanus argentimaculatus* (see box), barramundi *Lates calcarifer*, snapper *Pagrus auratus*, blue threadfin *Eleutheronema tetradactylum*, sea mullet *Mugil cephalus* and bream *Acanthopagrus australis*, also banana prawns *Penaeus merguensis* and king prawns *Penaeus plebejus*, which are captured in commercial or recreational fisheries — though not necessarily in the mangrove wetlands — are to some extent dependent on the availability of mangrove nurseries. Banana prawns are typically caught by trawling in coastal waters adjacent to major estuarine nursery areas. Juvenile stages of some non-commercial fishes also live in mangroves and on migrating to the open ocean they become the food source of sport-fished marlin *Scorpaenidae* spp. and other billfish.



Mudskippers are a conspicuous inhabitant of mangrove wetlands and have specially adapted fins for moving across mud and climbing mangrove roots. Photo: Roger Jaensch, Wetlands International

Crustaceans and molluscs are the most conspicuous abundant animals in mangrove wetlands. Around 60 species of crabs live in mangrove wetlands. Some cling to trunks and roots at high tide; others such as fiddler crabs emerge from mud burrows at low tide and display their enlarged orange claws; others occupy abandoned shells. Certain species play an important role in consuming mangrove leaf litter or algae and detritus on the substrate, thereby assimilating nutrients into the food chain. The mangrove or mud crab *Scylla serrata* (see box) is commercially harvested. The mud lobster *Thalassina anomala* constructs a mud tower at its burrow entrance on the floor of the forest. Mud whelks *Pyrazus ebininus*, mangrove oysters *Saccostrea commercialis* and barnacles can be seen around tree bases or attached to tree trunks and roots. Loud click sounds are made by pistol shrimps. Other invertebrates may be less conspicuous but no less important: polychaete worms are part of the benthic fauna and shipworms associate with rotting wood. Human visitors are well aware of the abundance of mosquitoes and sandflies in mangrove wetlands.



Mangrove leaf litter forms an important part of the food chain of a mangrove wetland.

Photo: Roger Jaensch, Wetlands International

Other animal groups are less well represented. Estuarine crocodiles *Crocodylus porosus* (see box) are the largest animals in mangroves but tend not to be abundant. The white-bellied mangrove snake *Fordonia leucobalia*, little file snake *Acrochordus granulatus* and various sea snakes occur in mangroves. Lizards such as the mangrove monitor *Varanus indicus* and rusty monitor *Varanus semiremex* eat fish, crabs and insects. Bats such as the black flying-fox *Pteropus alecto* congregate in camps comprising of tens to hundreds of thousands of individuals. Other bat species common to mangroves include the little red flying-fox *Pteropus scapulatus* of which up to 1,000,000 individuals can be camped together, and the vulnerable (EPBC Act) grey-headed flying-fox *Pteropus poliocephalus* is known to eat mangrove leaves. The mangroves provide perfect habitat conditions for the flying-fox including proximity to waterways for navigation, large expanses of strong branches for roosting, and a broad distribution of stop-over points along the east coast for seasonal migrations in search of blossoms. The bats rely on a range of native forest types for feeding and prefer the blossoms of eucalypts, paperbarks, turpentines and acacias primarily, but will feed on mangrove flowers, particularly *Sonneratia alba*, when in season. Some species also eat rainforest and native plant fruits when available and cultivated fruit when these natural foods are scarce (see Other issues section). The false water-rat *Xeromys myoides* is also a mangrove specialist (see Species of conservation significance section).



Black flying-fox *Pteropus alecto* roost in mangrove wetlands. Photo: Graeme Russell, EPA

Unlike many other wetland types, mangroves tend not to support a high diversity or numbers of waterbirds. In a few locations (for example Broad Sound; south-east Gulf of Carpentaria), egrets *Ardea* spp., Australian white ibises *Threskiornis molucca*, royal spoonbills *Platalea regia*, cormorants *Phalacrocorax* spp. and/or other colonial species establish dense colonies of hundreds to thousands of breeding pairs in mangrove canopies, though the birds mainly feed in nearby freshwater wetlands. The most widespread waterbirds in Queensland's mangrove wetlands, usually seen hunting fish or invertebrates on exposed mud along channels or in gaps between mangroves, are the striated (mangrove) heron *Butorides striatus* and eastern reef-egret *Egretta sacra*, and in season, the whimbrel *Numenius phaeopus* (see box) and several other migratory shorebirds (see Species of conservation significance section). The great-billed heron *Ardea sumatrana*, another fish/invertebrate predator, is rare on Queensland's east coast but is more prevalent in undisturbed mangrove estuaries of the Gulf coastline. Even less often observed is the ground-dwelling chestnut rail *Eulabeornis castaneiventris*, a large crab-eating member of its family, which in Queensland is confined to mangroves on the southern Gulf coast.

Other birds inhabit the edges and forest of mangrove wetlands. Raptors such as the brahminy kite *Haliastur indus* and white-bellied sea-eagle *Haliaeetus leucogaster* (widespread coastal species) and kingfishers such as the little kingfisher *Alcedo pusilla* and collared kingfisher *Todiramphus chloris* hunt fish in mangrove wetlands. Many canopy and sub-canopy birds of Queensland's coastal dryland forests also occur in contiguous mangrove wetlands. The following are perhaps most typically associated with mangroves, though none exclusively: mangrove robin *Eopsaltria pulverulenta*, mangrove golden whistler *Pachycephala melanura*, white-breasted whistler *P. lanioides* and broad-billed flycatcher *Myiagra ruficollis* (insectivorous species, on northern coasts); shining flycatcher *M. alecto* and mangrove gerygone *Gerygone levigaster* (insectivorous, east coast); red-headed honeyeater *Myzomela erythrocephala* and varied honeyeater *Lichenostomus versicolor* (insectivorous/nectivorous, on northern and eastern coasts respectively); and black butcherbird *Cracticus quoyi* (carnivorous). Lorikeets visit mangroves for nectar during flowering events and Australian pied imperial pigeons *Ducula bicolor* use mangrove trees for nesting.

MANGROVE JACK

The mangrove jack *Lutjanus argentimaculatus* is a member of the snapper family that occurs mainly in tropical marine waters of the Indo-West and Central Pacific and in Australia it ranges around the northern half of our coastline. Mangrove wetlands are important for this fish because juveniles frequent mangrove estuaries and tidal rivers. Adults prefer reef and sheltered marine habitats to depths of over 100m. Young are typically red-brown or copper coloured and may show pale bars on their sides, but with age become pale and often have a pearly mark in the centre of each scale (hence the scientific name *argentimaculatus*, meaning "silver spotted"). Individuals reach maturity in about three years and eventually can grow to over 1.2m in length and weigh up to 16kg.



Mangrove jack *Lutjanus argentimaculatus*.

Photo: DPI&F

With these dimensions and being an energetic and powerful fighter, the mangrove jack is a prized target for recreational fishing. It is a regulated fish in Queensland to ensure sustainable harvest (see www.dpi.qld.gov.au/cps/rde/xchg/dpi/hs.xsl/28_1203_ENA_HTML.htm for further information including size and take/possession limits).

MUD OR MANGROVE CRAB

The mud crab *Scylla serrata* is widespread in the Asia Pacific region and in Australia it occurs on the northern and eastern coastline in estuaries and intertidal flats including mangrove wetlands. Spawning occurs in open ocean waters but the crabs prefer sheltered, shallow waters with a soft, muddy floor, hence mangrove wetlands provide good habitat. Mud crabs are dark brown, green and/or blue in colour and have a smooth, broad carapace (body shell) and flattened hind legs for swimming. Using its rugged claws, the mud crab eats barnacles, bivalves, other crabs and dead fish and is an omnivorous scavenger. Males of this crab can grow to more than 25cm in shell breadth and 2kg in weight, which is why it is popular as food for humans. It is a regulated crab in Queensland to prevent over-harvesting (see www.dpi.qld.gov.au/cps/rde/xchg/dpi/hs.xsl/28_1203_ENA_HTML.htm for further information including size and take/possession limits). In year 2000, the gross value of mud crabs harvested between Cape Tribulation and Bowling Green Bay was \$1.7 million. Attempts have been made to establish commercial aquaculture of mud crabs to fulfil this demand.



Mud crab *Scylla serrata* prefers sheltered habitat of estuaries and intertidal flats. It makes characteristic oval burrows in muddy banks of estuaries and mangrove flats. Photo: EPA

A number of commercial enterprises and government agencies are researching ways to improve the hatchery technology, develop cost-effective formulated diets and improve the crabs' growth and survivorship in the grow-out (maturing) phase. Persons intending to develop an aquaculture enterprise in Queensland must apply for an aquaculture approval under the *Integrated Planning Act 1997* (see the DPI&F website).

Species of conservation significance

Few threatened species are known to occur in Queensland's mangrove wetlands.

The vulnerable epiphytic ant plant *Myrmecodia beccarii* (NC and EPBC Acts) grows in the canopy of mangrove and melaleuca wetlands of northern Queensland. The ant plant has enlarged stems that form a tuberous structure and as the plant grows, hollow chambers form within the plant, allowing the golden ant *Philidris cordatus* to colonise it. Caterpillars (hatched larvae), of the vulnerable Apollo jewel butterfly *Hypochrysops apollo apollo* (NC Act) have glands that secrete a sugary substance that attracts the golden ant and after hatching, are carried inside the plant by the ants. In the process of feeding, the larvae further enlarge the ant galleries and over many generations can eat out the host plant and leave only its shell. No more than one larva is generally found in any one plant. The butterfly larvae feed primarily on the internal tissue of the ant plant and sometimes on the leaves at night.



Ant plant *Myrmecodia beccarii*. Photo: Roger Jaensch, Wetlands International



The vulnerable Apollo jewel butterfly *Hypochrysops apollo apollo*. Photo: Chris Hill/Leanne Sommer, EPA

Illidge's ant-blue butterfly or mangrove butterfly *Acrodipsas illidgei* of south-east Queensland is another vulnerable (NC Act) insect that uses the mangrove wetlands as its primary habitat. It prefers wetlands dominated by the red (spotted) mangrove and the grey mangrove from which the females very occasionally feed on the flowers. They are also found in adjacent woodlands of *Corymbia* spp. and swamp she-oak *Casuarina glauca* where their associated ant *Crematogaster* sp. occurs in dead branches or under bark of the older trees.



Mangrove wetlands provide habitat for the vulnerable Illidge's ant-blue butterfly *Acrodipsas illidgei*. These images show the different colours of a male's wings from above and below. Photos: Queensland Museum

The water mouse or false water-rat *Xeromys myoides*, listed as vulnerable under the Commonwealth EPBC Act, the Queensland NC Act and on the IUCN Red List (see *Saltmarsh wetlands* management profile www.epa.qld.gov.au/nature_conservation/habitats/wetlands/wetland_management_profiles/), feeds among mangroves by night at low tide eating crabs and other small crustaceans, shellfish and flatworms. It nests in either large termite-like mud mounds, hollow bases of large decayed eucalypt stumps near the mangrove zone or in simple tunnels above the high water mark. It has been found in small numbers in the Proserpine-Mackay, Wide Bay, Great Sandy and Moreton Bay districts. Destruction of mangrove habitat for urban, industrial, mining, marine and agricultural development, or disassociation of mangroves from saltmarsh breeding sites, as well as predation by feral animals are potential threats to this species. It is also vital that water quality and natural hydrology (normal tidal and freshwater patterns and an undisturbed water table) be maintained when conducting activities on or adjacent to false water-rat habitat.

The estuarine crocodile *Crocodylus porosus* (see Ecological values — fauna section and box) is listed as vulnerable under the NC Act and as a migratory species under the EPBC Act.

Occasionally, the vulnerable beach stone-curlew *Esacus neglectus* (NC Act) is recorded on mudflats within mangrove wetlands (see Appendix 2).



The vulnerable beach stone-curlew *Esacus neglectus* can sometimes be found in mangrove wetlands. Photo: Roger Jaensch, Wetlands International

Migratory shorebirds that commonly feed on worms, small crabs and other benthic fauna on exposed mudflats within mangrove wetlands include the eastern curlew *Numenius madagascariensis*, whimbrel *N. phaeopus*, grey-tailed tattler *Heteroscelus brevipes* and common sandpiper *Actitis hypoleucos*.

The whimbrel and grey-tailed tattler often roost in mangrove trees at high tide. These birds breed in Asia and are listed as migratory species under the EPBC Act (see Appendix 2). A number of coastal wetlands in Queensland qualify for listing in the Shorebird Site Network of the East Asian – Australasian Flyway (www.deh.gov.au/biodiversity/migratory/waterbirds/infosn1.html#sites) and some include mangroves; so far, Moreton Bay has been included in this non-regulatory network and other sites have been proposed for inclusion.

Several other waterbirds that use mangrove wetlands for feeding, roosting and/or nesting are listed under JAMBA/CAMBA and thus under the EPBC Act (see Appendix 2), though they are not truly migratory: they include the eastern reef egret *Egretta sacra*, osprey *Pandion haliaetus* and white-bellied sea-eagle *Haliaeetus leucogaster*.

Bird species listed as rare in Queensland (NC Act) and that use mangrove wetlands are:

- radjah shelduck *Tadorna radjah* (mainly in tropical regions; occasionally on mudflats)
- black-necked stork *Ephippiorhynchus asiaticus* (sometimes nests in mangroves)

- grey goshawk *Accipiter novaehollandiae* (uses forest habitat)
- eastern curlew *Numenius madagascariensis* (migratory shorebird; feeds on mudflats)



Eastern reef egrets *Egretta sacra* feed in mangrove wetlands. Photo: Roger Jaensch, Wetlands International

ESTUARINE OR SALTWATER CROCODILE

Despite occurring from India to Australia, the vulnerable (NC Act) estuarine crocodile *Crocodylus porosus* has declined markedly in Asia, thereby increasing the conservation value of the sizeable protected population in Australia. In Queensland, this crocodile occurs in mangrove wetlands, estuaries and associated wetlands (fresh and saline) from the Gulf of Carpentaria to the Fitzroy River delta in Central Queensland. In tidal rivers, crocodiles up to two metres long feed mainly in the mangrove wetlands during the dry season, a time of scarce resources. Mainly a nocturnal feeder, the crocodile captures crabs, prawns, mudskippers and other small fish when it is young; when it is mature, mud crabs remain an important food and larger prey such as birds, pigs and wallabies form part of its diet. Mangroves provide shade for the cold-blooded crocodile in hotter months. Most adults are less than 4–5m long. Estuarine crocodiles present a management challenge to the Queensland Parks and Wildlife Service and other authorities: to protect people from crocodiles but also to protect crocodiles.



Estuarine crocodile *Crocodylus porosus* basking under mangroves. Photo: EPA

Potentially dangerous crocodiles are often captured and relocated away from people and education on living in crocodile country is a key management strategy (see www.epa.qld.gov.au/nature_conservation/wildlife/living_with_wildlife/crocodiles/). Large tracts of mangrove wetland, where contact with people is reduced, provide important refuge areas for crocodiles.

WHIMBREL

From breeding grounds in north-east Asia, the whimbrel *Numenius phaeopus* travels over 10,000km to Queensland in August-October, and back again in March-May, each year. It is one of the larger shorebirds that visit Australia and its remarkable migration requires a substantial energy reserve to be accumulated. Securing shrimps, crabs, worms and other benthic food items by probing its curved beak deep into soft mud, the whimbrel ranges across intertidal mudflats and along creeks and river banks through mangrove wetlands. At high tide, it commonly roosts on mangrove trees beside channels until it can resume feeding. Excessive disturbance of feeding or roosting whimbrels caused by passage of boats may increase the effort that this bird needs to invest in preparing for migration. This might be avoided by reducing boat speeds and appropriate timing of boat travel and exclusion of boats around key roost sites. Pollution of water entering mangroves and subsequent loss of benthic feed should also be avoided. Whimbrels occur around the entire Australian coastline and their population size in the East Asian — Australasian Flyway is estimated to be 55,000 birds (www.wetlands.org/pubs&/pub_online/WPE/165-171.pdf). Five sites in Queensland,



The whimbrel *Numenius phaeopus* migrates for the austral summer from its breeding grounds in the Arctic Circle and feeds and roosts in mangrove wetlands.

Photo: EPA

for example the Great Sandy Strait, are known to support at least one percent of the Flyway population of the whimbrel and all include substantial areas of mangrove wetland.

Managing mangrove wetlands

In Queensland, mangrove wetlands mainly fall under the jurisdiction of several government agencies but industry and other community members are also stakeholders in their management. The Department of Primary Industries and Fisheries (DPI&F) manages marine plants, including mangroves, throughout Queensland and any disturbance to mangroves requires an approval under the *Integrated Planning Act 1997*. Self assessable codes under the *Queensland Fisheries Act 1994* may also apply to proposed mangrove (and other marine plant) disturbance. Many mangroves occur below the level of Mean High Water Spring (MHWS) and so are not in private tenure.

Some mangrove wetlands are in protected areas managed by Queensland's Environmental Protection Agency (EPA) and/or have additional protection as declared Fish Habitat Areas, administered by the DPI&F (see Queensland conservation status). Outside of protected areas and tenured lands, they occur on freehold, leasehold and unallocated State Land; in each case being managed by the DPI&F under the *Fisheries Act 1994*. This arrangement applies along the mainland coast of the Great Barrier Reef system

because the landward boundary of the Great Barrier Reef Marine Park is the low water mark. However, the Australian Government has some jurisdiction over mangroves on this same coast because the boundary of the Great Barrier Reef World Heritage Area extends to the high water mark (MHWS). Some sections of this coast (for example near Cairns, Townsville, Mackay, Gladstone) have been excluded from the Marine Park and/or World Heritage Area and are managed by a number of port authorities, for example the Port of Brisbane. The Australian Government Department of Defence manages training areas at Wide Bay, Shoalwater Bay and Cowley Beach that include areas of mangrove wetlands. The Australian Government's Department of the Environment and Heritage is a stakeholder in Ramsar sites that include mangrove wetlands (see the National conservation status section).

Local government and relevant state agencies also have wetland management policies (see Town, coastal and regional planning section) that include mangrove wetlands. Similarly, regional and catchment bodies such as the Fitzroy Basin Association have included coastal/mangrove management in their regional investment plans for federal funding of specific actions (see Town, coastal and regional planning section).

Other non-government organisations with a direct interest in mangrove wetlands include enterprises and organisations for commercial fishing and tourism. Private landholders and industry groups have a responsibility to manage any indirect impacts their land use may cause in catchments where water flows into mangrove wetlands (see Control of water flows and Protecting water quality sections).

AN integrated approach to management of mangrove wetlands is vital due to the complex tenure scenario and diversity of managers and stakeholders.

Town, coastal and regional planning

With this complex tenure scenario and diversity of managers and stakeholders, it is vital that an integrated approach to management of mangrove wetlands is undertaken. In the past, development in the coastal zone often has been unplanned and unregulated resulting in the loss and degradation of mangroves in a number of areas, for example by the construction of canal housing estates in mangrove wetlands. Today, town and coastal plans provide the basis for a holistic and comprehensive solution, facilitating linkages between responsible government agencies, scientific institutions and the wider community.



Mangrove wetlands have been replaced by canal estate developments in some areas. Photo: EPA

Under the Queensland *Integrated Planning Act 1997* (IP Act), local government must have regard to the policies of the State and Regional coastal plans when assessing proposed developments in the coastal zone. Local governments must also reflect these policies in their town or shire planning schemes. These policies are whole-of-government documents, ensuring integrated implementation across the State's multiple government agencies.

Coastal wetlands, including mangroves, are given a high priority in coastal planning because they protect coastal shores. This is highly relevant to the Queensland coast which is subject to cyclone damage from time to time. Mangroves dissipate wave energy initially at the seaward edge, but during high tides and storm surges this occurs farther inside the wetland. It is therefore important to maintain mangrove wetlands that are as intact and wide as possible.

The Queensland *Fisheries Act 1994* is managed by DPI&F and protects both marine plants, including mangroves and mangrove associates and important areas of fish habitat (see Queensland conservation status and Control of water flows sections for more details).

Another sector of the community with an interest in protecting the values of wetlands, including mangrove wetlands, are the regional natural resource management (NRM) bodies. These are community-based organisations in various regions across the state, established to promote sustainable development through integrated catchment management processes. This involves the development of federally accredited NRM plans and sub-catchment plans that provide an integrated approach for on-ground actions and identify where Natural Heritage Trust (NHT2) and National Action Plan for Salinity and Water Quality (NAP) funding will be invested to achieve the identified outcomes.

The NRM plans produced by the regional bodies are designed to focus on catchment assets and pressures and are part of a larger picture for natural resource management. The plans operate within other local, regional, State and Australian Government planning processes (legislation, policies and strategies) and industry codes of practice. These regional bodies have trained project officers who co-ordinate field days, conduct property visits and assist landholders and councils in accessing current land management information as well as providing incentive funding to complete on-ground works. For more information on the regional body operating in your catchment and their funded project opportunities go to www.nrm.gov.au/state/qld/index.html#regions.

THE health of mangrove wetlands depends on particular regimes of seawater and freshwater inflow — the exclusion of tidal or freshwater inflows can cause soil salinity to reach levels that are lethal for mangrove plants.

BUNDABERG CITY COUNCIL MANGROVE MANAGEMENT

The Bundaberg City Council and Department of Primary Industries and Fisheries (DPI&F) have been working on a strategic approach to mangrove management along the Burnett River for almost two years. Previously works conducted by council on the mangrove systems (between the barrage to the port) were on an ad hoc basis and did not holistically manage the habitat and other values of these communities. Now this section of the river has been divided into 26 River Bank Units (RBUs) and the sites described and marked using [Global Positioning System](#) (GPS) points. The RBUs have been assigned one of four classification levels which provides an operational plan that guides works crews as to the type and level of operational or maintenance works that are recommended for that level. The aim is for the operational plan for each RBU to list the site-specific activities and actions to occur within that unit. Council has the opportunity to define what works can be done and DPI&F can ensure protection of the mangrove resource.

A trial is occurring at one site where the Council is manipulating a 15m section, by thinning out the adult grey mangroves and looking at the rates of light penetration and regrowth.

All operational plans are under a broader council Strategic Plan for Mangrove Management and align with the self assessable codes under the *Fisheries Act 1994* and have been approved in principle by DPI&F. It is intended they will also be approved under the *Integrated Planning Act 1997*. The Strategic Plan will be reviewed every four years. Bundaberg City Council is the first council in Queensland to define a strategic approach to mangrove management. DPI&F is working with other councils to try to get a standardised approach across the State. Much of this approach will draw on the experiences of the Bundaberg City Council and DPI&F on the Burnett River.

MANAGING MANGROVES IN THE GLADSTONE PORT AND INDUSTRIAL AREA

In the Port Curtis area, near Gladstone, 38 percent of mangrove wetland was lost from 1941 to 1999, largely due to reclamation of tidal lands for industrial and urban development. Reduced outflow of freshwater in the Boyne River since construction of the Awoonga Dam may be contributing to changes in mangrove wetlands in Port Curtis. Dieback of seaward grey mangrove *Avicennia marina* trees, possibly caused in part by pollutants in coastal waters, occurred in the 1970s and may be continuing. Other impacts that are possibly harmful to mangroves in this area are the

release of hot water from a coal-fired power station and of wastewater from a sewage treatment plant and industries. There is an ongoing threat of marine pest species being introduced to the mangroves via ballast water or the hulls of ships in this particularly busy port. The Port Curtis Integrated Monitoring Program, involving a number of key stakeholders (including the Central Queensland Port Authority, Port Alma and the Environmental Protection Agency) is monitoring the harbour and the implementation of policies to ensure the area is protected against such threats.

Control of water flows

The health of mangrove wetlands depends on particular regimes of seawater and freshwater inflow. Exclusion of tidal movement or the influx of freshwater can cause soil salinity to reach levels that are lethal for the mangrove plants.

A common cause of changed flow regimes is construction of seawalls, [bunds](#), roads, bridge embankments and industrial infrastructure through mangrove wetlands, with inadequate piping for water exchange or none at all. Water ponding in mangrove wetlands often causes mangrove dieback through

altered inundation regimes and waterlogging of the roots. Changed flow regimes may be prevented or rectified by choosing alternative designs to barriers, or alternative infrastructure, and/or by ensuring there are culverts or pipes for adequate water exchange.

At a different scale but still locally significant, construction of [block banks](#) on tidal channels in saltmarsh wetlands and longer bunds across marine plains, can have similar impacts to walls constructed through the mangrove wetland. Both mangroves and fishes that normally migrate between mangrove and saltmarsh wetlands are negatively affected.



Waterlogging has killed mangroves at Luggage Point. Photo: Sarah Young

Following the proliferation of such structures over past decades, often for development of ponded pastures, the State Government introduced controls. The Queensland *Policy for Development and Use of Pounded Pastures (DNRM, 2001)* and the Queensland *Fisheries Act 1994* prevent and control the construction of barriers to tidal flows in wetlands subject to tidal inundation such as mangroves and saltmarshes. A Development Approval for Waterway Barrier Works is required under the *Integrated Planning Act 1997* for the building of a new barrier or raising an existing structure across any waterway and in the event of an approval, applicants may be required to construct a “fishway” to enable fish migration into and out of the mangrove or saltmarsh nursery areas.

Upstream of mangroves, emplacement of new dams on river systems can greatly reduce freshwater outflows to estuaries and the nearby coast where mangroves grow, especially outside of major flood periods.

Acid sulfate soils

Mangrove wetlands are commonly associated with substrates that naturally contain acid sulfate soils (ASS). Potential acid sulfate soils are a problem when exposed to air by excavation or lowering of the water table. Bacteria in estuarine sediments turn sulfates into sulfides under anaerobic conditions. Once exposed to air, the iron sulfides (pyrite) in the soils react with oxygen to form sulfuric acid. After rain the acid can be flushed into creeks where the water turns so acidic that fish may be killed.

Degradation of concrete and steel structures can occur. In addition, toxic metals may be dissolved out of the soils by the acid, and leach into the environment.

A State planning policy for ASS (*State Planning Policy 2/02: Planning and Managing Development Involving Acid Sulfate Soils* and associated *State Planning Policy 2/02 Guideline: Acid Sulfate Soils* — www.nrm.qld.gov.au/land/ass/qassit/planning_policy.html) came into effect in 2002. For any development on land, soil or sediment at or below five metres above sea level the policy requires that the release of acid and associated metal contaminants into the environment be avoided by either not disturbing the soils, or by treating and managing the soil and associated drainage water. Prior to disturbing the soil a management plan must be developed in consultation with a soil scientist or engineer with experience in ASS. After disturbance ongoing monitoring at the site is essential. Further information regarding ASS and its management is available from the Queensland Department of Natural Resources and Mines (www.nrm.qld.gov.au/land/ass/what_are_ass/index.html). Local development control plans, regional coastal zone plans and building codes may also provide additional information.

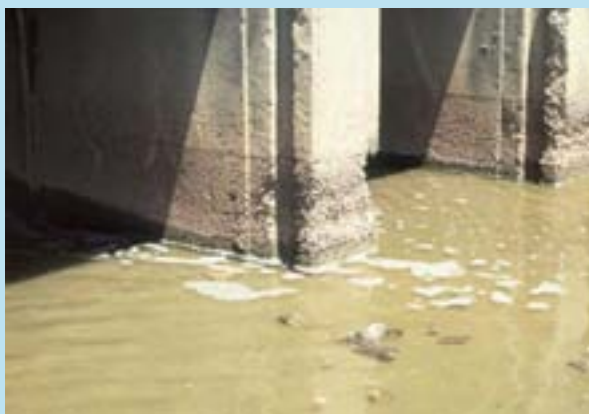


Potential acid sulfate soils (also called “marine mud” or “mangrove mud”) are typically dark grey, wet and sticky. They can range from sand to clays. Photo: Queensland Acid Sulfate Soils Investigation Team (QASSIT), NR&M

WHAT ARE ACID SULFATE SOILS?

Acid sulfate soils (ASS) are a natural phenomenon, with an estimated 2.3 million hectares occurring along the Queensland coast. The acid sulfate soils found today have predominately formed over the last 20,000 years as mangroves and other organic matter accumulated on tidal flats and mixed with saline water under anaerobic conditions. ASS usually occur at elevations less than five metres above sea level (reflecting the extent of sea level and tidal influence in recent times) and are common under low lying areas such as estuaries, saltmarshes, floodplains, tidal and brackish lakes, mangrove flats, coastal melaleuca swamps and coastal grass-sedge wetlands.

ASS is highly variable in form, ranging from mud to sand and peat, however they all contain iron sulfide. In their normal waterlogged state, ASS are harmless to the environment, however when disturbed by drainage, excavation or other activities, the sulfides in the soil are exposed and react with oxygen in air to produce sulfuric acid. Sulfuric acid breaks down the soil and releases toxins such as aluminium, iron and other metals. These toxins leach into waterways and can cause serious consequences such as poisoning of fish, oysters, crabs and other aquatic life. ASS can also promote diseases such as fish red-spot, and corrode and destroy concrete and steel structures. Exposed acid sulfate soils often irreversibly shrink and crack, causing building foundations or roads to subside or split.



Concrete bridge pylons in the Pimpama River, south-east Queensland corroded by acid sulfate soils.



Sulfuric acid produced during the oxidation of acid sulfate soils strips iron from the soil and toxic amounts of the colourless iron can then be washed into waterways. The colourless iron in the acid water changes to rust red when it contacts less acid water, such as rainwater or seawater. This results in a rust-coloured iron oxide scum or "floc" which can smother vegetation and stain concrete and soil.



Exposure to acid water and toxic heavy metals associated with disturbed acid sulfate soils damages fish skin and gills, increasing the susceptibility of fish to fungal infections such as "red-spot" disease. Red-spot disease results in red ulcerative lesions, leaving them unsaleable and may result in fish death.

Photos: Queensland Acid Sulfate Soils Investigation Team (QASSIT), NR&M

EAST TRINITY ACID SULFATE SOIL STORY

In the 1970s, a seawall was built through mangrove wetlands on a 940ha area of land on the eastern side of Trinity Inlet, Cairns. The natural creeks were either cut off by the seawall or floodgated to prevent saltwater entering the site. Much of the land was cleared, levelled and drained to create new land for sugar cane production. Mangroves soon died on both the landward and seaward sides of the wall, a result of the draining, cultivation and exposure of acid sulfate soils in the reclaimed area. The exposure of the soils threatened the viability of any future agriculture on the site as well as the productivity of the adjacent fishing grounds. The property fell into disrepair and following several failed developments was purchased in May 2000 by the Queensland Government. The Queensland Government launched a remediation project in the Hills Creek sub-catchment using lime-assisted tidal exchange. The project involves the modification of existing

floodgates to progressively allow seawater into low-lying areas to neutralise the acid in combination with the application of a hydrated lime (calcium hydroxide) slurry. The installation of “smart gates” is intended to ensure the soils are exposed to consistent inundations of seawater on a daily basis. Results within this sub-catchment to date have been promising, with mangroves and mangrove ferns naturally regenerating, soldier crabs recolonising and some fish species being found in the surrounding waters. The Department of Natural Resources and Mines (NR&M) will use \$4 million of State funding over the next four years to introduce similar techniques within the Firewood Creek sub-catchment as well as manage the broader site’s ASS issues. The aim is to ensure the water discharged from the site meets national water quality guidelines. Techniques trialled at the site may be useful for similarly damaged areas within Queensland and internationally.



Treating an acidic water body at East Trinity with a hydrated lime slurry.



The floodgates on Hills Creek at the seawall, East Trinity, Cairns are being altered to allow seawater into low-lying areas to neutralise acid in combination with a hydrated lime slurry.



Mangroves (above) and mangrove ferns *Acrostichum speciosum* (below) are beginning to recolonise East Trinity. Photos: Queensland Acid Sulfate Soils Investigation Team (QASSIT), NR&M

AN increase in nutrient inflows may cause proliferation of algae that alter the natural functioning of the mangrove wetland ecosystem.

Protecting water quality

Stormwater drained from urban areas, farmland and industrial sites into mangrove wetlands may alter the ecology of the wetland. By reducing the salinity, mangrove plants and invertebrates may be disadvantaged. Sediments carried by stormwater may smother mangrove pneumatophores. Drainage from industrial sites, canefields and other irrigated agricultural areas into mangrove wetlands may introduce heavy metals, oils and other chemicals into the marine food web and potentially affect fish stocks.

Wastewater from aquaculture and sewage treatment ponds may have a similar effect if not managed properly. An increase in nutrient inflows may cause proliferation of algae that alter the natural functioning of the mangrove wetland ecosystem.

Aquaculture activities are managed under the Queensland *Fisheries Act 1994* and the *Integrated Planning Act 1997*. An aquaculture approval is required for the culture of any fisheries resources (including fish, crustaceans and marine plants) for sale. Self assessable and assessable codes exist to ensure developers identify the benefits and potential impacts of any aquaculture activities as well as the species and production system and types of mitigation if required. For more information on developing aquaculture enterprises in Queensland see the DPI&F website at www.dpi.qld.gov.au/cps/rde/xchg/dpi/hs.xml/28_141_ENA_HTML.htm.

MANGROVE DIEBACK IN THE MACKAY AREA

In June 2000 an investigative team from the Marine Botany Unit of the University of Queensland (in association with the Coasts and Clean Seas initiative of the Australian Government's Natural Heritage Trust) began a field study of the dieback of mangroves affecting the Pioneer Catchment of Mackay. The three estuaries affected by the dieback were McCready's Creek, the Pioneer River and Bakers Creek. The extent of dieback in McCready's Creek and Bakers Creek was less than in the Pioneer River, with dieback occurring only in isolated patches. Aerial surveys of mangrove areas in the Pioneer River showed that notable dieback dominated most sections of the estuary from the river mouth to the farthest extent of mangroves upstream. The grey mangrove *Avicennia marina* was the main species affected and all areas of this species were affected by moderate or severe dieback. The onset of the dieback in the catchments may have been from as early as the mid 1990s and possibly occurred in the upstream mangrove stands first.

During field studies, the appearance of anomalous pneumatophores was noted. Forking of the tips of the roots into flower-shaped arrangements in Bakers Creek was unlike anything seen at other sites. The formation of these abnormal-looking pneumatophores is believed to be a technique used by the mangrove plant to increase the surface area available for oxygen uptake and improve their likelihood of survival. It is also believed to be a response to persistent sublethal stress in the rhizosphere, extensive death of supporting

pneumatophores and/or an inability to regenerate new pneumatophores.

The study summarised a list of the agents most likely to cause mangrove dieback. These included heavy metals, excess nutrients, pneumatophore burial, herbicides and more complex factors. Secondary consequences of such extensive mangrove dieback include sedimentation, erosion and bank slumping causing a mass mobilisation of sediment from the upper intertidal areas to the lower intertidal areas, resulting in erosion and exposure of roots in the upper zones and burial of mangroves in the lower section. This sediment movement also has implications for adjacent seagrass beds and coral ecosystems as the sediment will be easily mobilised in the next large rainfall/runoff event.

According to this study, herbicides, particularly diuron, was the most likely factor to have caused the dieback. Other factors appeared to have only synergistic effects in either enhancing or reducing severity of dieback.

It should be noted that there is no general acceptance of the cause identified in this study. An equally plausible cause — smothering of the pneumatophores by excessive siltation — has also been identified and has not been discounted. The Mackay Whitsunday Natural Resource Management Group is monitoring the continuing dieback and giving further consideration to the causes and also the actions required to mitigate dieback in the Pioneer River and its sub-catchments.

MANAGING THE IMPACTS OF OIL SPILLS

Industrial oil spilt from sea-going tanker ships or from land-based facilities can kill mangrove fauna and also kill mangrove seedlings and trees by preventing pneumatophores from obtaining oxygen. In 1995, a major research project on oiling of mangroves was conducted by the Cooperative Research Centre for Ecologically Sustainable Development of the Great Barrier Reef and the Australian Institute of Marine Science (AIMS) in collaboration with the Australian Petroleum Production and Exploration Association and the Energy Research and Development Corporation. At an area of mangrove wetland earmarked for reclamation (*Rhizophora stylosa* 6-8m in height) in Port Curtis, Gladstone, nine plots of mangrove were enclosed using curtains of vinyl fabric and tidal oil-gates. With approval from the Queensland Department of Primary Industries and Fisheries, pre-weathered oil of a type typically shipped around Australia was applied to the plots at a rate of around five litres per square metre, to simulate a large offshore oil spill. Some oil was treated with chemical dispersant. Floating absorbent booms were installed in surrounding areas and a skimmer vessel was put on standby to safeguard against wider spread of the applied oil. Over two years, biological studies were conducted on leaf litter fall, canopy productivity, shoot growth, photosynthesis of leaves, removal of fallen leaves by crabs, and presence and diversity of crabs and burrowing worms. Dead fauna collected after 40 hours from oil application were mainly crabs, pistol shrimps and mud lobsters. Leaf removal by crabs reduced by 50 percent and sipunculid worms did not recover within the study period. Significant death of seedlings occurred within 1-2 months and of trees within 2-7 months, while leaf biomass in canopies of surviving trees was reduced by 20-30 percent. Plant house trials showed that the impact of oil varied with tree species and type of oil. These research projects together with assessment of past spills have contributed to a response strategy for managers of mangrove wetlands, comprising four phases. The first (pre-spill) involves assessment of past incidents and identification of research into appropriate control and recovery methods. The second stage (soon after spill) focuses on reducing the amount of oil that reaches mangroves, using booms and collection apparatus, toxic dispersants (in deep water) and promoting biodegradation of the oil; as well as delaying the arrival of the oil so that it is timed to match the highest tides to protect the vital seaward fringe of mangrove trees.

Thirdly, once oil has entered the mangrove wetland, managers should map and quantify the oil, collect surface sediments for analysis and document oiled and dead mangrove fauna and flora. Finally, once oil has killed mangroves, the areas of tree death should be mapped and species identified, and natural recruitment of seedlings should be promoted (replanting is not necessarily advocated) until recovery becomes self-sustaining (see www.aims.gov.au/pages/research/mangroves/fae/fae01.html for full details.)



Oiled grey mangrove *Avicennia marina* in the Brisbane River at Bulwer Island after a fuel oil spill in the harbour in 2001. Photo: Norman C. Duke, University of Queensland



A boom to reduce the effects of a large oil spill across an *Avicennia marina* mangrove-bordered drain at Lytton on the Brisbane River. Photo: Norman C. Duke, University of Queensland

THE DPI&F's policy on buffer zones relates to the provision of naturally vegetated buffer zones between developments and natural waterways, including mangrove wetlands.

Using buffers to protect wetlands

Buffer zones are recognised as being vital to maintain the ecological values of waterways. The Department of Primary Industries and Fisheries has a policy on buffer zones entitled *Fish Habitat Buffer Zones* (2001). This policy mainly pertains to the provision of naturally vegetated buffer zones of 100 metres between developments (for example urban areas or agricultural areas) and natural waterways, including mangrove wetlands. See the DPI&F website (www.dpi.qld.gov.au/cps/rde/xchg/dpi/hs.xsl/28_142_ENA_HTML.htm) for further information.

Change in extent of mangroves

The structure and extent of mangrove wetlands can change naturally due to the ravages of cyclones and other storms, which may defoliate or flatten trees and/or cause severe erosion of sea-front mangroves. Erosion (undercutting and collapse) of mangroves along tidal channels and estuaries may also occur, especially where meandering channels are prone to lateral shift or where rivers are prone to major flooding. Rising sea-level, accelerated by global warming, may also be contributing to changes in extent of mangrove wetlands. However, in many instances the reasons for change are not clear.

Mangrove wetlands can also spread seaward by establishing seedlings on previously exposed mudflats or on new sediment deposits created by changes in coastal currents, artificial modifications to coastal sedimentation patterns, or erosion of inland catchments. In the Johnstone River catchment, a 14 percent increase in area of mangrove wetland was recorded between 1951 and 1992. Removal of mangroves may alter sedimentation patterns in port areas, requiring costly dredging work.

In the Great Barrier Reef WHA, it has been determined that the mangrove wetlands are resilient: there has been no net decline in area of mangrove wetlands over the last 40 years. Many of these mangrove wetlands are considered to be of old age and responding to natural events over long time periods, less so around river estuaries in high rainfall areas.

However, it is feared that localised impacts have been accumulating to the extent that substantial areas are now threatened, and that the present collective capacity of managers to respond to such a threat will be inadequate.

IMPROVED public education on mangrove wetlands compliments the multitude of planning processes, providing simple messages and raising awareness of the linkages between mangrove wetlands and their landward and seaward ecosystem neighbours.

Ecotourism and education

Improved public education on mangrove wetlands compliments the multitude of planning processes, providing simple messages and raising awareness of the linkages between mangrove wetlands and their landward and seaward ecosystem neighbours. Over the last 30 years or so, there has been an increase in both scientific and public interest in mangrove wetlands, inspired by our increasing awareness of ecosystem fragility and the greater demand for coastal land for development. Subtle changes in language may indicate a change in attitudes towards mangrove wetlands. Words used to describe mangroves seem to be less derogatory and marked by fewer references to "scrubs, swamps and bogs" and to more about "trees, forests, mudflats and fisheries habitats".

Many mangrove wetland tours and boardwalks exist across Queensland. The Brisbane City Council has developed the "Mangrove Meander" wetland tour at the Boondall Wetlands Reserve. The Boondall Wetlands Environment Centre offers a range of displays and activities on the environmental and cultural heritage values of the reserve for visitors and organised groups and provides self-guided resources. The Brisbane City Council also has a self-guided walk over a hand-built, floating boardwalk along the Brisbane River in the Brisbane Botanic Gardens, Gardens Point. Mangroves are also a prominent feature of Hays Inlet, a declared Fish Habitat Area managed by the Department of Primary Industries and Fisheries and a Conservation Park, managed by the Redcliffe City Council. Hays Inlet is also a key coastal site under the South East Queensland Coastal Management Plan. The Cairns airport also contains a mangrove boardwalk.



Visitor education centres such as the Boondall Wetlands Environment Centre help to raise awareness of the importance of mangrove wetlands and their surrounding ecosystems.

Photo: Sarah Young

The Queensland Parks and Wildlife Service offers a number of self-guided mangrove wetland walks at Cape Hillsborough National Park, Bowling Green Bay National Park, Hinchinbrook Island National Park and Thorsborne Trail, Cape Palmerston National Park and at David Fleay Wildlife Park on the Gold Coast. These have been designed specifically for groups to study mangroves.

Many of the national parks have Visitor Information Sheets that provide maps and a summary of the values and things to look out for along the tracks. These are available from local offices or on the EPA website (www.epa.qld.gov.au).

Other issues

Mangroves possess peculiar chemical properties, perhaps as a result of the stressful conditions they live under. Furthermore, many mangrove plants have been used in traditional medicine and the scientific analysis of these extracts can be expected to develop effective agents against human, animal and plant diseases. It is important to protect mangrove wetlands for their rich sources of chemicals including saponins, alkaloids and flavonoids and potentially many other substances of value to industry and medicine.

The use of mangrove wetlands by a number of Australia's flying-fox species creates contentious issues within urban environments. Their consumption of cultivated fruit when natural foods are not available (due to prolonged droughts or clearing activities) brings them into direct conflict with humans. The continued urban expansion in coastal areas also contributes to human conflicts when housing developments and public lands are located adjacent to mangrove wetlands.

FLYING-FOX MANAGEMENT IN COASTAL CENTRAL QUEENSLAND

The Queensland Parks and Wildlife Service (QPWS) has developed a policy for the *Management of Urban Flying-fox colonies in Queensland* and is working with a number of local government councils on ways to deal with issues arising from flying-fox occupation in urban areas. An example is the draft Memorandum of Agreement between QPWS and the Calliope Shire Council in Central Queensland, which details the roles and responsibilities of these two stakeholders and that of the community. It provides guidelines for the management of flying-foxes in the shire and outlines practical actions that ensure sustainability of the species, whilst addressing the concerns of their human neighbours. Such actions include planting appropriate street trees and educating residents about backyard planting, ensuring provision of suitable habitat away from

urban areas and providing buffers to known camp sites in the Shire's planning scheme and strategic plan under the *Integrated Planning Act 1997* and in the Shire's Green Space plan, and outlining if/when dispersal methods will be used. Affected residents can have input into a consultative committee that includes representatives from QPWS, local government and conservation groups and incorporates the interests of the local Aboriginal people — the Bulgwoyn Bulgwoyn clan of the Gooreng Nation, for whom the flying-fox is a clan totem with spiritual significance. QPWS hopes to develop similar agreements with other councils and contribute to the broader understanding of mangroves and their fauna. Tips for living with flying-foxes can be found on the EPA website at www.epa.qld.gov.au/nature_conservation/wildlife/native_animals/living_with_wildlife/flyingfoxes/.

Glossary

Acid sulfate soil (ASS) A soil which is potentially extremely acidic (pH <3.5) because of large amounts of reduced forms of sulfur that are oxidised to sulfuric acid if the soils are exposed to oxygen when they are drained or excavated.

Amplitude The maximum height of a wave crest or depth of a trough.

Anaerobic Without oxygen.

Benthic Aquatic organisms that live on the bottom of a river, lake or ocean.

Bioregion (biogeographic region) An area of the continent defined by a combination of particular geology, landforms, climate and vegetation. For the definition of regional ecosystems, the bioregions of Sattler and Williams (1999) are adopted.

Block bank A small earthen wall laid across a channel used to retain freshwater flows or impede tidal saline influence.

Bonn Convention The Convention on the Conservation of Migratory Species of Wild Animals, to which Australia is a signatory, and a Range State for many migratory species.

Bunds Low embankments for an area of containment used to describe features such as dams, pond walls and flood banks.

CAMBA The Agreement between the Government of Australia and the Government of the Peoples Republic of China for the Protection of Migratory Birds and their Environment is a treaty that aims to protect and conserve the birds and their habitat of those species that migrate between China and Australia.

Carbonate A compound containing carbon and oxygen; an example is calcium carbonate (limestone).

Catchment The area of land drained by a creek or river system.

Contiguous Something that is sharing an edge or boundary with something else; is adjacent to.

Crustaceans Animals with jointed legs and segmented bodies that have a hardened outer shell and usually live in water including prawns, crabs and crayfish.

Cultural services Non-material benefits derived from ecosystems such as recreational, spiritual, religious benefits.

Ecosystem services The benefits people obtain from ecosystems including provisioning, regulating, cultural and supporting services.

Ecotone A transition zone between two or more ecological communities.

Endemic Found only in one particular area.

Environmental values Under the Queensland *Environmental Protection Act 1994*, an environmental value is defined as (a) a quality or physical characteristic of the environment that is conducive to ecological health or public amenity or safety; or (b) another quality of the environment identified and declared to be an environmental value under an environmental protection policy or regulation (see www.legislation.qld.gov.au/LEGISLTN/CURRENT/E/EnvProtA94.pdf and www.legislation.qld.gov.au/Legislation%20Docs/CurrentE.htm).

Epiphytic A plant growing upon another plant but is not parasitic upon it and receives water and nutrients from the air and rain.

Estuarine An area where a freshwater river or stream meets the ocean and tidal influences result in fluctuations in salinity.

Global Positioning System (GPS) A network of satellites which provide accurate position and time information.

Highest Astronomical Tide (HAT) The highest water level that can be predicted to occur under average meteorological conditions. Note: HAT is higher than MHWS and varies between geographic locations, see www.msq.qld.gov.au/qt/msq.nsf/index/tides_tidal_planes for further information.

Holocene The geological period of time (epoch) from about 11,000 years ago to the present, following the Ice Age (Pleistocene epoch).

Intertidal zone Where the sea meets the land; the area along the shore that is covered by water at high tide but is exposed to the air at low tide.

IUCN Red List A list of globally threatened species assessed and maintained by the World Conservation Union (IUCN). The List provides taxonomic, conservation status and distribution information and highlights those species or groups of species that are facing a higher risk of global extinction.

JAMBA The Agreement between the Government of Japan and the Government of Australia for the Protection of Migratory Birds and Birds in Danger of Extinction and their Environment is a treaty that aims to protect and conserve the birds and their habitat of those species that migrate between Japan and Australia.

Land zone 1 Marine deposits, subject to periodic inundation by saline or brackish marine waters.

Land zone 3 Near-level alluvial plains with riverine patterns, wetlands and lakeside dunes.

Marine Pertaining to seas or oceans.

Marine plants Marine plants are defined under the Queensland *Fisheries Act 1994* as a plant that usually grows on, or adjacent to, tidal land, whether it is living or dead, standing or fallen; the material of a tidal plant, or other plant material on tidal land.

Mean High Water Spring (MHWS) The highest level to which spring tides reach on the average over a period of time (often 19 years). This level is generally known as "high water mark". Note: In Queensland, MHWS is specifically defined by legislation. Refer to www.msq.qld.gov.au/qt/msq.nsf/index/tides_notes. MHWS is lower than HAT, see www.msq.qld.gov.au/qt/msq.nsf/index/tides_tidal_planes for further information.

Migratory (Bonn Convention definition) "migratory species" means the entire population or any geographically separate part of the population of any species or lower taxon of wild animals, a significant proportion of whose members cyclically and predictably cross one or more national jurisdictional boundaries.

Mollusc Soft-bodied organisms that usually have a hard shell that may be external and obvious, for example snails (gastropods) and mussels (bivalves), or internal and small, for example squids (cephalopods).

Omnivorous Eats both plants and animals.

Peat Partially decomposed organic matter (mostly plant material) which has accumulated in water-saturated environments, deficient in oxygen; resulting from anaerobic respiration.

Pectoral Uppermost fins on either side of the body of a fish, usually just behind the gill, that help control the direction of movement.

Plankton Microscopic aquatic plants (phytoplankton) and animals (zooplankton) that depend chiefly upon currents for their movements. They form the important beginnings of food chains for larger animals.

Pneumatophores Aerial roots of a mangrove that typically rise into the air above the low tide level, allowing the plant to obtain oxygen directly from the air.

Polychaete Generally marine worms that have a pair of fleshy, leg-like appendages covered with bristles on most segments (also known as bristle worms).

Ponded pasture The practice developed by pastoralists to create an environment by either the construction of banks or the modification of naturally wet areas, in which fresh water is impounded or used primarily to grow suitably adapted plant species and produce fodder for grazing.

Propagule Any part of a plant that can give rise to a new individual and aids in dispersal of the species; includes seeds, roots and rhizomes.

Provisioning services Products obtained from ecosystems such as food and water.

Ramsar Convention The Convention on Wetlands (Ramsar, Iran, 1971) is an international treaty that aims to halt the worldwide loss of wetlands and to conserve those that remain through wise use and management.

Regional ecosystem The vegetation community that is consistently associated with a particular combination of geology, landform and soil (see Sattler and Williams 1999).

Regulating services Benefits obtained from the regulation of ecosystems processes such as regulation of floods, drought, land degradation and disease.

Rhizosphere The soil that immediately surrounds mangrove plant roots.

Saltmarsh Saltwater wetland occupied mainly by herbs and dwarf shrubs, characteristically able to tolerate extremes of environmental conditions, notably waterlogging and salinity.

Samphire Semi-woody plants of low shrub or prostrate habit, tolerant of saline conditions and brief inundation (daily or intermittent), many of which have succulent stems.

Sp./Spp. Sp. is an abbreviation for “species” and is often used when the genus is known, but the species is not. For example, *Eucalyptus* sp. means an undetermined species of *Eucalyptus*. Spp. is an abbreviation for more than one species without naming them individually.

Substrate The surface or material on which an organism lives — rock, sand, mud, pilings, shells.

Supporting services Ecosystem services that are necessary for the production of all other services such as soil formation, nutrient cycling and primary production.

Tannins A group of organic compounds found in the bark, roots, stems, leaves and seeds of many plants which can leach out and impart colour to water bodies.

World Heritage Convention The Convention Concerning the Protection of the World Cultural and Natural Heritage is an international treaty that seeks to encourage the identification, protection and preservation of cultural and natural heritage around the world considered to be of outstanding value to humanity.

Information sources

Australian Institute of Marine Science, *A mangrove is more than just a tree*, (web address www.aims.gov.au/pages/research/project-net/mangroves-01/apnet-mangroves01.html), September 2005.

Australian Institute of Marine Science, *Field Guide to the Mangroves of Queensland*, (web address www.aims.gov.au/pages/reflib/fg-mangroves/pages/fgm-qld-index.html), September 2005.

Australian Institute of Marine Science, *Mangroves index*, (web address www.aims.gov.au/pages/search/search-mangroves.html), September 2005.

Australian Government Department of the Environment and Heritage (2005), *A Directory of Important Wetlands in Australia, Third Edition*, Environment Australia, Canberra, online database accessible at www.deh.gov.au/water/wetlands/database/index.html.

Australian Government Department of the Environment and Heritage, The East Asian-Australasian Shorebird Site Network, (web address www.deh.gov.au/biodiversity/migratory/waterbirds/infosrn1.html), September 2005.

Bruinsma, C. (2001), *Queensland's coastal wetland resources, Cape Tribulation to Bowling Green Bay*, Department of Primary Industries, Queensland.

Churchill, S. (1998), *Australian Bats*, New Holland Publishers, NSW.

Danaher, K. and de Vries, C. (2003), *Queensland's coastal wetland resources, Maps of Queensland's mangrove and saltmarsh communities*, Department of Primary Industries, Brisbane.

Duke, N.C. (n.d.), "Mangroves in the Great Barrier Reef World Heritage Area: current status, long-term trends, management implications and research", *Proceedings of the State of the Great Barrier Reef World Heritage Area Workshop*, Great Barrier Reef Marine Park Authority, Queensland.

Duke, N.C. and Burns, K.A. (1999), *Fate and effects of oil and dispersed oil on mangrove ecosystems in Australia*, Final report to the Australian Petroleum Production Exploration Association, Australian Institute of Marine Science and CRC Reef Research Centre, (web address www.aims.gov.au/pages/research/mangroves/fae/fae01.html).

Duke, N.C., Roelfsema, C., Tracey, D. and Godson, L. (2001), *Preliminary Investigation into Dieback of Mangroves in the Mackay Region: Initial Assessment and Possible Causes*, Report to the Queensland Fisheries Service (Northern Region) and the Community of Mackay Region, Mangrove Ecosystem Research and Marine Botany Group, Botany Department, UQ, Brisbane.

Fitzroy Basin Association (2004), Draft Boyne/Calliope and Curtis Coast Catchments natural resource management plan, CRC for Coastal Zone, Estuary and Waterway Management and Fitzroy Basin Association.

Hutchings, P. and Saenger, P. (1987), *Ecology of Mangroves*, University of Queensland Press, Brisbane.

McComb, A.J. and Lake, P.S. (1990), *Australian Wetlands*, Angus and Robertson.

Maritime Safety Queensland, Tides — Tidal planes and average tide time differences, (web address www.msq.qld.gov.au/qt/msq.nsf/index/tides_tidal_planes), September 2005.

McKinnon, S., Sheppard, R. and Sully, D. (2003), "Fish Habitat Area network in Queensland, Australia — an innovative aquatic protected area approach", pp. 313–322, in Beumer, J.P., Grant, A. and Smith, D.C. (eds), *Proceedings of the World Congress on Aquatic Protected Areas, Cairns, 2002*, Australian Society for Fish Biology.

Queensland Department of Primary Industries and Fisheries, Coastal Habitat Resources Information System (CHRIS), (web address <http://chrisweb.dpi.qld.gov.au/CHRIS/>), September 2005.

Queensland Department of Primary Industries and Fisheries, commercial species, regulated fish, www.dpi.qld.gov.au/cps/rde/xchg/dpi/hs.xsl/28_ENA_HTML.htm

Queensland Government, *Nature Conservation Act 1992, Nature Conservation (Wildlife) Regulation 1994*, Vulnerable animals (web address www.legislation.qld.gov.au/LEGISLTN/CURRENT/N/NatureConWilR94.pdf).

Queensland Parks and Wildlife Service (2002), *Guidelines for the Management of Flying-foxes in Calliope Shire*, in consultation with the Calliope Shire Council and other stakeholders, Rockhampton.

Sattler, P. and Williams, R. (eds) (1999), *The Conservation Status of Queensland's Bioregional Ecosystems*, Environmental Protection Agency, Brisbane, Australia.

Scott, G.A.M., Entwisle, T.J., May, T.W., and Stevens, G.N. (1997), *A Conservation Overview of Australian Non-marine Lichens, Bryophytes, Algae and Fungi*, Environment Australia, Canberra (web address <http://www.deh.gov.au/biodiversity/threatened/action/cryptogams/7.html>).

Wachenfeld, D.R., Oliver, J.K. and Morrissey, J.I. (eds) (1999), *State of the Great Barrier Reef World Heritage Area 1998: Mangroves*, Great Barrier Reef Marine Park Authority.

Webb, G. and Manolis, C. (1989), *Crocodiles of Australia*, Reed, Frenchs Forest.

Appendices

Appendix 1: Description and status of mangrove wetland regional ecosystems (REs) in Queensland and examples in protected areas.

Bioregion	Regional ecosystem (RE)	RE description	Queensland Biodiversity Status*	Queensland Vegetation Management Status**	Examples of protected areas that include mangrove wetlands^
Gulf Plains***	2.1.2	Tidal low coastal rises of shells, sand or mud and associated gutters, usually with mangroves.	No concern at present	Not of concern	Morning Inlet — Bynoe River FHA.
	2.1.3	Tidal channels and associated levees, usually with mangroves.	No concern at present	Not of concern	Morning Inlet — Bynoe River FHA.
Cape York Peninsula***	3.1.1 3.1.1a 3.1.1b 3.1.1c	Closed forest of <i>Rhizophora stylosa</i> and/or <i>Bruguiera gymnorhiza</i> . Occurs as outer mangroves.	No concern at present	Not of concern	Cape Melville NP, Endeavour River NP, Iron Range NP, Jardine River NP, Lakefield NP, Annan River FHA, Escape River FHA, Margaret Bay FHA, Princess Charlotte Bay FHA, Starcke River FHA, Great Barrier Reef WHA.
	3.1.2	<i>Avicennia marina</i> and/or <i>Ceriops tagal</i> low open forest landward side of mangroves.	Of concern	Of concern	Endeavour River NP, Lakefield NP, Annan River FHA.
	3.1.3	<i>Ceriops tagal</i> and/or <i>Avicennia marina</i> low closed forest. Extensive on intertidal areas.	No concern at present	Not of concern	Cape Melville NP, Endeavour River NP, Heathlands RR, Iron Range NP, Iron Range RR, Jardine River NP, Lakefield NP.
	3.1.4	<i>Excoecaria agallocha</i> and/or <i>Aegiceras corniculata</i> closed scrub. Upper tidal reaches of rivers.	Of concern	Of concern	Lakefield NP.
	3.2.30	<i>Pemphis acidula</i> and/or low closed forest. Restricted to coral atolls, shingle cays and sand cays.	Of concern	Of concern	Island NPs.
	Wet Tropics	7.1.1	Mangrove forests on coastal lowland saline alluvial soils.	No concern at present	Not of concern

Bioregion	Regional ecosystem (RE)	RE description	Queensland Biodiversity Status*	Queensland Vegetation Management Status**	Examples of protected areas that include mangrove wetlands [^]
Central Queensland Coast	8.1.1	Mangrove vegetation of marine clay plains and estuaries. Estuarine wetland.	No concern at present	Not of concern	Byfield NP, Cape Palmerston NP, Conway NP, Newry Islands NP, Whitsunday Islands NP, Bassett Basin FHA, Cape Palmerston FHA, Marion FHA, Repulse FHA, Great Barrier Reef WHA.
Brigalow Belt	11.1.4 11.1.4a 11.1.4b 11.1.4c 11.1.4d 11.1.4e	Mangrove forest/woodland on marine clay plains.	No concern at present	Not of concern	Abbott Bay RR, Bowling Green Bay NP, Causeway Lake CP, Charon Point CP, Keppel Sands CP, Shoalwater Bay CP, Townsville Town Common CP, Burdekin FHA, Broad Sound FHA, Cawarral Creek FHA, Bohle River FHA, Edgumbe Bay FHA, Great Barrier Reef WHA.
Southeast Queensland	12.1.3	Mangrove shrubland to low closed forest on marine clay plains and estuaries.	No concern at present	Not of concern	Barubbra Island CP, Bribie Island NP, Broadwater CP, Burrum Coast NP, Curtis Island NP, Eurimbula NP, Southern Moreton Bay Islands NP, Great Sandy NP, Maroochy River CP, Baffle Creek FHA, Beelbi FHA, Deception Bay FHA, Seventeen Seventy-Round Hill FHA, Susan River FHA, Fraser Island WHA, Great Barrier Reef WHA.

* Biodiversity Status as listed by the Environmental Protection Agency.

** Queensland *Vegetation Management Act 1999* status as of September 2003.

[^] Protected areas include national parks (NP), resources reserves (RR), conservation parks (CP), Fish Habitat Areas (FHA), marine parks (MP) and World Heritage areas (WHA).

*** Mapping is still being completed for the REs in these bioregions and will be updated as data is released.

Appendix 2: Threatened and migratory fauna commonly associated with Queensland's mangrove wetlands.

Taxon group	Common name	Scientific name	NC Act status*	EPBC Act status*	IUCN Red List of threatened species status **
Mammals	false water-rat	<i>Xeromys myoides</i>	vulnerable	vulnerable	vulnerable
	dugong	<i>Dugong dugon</i>	vulnerable	–	vulnerable
Birds	eastern curlew	<i>Numenius madagascariensis</i>	–	listed migratory species [#]	–
	whimbrel	<i>Numenius phaeopus</i>	–	listed migratory species [#]	–
	grey-tailed tattler	<i>Heteroscelus brevipes</i>	–	listed migratory species [#]	–
	common sandpiper	<i>Actitis hypoleucos</i>	–	listed migratory species [#]	–
	terek sandpiper	<i>Xenus cinereus</i>	–	listed migratory species [#]	–
	beach stone-curlew	<i>Esacus neglectus</i>	vulnerable	–	–
Reptiles	estuarine crocodile	<i>Crocodylus porosus</i>	vulnerable	listed migratory species [#]	–
Insects	Apollo jewel butterfly	<i>Hypochrysops apollo apollo</i>	vulnerable	–	–
	Illidge's ant-blue butterfly	<i>Acrodipsas illidgei</i>	vulnerable	–	endangered

* Under the Queensland *Nature Conservation Act 1992* threatened wildlife are those species listed as presumed extinct, endangered or vulnerable. Under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* threatened wildlife includes species listed as extinct, extinct in the wild, critically endangered, endangered, vulnerable or conservation dependent.

** The IUCN Red List of threatened species is an internationally recognised inventory for the conservation status of plant and animal species worldwide.

Under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* listed migratory species include those species listed in appendices to the Bonn Convention, and in CAMBA and JAMBA.

Appendix 3: Threatened flora commonly associated with Queensland's mangrove wetlands.

Taxon group	Common name	Scientific name	NC Act status*	EPBC Act status*	IUCN Red List of threatened species status **
Epiphyte	ant plant	<i>Myrmecodia beccarii</i>	vulnerable	vulnerable	–
Orchid	mangrove orchid	<i>Dendrobium mirbelianum</i>	endangered	endangered	–

* Under the Queensland *Nature Conservation Act 1992* threatened wildlife are those species listed as presumed extinct, endangered or vulnerable. Under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* threatened wildlife includes species listed as extinct, extinct in the wild, critically endangered, endangered, vulnerable or conservation dependent.

** The IUCN Red List of threatened species is an internationally recognised inventory for the conservation status of plant and animal species worldwide.

Appendix 4: Wetlands in Queensland that are listed in *A Directory of Important Wetlands in Australia* (2005) and/or are Ramsar sites and that include mangrove wetlands.

Bioregion	Directory reference	Directory wetlands	Ramsar wetlands
Brigalow Belt	QLD001	Abbot Point — Caley Valley	–
	QLD003	Broad Sound	–
	QLD004	Burdekin Delta Aggregation	–
	QLD005	Burdekin — Townsville Coastal Aggregation	Bowling Green Bay
	QLD009	Southern Upstart Bay	–
	QLD012	Fitzroy River Delta	–
	QLD022	Yeppoon — Keppel Sands Tidal Wetlands	–
Cape York Peninsula	QLD060	Cape Genville Area	–
	QLD061	Cape Melville — Bathurst Bay	–
	QLD062	Harmer Creek — Shelburne Aggregation	–
	QLD063	Jardine River Wetlands Aggregation	–
	QLD064	Lloyd Bay	–
	QLD066	Newcastle Bay — Escape River Estuarine Complex	–
	QLD070	Orford Bay — Sharp Point Dunefield Aggregation	–
	QLD072	Princess Charlotte Bay Marine Area	–
	QLD073	Silver Plains — Nesbit River Aggregation	–
	QLD076	Temple Bay	–
Central Queensland Coast	QLD043	Corio Bay Wetlands	Shoalwater and Corio Bays Area
	QLD045	Edgecumbe Bay	–
	QLD047	Four Mile Beach	–
	QLD048	Island Head Creek — Port Clinton Area	Shoalwater and Corio Bays Area
	QLD049	Iwasaki Wetlands	–
	QLD050	Proserpine — Goorganga Plain	–
	QLD055	St. Helens Bay Area	–
	QLD051	Sand Bay	–
	QLD052	Sandringham Bay — Bakers Creek Aggregation	–
	QLD053	Sarina Inlet — Ince Bay Aggregation	–
	QLD054	Shoalwater Bay	Shoalwater and Corio Bays Area
	QLD178	Shoalwater Bay Military Training Overview	Shoalwater and Corio Bays Area
Gulf Plains	QLD111	Nicholson Delta Aggregation	–
	QLD113	Southeast Karumba Plain Aggregation	–
	QLD114	Southern Gulf Aggregation	–

Bioregion	Directory reference	Directory wetlands	Ramsar wetlands
Southeast Queensland	QLD017	Northeast Curtis Island	–
	QLD019	Port Curtis	–
	QLD021	The Narrows	–
	QLD126	Burrum Coast	–
	QLD127	Bustard Bay Wetlands	–
	QLD128	Carbrook Wetlands Aggregation	–
	QLD129	Colosseum Inlet — Rodds Bay	–
	QLD131	Fraser Island	–
	QLD132	Great Sandy Strait	Great Sandy Strait
	QLD133	Lake Weyba	–
	QLD134	Moreton Bay Aggregation	Moreton Bay
	QLD135	Noosa River Wetlands	–
	QLD179	Wide Bay Military Training Area	–
	QLD182	Deepwater Creek	–
	QLD185	Coolum Creek and Lower Maroochy River	–
	QLD187	Lower Mooloolah River	–
	QLD188	Upper Pumicestone Coastal Plain	Moreton Bay
	QLD190	Pine River and Hays Inlet	–
QLD194	Lake Coombabah	Moreton Bay	
Wet Tropics	QLD137	Alexandra Bay	–
	QLD139	Bambaroo Coastal Aggregation	–
	QLD142	Cowley Area	–
	QLD143	Edmund Kennedy Wetlands	–
	QLD146	Herbert River Floodplain	–
	QLD148	Hinchinbrook Channel	–
	QLD150	Kurrimine Area	–
	QLD154	Lower Daintree River	–
	QLD155	Missionary Bay	–
	QLD157	Port of Cairns and Trinity Inlet	–
	QLD158	Russell River	–