Report on the Condition of Estuarine, Coastal and Marine Resources of the Burdekin Dry Tropics Region

Report to the Burdekin Dry Tropics Board

2005

D.M. Scheltinga and L. Heydon (eds)

Natural Heritage Trust
Helping Communities
Helping Australia
A Commonwealth Government Initiative

CSIRO

BURDEKIN DRY TROPICS BOARD

CRC for Coastal Zone Estuary & Waterway Management

Report on the Condition of Estuarine, Coastal and Marine Resources of the Burdekin Dry Tropics Region

August 2005

Edited by: Scheltinga, D.M. and Heydon, L. Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management.

Contributions from:
Lana Heydon (Coastal CRC)
David Scheltinga (Coastal CRC)
Kumar Narayan (CSIRO Land and Water)
Jan Tilden (Coastal CRC)
Maria Vandergragt (Coastal CRC)
Keith Bristow (CSIRO Land and Water)

This document was commissioned by the Burdekin Dry Tropics Board.

For copies please contact:

Burdekin Dry Tropics Board
Level 2 St James Place
155-157 Denham Street
Townsville
QLD 4810
Ph: 07 47243544
Fax: 07 47243577
Email: info@burdekindrytropics.org.au
http://www.burdekindrytropics.org.au

OR

Coastal CRC
80 Meiers Rd
Indooroopilly
QLD 4068
Ph: 07 3362 9399
www.coastal.crc.org.au

Table of Contents

List of Maps

1 EXECUTIVE SUMMARY

In 2004 the Burdekin Dry Tropics Board (BDTB) (2004a,b) released an information paper and then a draft NRM plan for their region, which was based around information on the condition of the catchment's natural resources. However, due to the arrangements of funding through the National Action Plan for Salinity and Water Quality (NAP), this information was generally limited to terrestrial and freshwater environments.

Under National Heritage Trust 2, funding has become available to develop this report on the condition of estuarine, coastal and marine environments of the region, which will underpin the future development of targets and actions to manage and protect the natural resources of these environments. This report does not reproduce verbatim the information provided previously in the BDTB's community information paper and draft NRM plan. This report builds on information provided previously and should be read in conjunction with the relevant estuarine, coastal and marine sections of the community information paper and draft NRM plan. It is not the purpose of this report to develop or provide NRM targets or actions.

The area addressed by this resource condition report encompasses the estuarine, coastal and marine areas of the Burdekin Dry Tropics NRM region from Crystal Creek in the north to the Don River in the south. In general, it covers the coastal strip, from approximately 5 km inland to the limit of State waters, including islands. However, due to the nature of water flow and downstream impacts, information from the entire coastal catchment is included where appropriate.

The Burdekin Dry Tropics coastal region comprises many estuarine, coastal and marine ecosystems, including: coastal floodplains, saltmarsh and saltpans, mangroves, seagrass meadows, macroalgal beds, inter-tidal mudflats, rocky shores, beaches, sandy shoals and dunes, sub-tidal sand/mud substrates, reefs, islands, marine waters, estuaries, wetlands and riparian vegetation. These ecosystems provide natural, commercial, recreational and aesthetic services and values to the region. The services provided by these ecosystems also support many industries in the region, such as tourism, fisheries and agriculture, which are based on the region's natural resources.

The region adjoins the Great Barrier Reef (GBR), and while the GBR is outside the regional NRM planning boundary, the catchments of the Burdekin Dry Tropics region have been identified as a significant contributor of sediments, nutrients and other pollutants to the GBR lagoon. Therefore, development of a regional NRM plan to improve the condition of the natural resources of the whole region (including the adjacent GBR) is an important step in the protection and sustainable development/use of resources on which the region, nation and world relies.

Major threats to estuarine, coastal and marine habitats and species in the Burdekin Dry Tropics coastal region include:

- coastal development;
- inappropriate agricultural activities;
- changes to hydrology;
- removal/disturbance of habitat and species;

- water quality declines (particularly nutrient enrichment or increased turbidity);
- pests (particularly weeds and marine pests);
- changes to the freshwater flow regime (both reduced flood flows due to impoundments and increased base flows due to release of irrigation waters);
- intrusion of seawater into overused aquifers;
- changes in groundwater level due to irrigation;
- vegetation removal;
- stormwater run-off; and
- inappropriate recreational activities (such as quad bikes on dunes).

Natural events such as cyclones or drought, particularly when they are exacerbated by the removal of natural vegetation, can also severely impact on ecosystems and water quality in the region.

1.1 Ecosystems of the Burdekin Dry Tropics Coastal Region

The Burdekin Dry Tropics coastal region is a unique area with considerable diversity of marine and terrestrial species and habitats. The region encompasses internationally significant wetlands, commercially and ecologically valuable animals and plants, and part of the Great Barrier Reef World Heritage Area.

Due to its drier climate the region is home to more saltmarsh than surrounding regions, though there has been some loss of this habitat, especially in the Ross River catchment.

There is high seagrass species richness in the region, which supports various commercial fisheries and megafauna such as dugongs and turtles. Extensive seagrass meadows occur in Upstart, Cleveland, and Bowling Green Bays and off Magnetic Island. These ecosystems are sensitive to long-term water quality declines (particularly increases in nutrients and turbidity).

The Burdekin Dry Tropics coastal region also supports high mangrove diversity (approximately 17 species) compared to more southern areas and this diversity in turn provides habitat for a range of species listed as vulnerable or rare, such as the coastal sheath tailed bat (*Taphozous australis*), saltwater crocodile (*Crocodylus porosus*) and the rusty monitor (*Varanus semiremex*), as well as providing habitat for commercially important fish, crab and prawn species at critical life stages.

Limited mapping or habitat status information is available for inter-tidal flats even though it is acknowledged that they are at risk of dredging, reclamation and infrastructure development and associated changes to hydrology, which can result in erosion. Dioxin congeners have been detected in the inter-tidal flats in Pallarenda and Upstart Bay.

The condition and trend of rocky shore ecosystems in the region has not been well documented. It is thought that these ecosystems are at risk from coastal development, heavy foot traffic, over-collection of specimens, removal of vegetative cover, declines in water quality, changes in tidal hydrodynamics and pollution from sewage and stormwater overflow.

Beaches in the area are important to species such as turtles, which utilise them as nesting grounds. Beaches are also popular tourist destinations. Damage to beaches and dunes by coastal development, quad bikes and other vehicles threaten not only the stability of these areas but also the species that inhabit them. Beaches and dunes are also very susceptible to erosion by cyclones. Surveys of foreshores indicate several erosion prone areas in the region including Abbot Bay, southern Bowling Green Bay, Cape Bowling Green, western Upstart Bay, parts of Bushland Beach, beaches north of Rollingstone Creek and around Toomulla.

Data on the condition and trends of sub-tidal areas is sparse. Threats to these ecosystems include dredging, natural impacts from cyclones and declines in water quality. Sediment testing for pollutants detected Dieldrin in sediments collected from Halifax Bay while DDT and its metabolites were detected in low concentrations at the mouth of the Burdekin River and in Halifax Bay. Most analyses of harbour sediments for metals find concentrations that are within ANZECC Sediment Quality Guidelines. However, occasionally samples exceed levels that are thought to have a high probability of having a toxic effect on benthic biota.

There are many notable reefs in the region, such as those with high soft coral abundance (>60% cover) just northeast of Townsville and another ‘hot spot’ of soft coral abundance near Cape Upstart. Magnetic Island’s offshore reef communities are notable for containing the Great Barrier Reef’s only population of the rare soft coral *Nephthyigorgia* sp. and on the island’s leeward side grows one of the largest colonies of *Montipora digitata* ever recorded in the Great Barrier Reef. Outcrops of the rare Brain Star Coral (*Goniastrea* sp.) can be found in the region. Inshore corals are particularly susceptible to declines in water quality from catchment activities. This has been evidenced by a significant decrease in coral cover around Townsville, especially on the reefs around Magnetic Island.

Another threat to coral is the crown-of-thorns seastar (COTS), which has dramatically increased in numbers on Townsville reefs from 1998 to 2000, reaching one of the two highest levels in Queensland for this period. Conversely, Cape Upstart has shown a consistently low population of these seastars for the last 10 years, highlighting the variation in COTS population trends in the region. Coral diseases have also been detected in Palm Island Group’s reefs, which may be a future concern and should be closely monitored.

The Palm Island Group and Magnetic Island are major inhabited continental islands found within the Burdekin Dry Tropics coastal region. Habitats present on these islands include beaches, eucalypt and other species woodlands, grasslands, mangroves and rocky headlands, while their marine habitats include important reef communities, sponges, algae and seagrasses. There are approximately ten endemic species of plants and one species of endemic lizard (Sadliers dwarf skink (*Menetia sadlieri*)) on Magnetic Island. Less information is available regarding the Palm Island’s terrestrial ecosystems. A trend of increasing development in the unprotected regions of Magnetic Island is stimulating concern amongst residents and scientists. This development is particularly prevalent in the unprotected lowland areas.

Some island ecosystems in the region are currently under threat from weed invasion and dominance. The eradication of these weed pests may prove to be more feasible than for mainland ecosystems due to their relative isolation. However, eradication should only be considered if the eradication program is implemented hand-in-hand with steps to prevent reintroduction (Tony Grice, pers. comm.).

Of the 26 estuaries in the region surveyed, seven are classified as ‘near pristine’, 11 as ‘largely unmodified’ and eight as ‘modified’. None were found to be in the poorest condition category of ‘extensively modified’. However, later reworking of the data, new information and local knowledge suggests that some of these estuaries may be in a lower condition classification (e.g. the Ross River has been report as being in a severely (= extremely) modified condition).

Bowling Green Bay and other wetlands in the Burdekin Dry Tropics coastal region provide important services (e.g. feeding grounds) for conservationally and internationally significant species such as dugong, saltwater crocodiles, green turtles and wader birds. Seven wetlands in the Burdekin Dry Tropics coastal region have been identified as having significant ecological value and have been placed on the Australian Directory of Important Wetlands. One, Bowling Green Bay, is listed as on the Ramsar list of wetlands of international importance. Most of the freshwater habitats adjacent to tidal areas in the Burdekin Dry Tropics coastal region have been substantially modified by human activity.

Riparian areas in the region, especially around Townsville, have experienced significant clearing and reclamation, reducing their distribution to narrow, sparsely vegetated remnant stands. The condition of many of the remnant riparian stands in the Burdekin Dry Tropics coastal region is further degraded by the invasion of exotic weeds, particularly rubbervine and, though more restricted, hymenachne. However, riparian areas have also been the focus of revegetation programs, particularly in Ross River and Stuart Creek.

1.2 Fauna and Flora of the Burdekin Dry Tropics Coastal Region

The Burdekin Dry Tropics coastal region supports a range of locally, regionally, nationally and internationally important bird, mammal, reptile, fish, amphibian, invertebrate and plant species.

A large and diverse bird population is found in the region. The Queensland EPA’s WildNet database estimates that there are approximately 437 species of birds in the region with four species classified as endangered, 11 species as vulnerable and 13 as rare. Loss and fragmentation of habitat is a major threat to the birdlife of the region.

Waters off the Burdekin Dry Tropics coast is on the Eastern Australia whale migration route, home to dugongs and three species of inshore dolphin, the irrawaddy dolphin (*Orcaella brevirostris*), the indo-pacific hump-backed dolphin (*Sousa chinensis*) (both classified as rare) and the common bottlenose dolphin (*Tursiops truncates*). Population studies and stranding reports suggest that the condition of the whales is good and is likely to be continuing the recovery process from the whaling operations that decimated their numbers ~50 years ago.

Cleveland Bay is one of only two core areas for dugong populations in the entire Great Barrier Reef. This is due in part to the extensive seagrass meadows that occur here. While the condition of dugong populations is thought to be acceptable, the rare inshore dolphins are over-represented in strandings in the region prompting concern over their conservation.

There are several terrestrial mammal species occurring in the coastal region which have been listed on the *Nature Conservation Act 1992* and *Environmental Protection and Biodiversity Conservation Act 1999* due to concerns over the conservation of their populations. These include six species of bats, with the bare-rumped sheathtail bat listed as critically endangered. Both the mahogany glider (*Petaurus gracilis*) and Sharman's rock wallaby (*Petrogale sharmani*) are listed as endangered and the lemuroid ringtail possum (*Hemibelideus lemuroids*) is listed as rare. Habitat loss, degradation and fragmentation caused by coastal development as well as road traffic are major threats to terrestrial mammals in the Burdekin Dry Tropics coastal region.

One hundred and forty-nine reptile species are found in the Burdekin Dry Tropics coastal region. This includes marine reptiles such as turtles, crocodiles and sea snakes that are found throughout the Coral Sea area with turtles also using beaches in the area to lay eggs. Eight reptile species are listed as rare, including the rusty monitor (*Varanus semiremex*) and robust burrowing snake (*Simoselaps warro*). Three reptile species are listed as vulnerable. Magnetic Island is home to its own endemic skink (Sadliers dwarf skink (*Menetia sadlieri*)). The status of sea snake populations is largely unknown though they are potentially threatened by trawling.

No fish in the Great Barrier Reef area associated with the Burdekin Dry Tropics region have been identified as threatened, vulnerable or endangered. However, surveys of lagoons adjacent to the Burdekin River in 2000-2003 found a severe reduction in freshwater fish species diversity (and potential productivity) resulting from a loss of estuarine connectivity. By restoring estuarine connectivity it is expected that the fisheries value of these water bodies would be significantly increased. Infestations of noxious fish (e.g. *Tilapia*) have occurred in the region, most notably in Ross Dam but also in Ross River, Alligator Creek, Louisa Creek, Rowes Bay drainage system, Healey Creek and the Bohle River. Coral bleaching of reefs in the area is result in local declines of coral eating fish.

There are approximately 50 species of frogs known to occur in the Burdekin Dry Tropics coastal region. The introduced cane toad (*Bufo marinus*) is also distributed throughout the region, threatening native frogs and other species. There are four species of frogs occurring in the coastal region that are listed as conservationally significant. These are the rare robust whistle frog (*Austrochaperina robusta*), the rare Mount Elliot nursery frog (*Cophixalus mcdonaldi*), the endangered Australian lace-lid (*Nyctimystes dayi*) and the endangered torrent tree frog (*Litoria nannotis*).

The marine waters off the Burdekin Dry Tropics coast are home to a huge diversity of invertebrate organisms. There is very little precise data available concerning species lists, distribution, conditions and threats for most marine and terrestrial invertebrate species with only the pest species receiving significant attention. This includes the crown-of-thorns seastar (COTS), which has been the focus of an AIMS long-term monitoring program. Recent surveys found that the highest numbers of COTS occurred in the mid-shelf reefs of the Townsville region and that new outbreaks have been detected in the Cape Upstart area early in 2004.

Within the Burdekin Dry Tropics coastal region, 20 species of plant are considered rare, six are considered vulnerable, and one, the endemic flowering shrub *Babingtonia papillosa*, is considered endangered. Other endemic species include *Eucalyptus paedoglauca*, also known as Mt Stuart Ironbark, which is found only on Mt Stuart, and *Croton magneticus*, growing on both Magnetic Island and Mt Stuart and has been classified as vulnerable. The plants of the coastal region are primarily threatened by weed invasion, land clearing and unmanaged public access.

1.3 Water Quality and Flows within the Burdekin Dry Tropics Coastal Region

Water quality is a central issue for the Burdekin Dry Tropics coastal region. Both the marine and freshwater environments are strongly affected by changes to flow as a result of current land management practices and the use of water resources (e.g. Burdekin Falls Dam and associated irrigation). The hydrology of the region is largely event-driven (i.e. dominated by wet season rainfall) and most of the bedload leaves the catchment during brief, major flood events occurring every five to twenty years.

Major flood plumes from the region, while predominantly remaining in the nearshore zone (i.e. within 20 km of the coast), have been shown to move as far north as Cairns under certain circumstances. Such plumes are known to persist for many days and can be transported over large distances offshore as far as the outer Great Barrier Reef. Current research shows that sediment export through washload (fine sediments suspended within the water column) delivery has increased about four-fold since European settlement with grazing practices being one of the major causes for the increased sediment load.

The long-term average annual sediment discharge from the Burdekin Dry Tropics region into the GBR lagoon is about 3.8 million tonnes. This represents about 20-40% of the terrestrial (allocthonous) total sediment being delivered to the GBR lagoon. As a result, washload, and its associated nutrients and other contaminants, is the main impact of terrestrial run-off on nearshore zones of the Great Barrier Reef lagoon. However, it is important to realise that the majority of the load is delivered in a few, infrequent, major flood events, interspersed by many years of low sediment discharge. The most recent reviews of current scientific understanding are almost unanimous in their assessment, that if left unchecked, further increases in the rate of sediment and nutrient delivery to the GBR lagoon will be detrimental for nearshore reefs and seagrass meadows.

Accessible data about ambient water quality in the Burdekin Dry Tropics coastal region is limited, particularly data required to establish a statistically sound baseline. Available information demonstrates the very poor oxygen conditions of wetlands on the coastal floodplains and the likely causative agents and processes.

Water quality monitoring of Cleveland Bay and Bowling Green Bay show relatively high levels of nutrients and suspended solids. Surveys conducted in 2000 show chlorophyll *a* levels (a proxy for nutrients) have doubled in Cleveland Bay since 1988.

River flow in the region is affected by several dams (Burdekin Falls Dam, Eungella Dam, Paluma Dam, Ross River Dam), many weirs (e.g. five in the lower Burdekin, three in the Ross River) and numerous extraction pumps.

Close to 2,000 large production bores extract around 330,000-550,000 ML/year of groundwater from the Burdekin delta aquifer for sugarcane production. An artificial recharge scheme (pit recharge, channel recharge and excess irrigation recharge) is also operating in the delta area. Preliminary modelling work suggests that groundwater discharge to the sea (base flow) from the delta area ranges between 4,000-13,000 ML/year. In the period 1997-2000, high nitrate concentrations (above 50 mg/L) were measured in 5% of the 397 sampled bores, while medium nitrate concentrations (25-50 mg/L) were measured in approximately 7% of the bores tested.

Water quality degradation (or even loss of groundwater resources) due to seawater intrusion is a major issue affecting the use of the Burdekin delta aquifer for irrigation purposes. The areas most susceptible to this are along the extended coastline of the lower Burdekin sub-catchment. As the Burdekin Haughton Water Supply Scheme area also borders the Ramsar wetlands of Bowling Green Bay, it is possible that groundwater extraction and irrigation may affect the hydrological integrity of the wetlands.

1.4 Land-use Resources of the Burdekin Dry Tropics Coastal Region

The coastal areas within the Burdekin Dry Tropics are more highly populated than inland regions and are dominated by urban, industrial and irrigated agriculture land-uses. Major industries in the coastal region include Townsville Port, Abbot Point Port, fisheries, agriculture and tourism. An aquaculture industry is also rapidly developing in the region. There has been growing concern over the potential environmental impacts, such as the clearing of vegetation and polluted stormwater run-off associated with increasing industrialisation and urbanisation of the coastal region.

The population of Townsville/Thuringowa, the major urban centres in the region, is likely to increase in the next decade while Bowen's population is predicted to decrease. The Townsville coast has been identified as one of four key areas of rising population within Queensland. Urban areas are important in terms of employment and earnings both locally and regionally.

The beaches north of Townsville are currently experiencing significant urban development, as is Magnetic Island and the coastal settlements at Phantom Springs and Cungulla south of Townsville. Urban development planning areas in Townsville are aimed at reducing urban sprawl and the associated cost of infrastructure development and are thus focused on the redevelopment of Townsville's CBD.

Extensive areas of rural residential development occur in Thuringowa City along the coast north of Townsville. Earth works in coastal floodplains can expose potential acid sulphate soil.

Agricultural development in the coastal region has resulted in widespread clearing and loss of riparian vegetation. Overgrazing and poor cropping practices have resulted in degraded land with problems such as salinisation and erosion impacting on downstream water quality. The Burdekin Haughton Water Supply Scheme (previously known as the Burdekin River Irrigation Area) has recently expanded, resulting in further loss of natural floodplain habitats and significant modifications to their hydrological patterns.

The mining industry contributes significantly to the gross regional product and has stimulated the development of several mineral-processing plants in Townsville, making it a major industrial centre, with implications for the port.

The aquaculture industry is seen as having growth potential in the Burdekin Dry Tropics coastal region and is expected to be important in the future development of the region. The southern coastal margin of the region in particular, will see significant aquaculture development and expansion in the future due to its high site suitability. There are 237 aquaculture licences/permits in the region. The majority of these licences/permits are for exotic fish (62), prawns (63) and native fish (58). Research species, such as sponges and anemones, are also cultured. Although statistics specifically applicable for the Burdekin Dry Tropics coastal region are not available, it is clear that aquaculture provides a substantial economic input into the region. Large-scale aquaculture of Australian marine fauna may bring ecological benefits as well as economic and social ones; for example, it may alleviate pressure on wild fisheries. However, aquaculture also brings environmental liabilities that could prove challenging such as the production of nutrient rich wastes, use of wild caught fish for food or breeding stock, possible transmission of disease and salinisation of surrounding land and groundwater resources.

Major marine industry infrastructure exists in the region in the form of the Townsville Port and marina consisting of a small craft facility and a full range of marine service industries and the Port of Abbot Point, Australia's most northerly coal port, 25 km north of Bowen. Marinas, moorings and boat ramps and other maritime infrastructure are also present at many locations in the area. The expansion of maritime industries with new port access, reclamation for port extension and port-related future industrial development are currently being proposed/occurring in Townsville. The increase in resource exports will see a large expansion of Queensland's port to accommodate transport needs.

Shipping poses a potential threat to local ecosystems through the introduction of invasive pest species via ballast water and hull fouling. Oil spills, waste disposal, contamination from toxic antifoulants, noise and boat strikes resulting from shipping/boating can have a detrimental impact on coastal resources. Laws, guidelines and environmental management plans have been developed in an attempt to manage these threats. Monitoring projects are also in place to detect marine pest introductions and pollution levels in the region's ports.

The Burdekin Dry Tropics coastal region supports a range of commercial, Traditional Owner and recreational fisheries. In 2003, the total nearshore (within approximately one 30 minute grid off the coast) commercial catch of all fisheries from the region was 4,198 tonnes (worth $39.66 million). The main target commercial species for these waters are prawn species (1,795 tonnes in total – mainly tiger (833 tonnes) and king (704 tonnes) prawns). Bugs (341 tonnes) and mud crabs (173 tonnes) are also important crustacean fishery species. The main commercial finfish fisheries for the region include shark (733 tonnes), grey mackerel (218 tonnes), barramundi (164 tonnes), Spanish mackerel (154 tonnes) and blue-threadfin (110 tonnes). The maintenance of the fishing fleet supports many ancillary industries in the region.

Recreational fishing is a popular activity for both residents and tourists of the region. In 1997, the total estimated recreational catch (including fish released) for the region was 1,176,776 fish (2.1% of Qld total) from 157,874 trips (1.5% of Qld total). Relatively little is known of Traditional Owner fishing methods, targeted species or catch rates within the Burdekin Dry Tropics coastal region.

Proximity to the Great Barrier Reef, the World Heritage listed Wet Tropics Rainforest and Magnetic Island, its warm, tropical climate and variety of festivals make the Burdekin Dry Tropics coastal region a popular spot for tourists. Townsville is one of the top four tourist destinations in the State. Tourism is a growing industry within the region with new coastal tourism developments occurring at Bowen and Magnetic Island in particular. Plans for the catchments and coastal land adjacent to Upstart Bay include subdivision, construction of tourist resorts and the development of aquaculture facilities.

As well as generating economic benefits and employment, the tourism industry can impact on the coastal, marine and estuarine ecosystems of the region unless properly managed. The effects of relatively low-impact activities, such as camping, swimming, boating, reef walking and fishing, accumulate and can have a significant impact after a number of years. High-density tourist boating activity and marinas can cause water and sediment pollution (nutrients, toxicants, pathogens) from spills, exhausts, untreated sewage and antifouling chemicals.

Although the environmental, social and economic issues faced within the Burdekin Dry Tropics coastal region are complex and numerous, the development and implementation of an integrated natural resource management plan, combined with education and adequate zoning, protection and enforcement can minimise many of the potentially damaging impacts resulting from human activities.

2 INTRODUCTION

2.1 Planning for Natural Resource Management

The management of our natural resources is an essential element for the long-term security and wellbeing of our society and of future generations.

Under the new regional arrangements for delivery of natural resource management (NRM) programs such as National Action Plan for Salinity and Water Quality (NAP) and the extension of the Natural Heritage Trust (NHT2), regional bodies are required to identify and address priority NRM issues in their regions. To do this, integrated regional NRM plans must be prepared and in-turn submitted to the Commonwealth and State governments for accreditation and funding, respectively.

The Burdekin Dry Tropics Board (BDTB) is a community-based organisation that promotes sustainable development in the Burdekin Dry Tropics NRM region through integrated catchment management processes. The role of the BDTB is to deliver a suite of NRM projects under NHT2 and NAP against priorities set by the Commonwealth, State and community that have been agreed to in the regional NRM plan. It aims to involve the major natural resource management stakeholders who have an interest in the use and management of the natural resources of the broader Dry Tropics region.

Initially, the BDTB has focused on the development of a NRM plan at the regional catchment level with funding from NAP. The emphasis of this planning was on matters relating to terrestrial and freshwater environments. Under NHT2, equal consideration is to be given to all matters for targets, including estuarine, coastal and marine environments to the limit of State water (3 nautical miles). Issues related to significant natural assets beyond that boundary such as the Great Barrier Reef and coastal islands must also be taken into account. Recently, funding has been made available under NHT2 to develop a NRM plan for the coastal catchments of the region. The aim is to provide an integrated approach to natural resource matters across the Dry Tropics region.

The plan will be an important part of the future investment decisions under the NHT2 and other Commonwealth, State and local investment arrangements and programs. It will provide the framework for directing investment of funds to restore, rehabilitate or protect natural assets such as the water quality, biodiversity and marine and coastal habitats of the region.

The Reef Water Quality Protection Plan has been devised by the Australian and Queensland governments with the aim of halting and reversing the decline in water quality entering the Reef within ten years, with a particular focus on diffuse pollution sources. This plan confers a special responsibility on regional NRM groups in Reef catchment areas, like the Burdekin Dry Tropics NRM Board. NRM Boards are required to take into account the agreed outcomes of the Reef Water Quality Protection Plan and play a key role in implementing many of the actions in the plan. Existing government, industry and community policies and funding programs are used to implement the plan (Australian and Queensland Governments, 2003). Funding for the development of coastal and marine monitoring activities is an important part of the plan, as are the development of coastal catchment initiatives, which are expected to be finalised soon.

2.2 Project Scope

Each regional body is required to identify regional natural resource assets and threatening processes, not all of which are necessarily covered by the 10 minimum matters for targets identified by the Natural Resource Management Ministerial Council (Commonwealth). Against a full set of matters, regional bodies must determine current condition and trend and, from this information, set natural resource management targets aimed at improving resource condition.

These targets must be 'SMART' (Specific, Measurable, Achievable, Relevant and Time bound) and are defined as Aspirational (50+ years), Resource condition (10 to 20 years) or Management action targets (1 to 5 years).

Targets should also be:

- based on best available science;
- benchmarked against current natural resource condition and trends;
- capable of being linked to management actions;
- defined at appropriate scales and set in specific locations; and
- able to take account of cumulative impacts of actions and the dynamic nature of natural systems.

This report identifies the Burdekin Dry Tropics region's estuarine, coastal and marine assets, their condition and trend, and associated threatening processes. From this information, a set of natural resource management targets to improve the condition of the region's estuarine, coastal and marine natural resources can be developed.

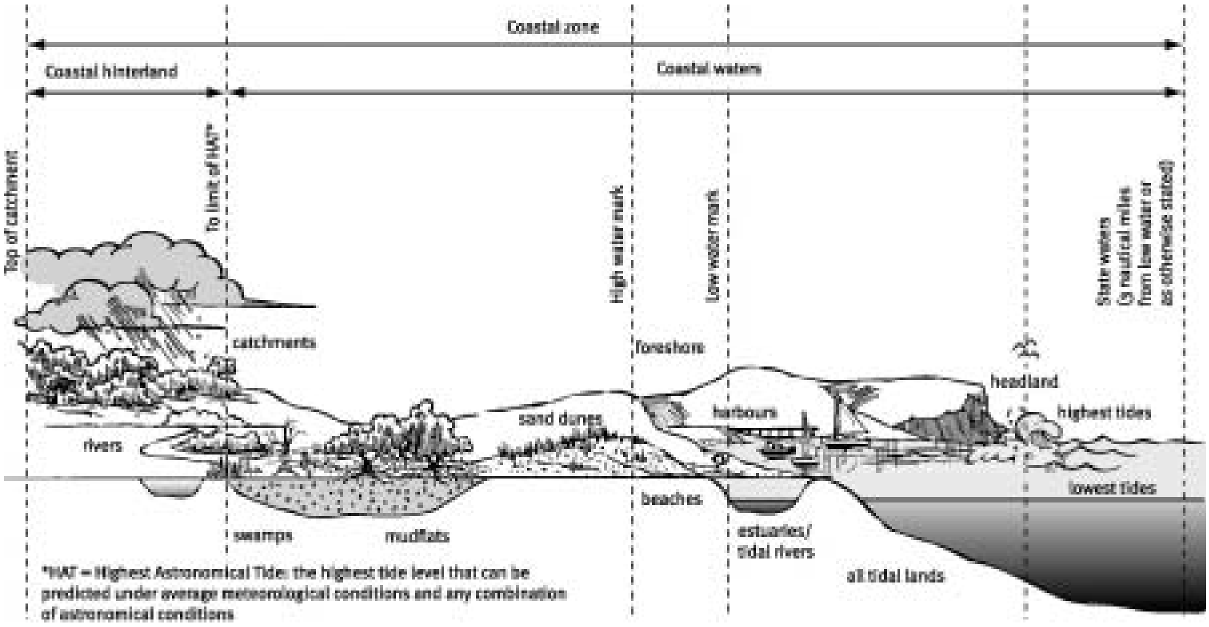
2.3 The Coastal Zone – Assets and Pressures

The coastal zone is defined in the *Coastal Protection and Management Act 1995* (Coastal Plan) as "coastal waters and all areas to the landward side of coastal waters in which there are physical features, ecological or natural processes or human activities that affect, or potentially affect, the coast or coastal resources" (Fig. 1). In practice, as used in the Queensland State of the Environment report (EPA, 2003a), this generally means the area within 5 km inland of the coastline and up to 10 m above sea level to 3 nautical miles offshore.

The coastal zone is valued for its environmental, economic and social values. It contains a variety of ecosystems, some of which are highly sensitive to human impacts, and is the site of intensive economic and recreational activities, such as urban development, ports, fisheries, shipping/boating, tourism and aquaculture. These economic and recreational activities provide benefits to the community but also add to the pressures on coastal ecosystems.

The increasing 'seachange' movement of people to coastal regions, with around 85% of the Queensland population living here, has placed additional pressure on our coastal resources. The Coastal Plan (EPA, 2001) lists Queensland's coastal resources and the major values and pressures associated with them (see Table 1 for a summary). In order to maintain the value that society places on our coastal resources the relevant pressures affecting them must be addressed in regional natural resource management plans.

Figure 1. The coastal zone.



Source: *State Coastal Management Plan* (EPA, 2001).

Table 1. Summary of Queensland's coastal resources, major values and pressures. The linkages between each of these columns are provided in the source document.

Coastal resource	Values	Pressures
Beaches and dune systems Coastal and estuarine waters Coastal forests and heathlands Coastal wetlands Coral reef systems Cultural sites Freshwater inflows Headlands Indigenous Traditional Owner cultural resources Islands Mainland Mid-water column (pelagic) systems Minerals, sand and gravel Rocky foreshores Soft-bottom (benthic) systems	Aesthetic features Beach stabilisation and replenishment Biological diversity and productivity Carbon sink Commercial collecting Cultural heritage Cultural understanding Dissipative barrier to erosive forces Educational role Extractive industry and dredging Fish migration Fishing Groundwater recharge (regional) Habitat for native plants and animals, and migratory animals Historic heritage Indigenous Traditional Owner: cultural resource values, cultural significance, economic significance, fishing practices, knowledge systems, significant animals and spiritual significance Localities for maritime infrastructure, primary industries, tourist facilities and urban settlements Moderates flood and water flows Nursery habitat Nutrient and organic matter source	Access impacts Acid sulphate soil disturbance Biting insect controls Boat strike of marine animals Boating and anchoring Catchment run-off and siltation Climate change impacts and sea level rise Coastal development Coastal landscapes Collecting selectivity/intensity Contamination by silts, muds and other pollutants Dams/weirs/irrigation channels/barriers Dredging and extraction Erosion and land degradation Fishing intensity Habitat loss Illegal collecting Inappropriate structures Insufficient data records Introduced marine species Invasive pests and weeds Lack of respect, clearing, drainage, reclamation and use restrictions Maritime incidents

Coastal resource	Values	Pressures
	Nutrient and sediment sink and source Recreational and scenic amenity Scientific or technological significance Shore and sediment stabilisation Significance for Indigenous Traditional Owner self determination Social and community identity Spiritual significance Sustains ecological integrity of wetlands	Ocean warming Recreational/tourism activities Rubbish dumping Sand mining Shipping access Storm and flood effects Trawling Water extraction Water pollution

Source: *State Coastal Management Plan* (EPA, 2001).

A list of the key coastal management issues for the Burdekin Dry Tropics region has been produced as part of the *State Coastal Management Plan* (EPA, 2001), see Appendix A.

3 THE REGION DEFINED

3.1 Project Area

The Burdekin Dry Tropics NRM region, located on Queensland's central-north coast, is an aggregation of the Black, Burdekin, Don, Haughton and Ross River catchments and includes several smaller coastal catchments, all of which empty into the Great Barrier Reef lagoon (Fig. 2). It covers an immense area (133,432 km^2) of remarkable tropical diversity, lying approximately 1,100 kilometres north of Brisbane, the State capital, and 300 kilometres south of Cairns. The region is home to a major population centre, the Townsville-Thuringowa area, a large tourism industry, irrigated sugarcane farming and horticultural cropping, fisheries industry and beef cattle grazing (Australian Government, 2004). It also services the mining industry through ports and hosts defence forces.

More than 80% of the region is drained by a network encompassing two large basins, the upper Burdekin and the Belyando/Suttor. These range 700 km from north to south and flow generally parallel to the coast before emptying into the upper reaches of Lake Dalrymple, formed by the construction of the Burdekin Falls Dam.

The area addressed by this resource condition report encompasses the estuarine, coastal and marine areas of the Burdekin Dry Tropics NRM region from Crystal Creek in the north to the Don River in the south. In general, it covers the coastal area, from the tidal limit (i.e. freshwater/saltwater interface) to offshore coastal waters to 3 nautical miles and includes islands within these State waters. However, due to the nature of water flow and downstream impacts, information from the entire coastal catchment is included where appropriate. For the purposes of this report it will be referred to as the Burdekin Dry Tropics coastal region (Fig. 2, Map 1).

Four local government authorities, Bowen, Burdekin, Thuringowa and Townsville, cover the coastal region (Map 2).

There are about 25 major Islands located within State waters (i.e. within approximately 3 nautical mile limit) off the Burdekin Dry Tropics coast (see Section 5.1.11 for a list).

3.2 Climate

The Burdekin Dry Tropics coastal region lies just north of the Tropic of Capricorn and has a tropical climate and temperatures similar to those of Queensland's coastal strip. The climate, being influenced by the warm waters of the Coral and Tasman seas, is generally free of extreme temperatures. Because of its geographical location, rainfall in the region is lower than other regions within tropical Queensland. Annual rainfall averages approximately 1,150 mm from on average 91 rain days. However, there is considerable variation from year-to-year due to the sporadic nature of tropical lows and storms (BoM, 2004a) with wet years regularly followed by a series of El Niño induced drought years. The wettest year on record was 2000, with 2,400 mm of

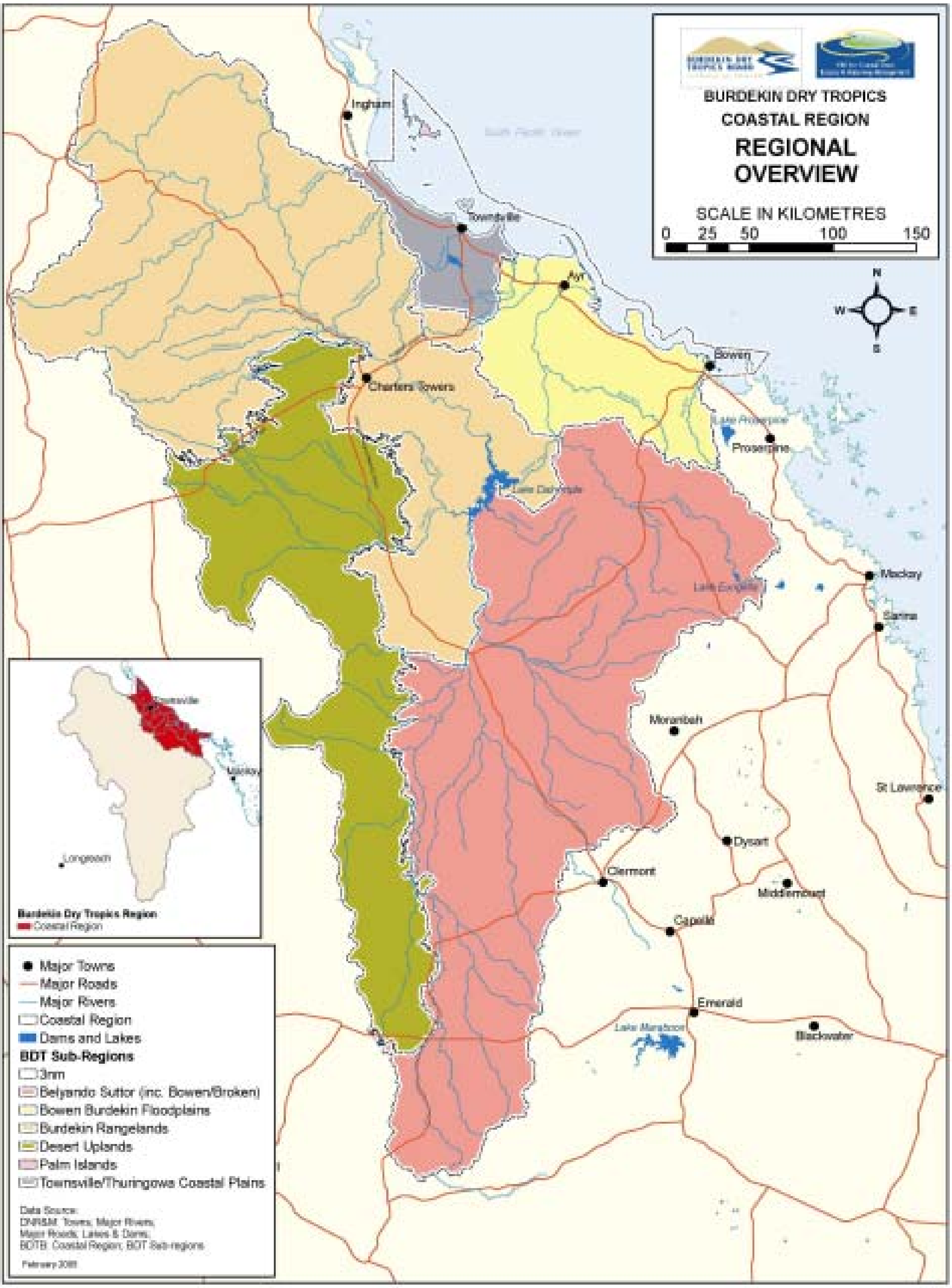


Figure 2. Map of the Burdekin Dry Tropics NRM region showing the coastal catchments covered by this report in grey and yellow.

rainfall recorded in Townsville – this was followed in 2001 by the second driest year on record with just 467 mm (BoM, 2004a). Approximately 75% of the average annual rainfall is received during December to March (BoM, 2004b). Much of this rainfall is a result of thunderstorms and the occasional cyclonic event. These tropical cyclones can result in destructive winds and phenomenal seas.

The region is also influenced by the El Niño/Southern Oscillation (ENSO), a weather pattern associated with great variation in annual rainfall and often bringing drought to the Burdekin Dry Tropics region.

3.3 Major Hydrographic Influences

The Burdekin River system drains much of the 133,000 km^2 area of the Burdekin Dry Tropics region with smaller rivers and creeks draining the coastal areas.

The hydrology of several waterways in the coastal region has been highly modified (see Section 5.3). The upper reaches of the Burdekin River flow into Lake Dalrymple before the regulated flow moves on to the coast. River flows are dominated by summer rainfall with many of the smaller rivers and streams in the region only flowing during the summer wet season. However, due to the regulation of flow by impoundments and the use of many streams within the Burdekin Haughton Water Supply Scheme area as water distribution channels (see Map 26), several coastal rivers and streams now flow continually throughout the year with little flow variation. Numerous other dams (e.g. Eungella Dam, Paluma Dam, Ross River Dam (or Lake Ross)), weirs (e.g. several on the Burdekin River system, five on the Ross River, two on the Haughton River, Collinsville weir on the Bowen River), tidal barrages, bund walls for ponded pasture and water extraction practices also affect river flows, and floodplains, in the region.

3.4 Early Settlement

The Burdekin Dry Tropics coastal region has a Traditional Owner history predating European settlement. Traditional Owner peoples lived and subsisted throughout the region, including Magnetic Island, Cape Bowling Green and Cape Cleveland where middens and other sites of cultural and historical importance can still be found (King, 2003; Veth and George, 2004). Tribes that historically lived for at least part of the year in the region include the Manbarra tribe of the Palm Island Group, Bindal tribe of the Townsville region, Wulgurukaba tribe who were the Traditional Owners of Magnetic Island and Cape Cleveland, Juru tribe of the Ayr region, the Wothan (Black Crow) clan and the Bumbarra group of the Gia tribe of the Cape Upstart region (GBRMPA, 2004c; Bruinsma *et al*., 1999).

There is evidence to suggest that Traditional Owners would travel from the mainland to the islands and return. Resources such as woodlands and reef platforms were mostly managed in a tropical, often maritime, hunter-gatherer system. Fishing using stone-walled fish traps was common, with visible remains of these structures occurring in the area. Quarry sites have also been located on Magnetic Island, demonstrating the systematic procurement, reduction and preparation of stone tools like scrapers and blades (Magnetic Island Community Development Association, 2004). The Abbot Point area also displays evidence of substantial Traditional Owner presence (PQC, 2005). Movement of sand at Abbot Point dunes continually reveals cultural material such as grindstones, hammer stones, backed blades, and implements such as juan knives, elouras, edge ground axes and baler shell water carriers and this area is recognised by Traditional Owners, researchers and the broader community as being of high cultural heritage significance. Mangrove ridges in the Abbot Point region have shell midden sites and some stone artefacts, highlighting their significance as a gathering site in the past (PQC, 2005).

Captain James Cook reached and named Cleveland Bay and Magnetic Island while sailing the Endeavour around Australia in 1770. The ship's scientist Joseph Banks and his artists made note of some of the area's plants, animals and topography. The first recorded contact with the area's Traditional Owners was in 1841 (King, 2003).

Settlement began along the Burdekin River and in Bowen (Nicholas, date unspecified) in 1861 with the port area selected and named Townsville during the following 3 years. The period 1867 to 1872 saw significant economic and social growth in the area due to a gold rush. This was followed by the development of the region's sugar industry. In the 1920s the defence forces established a base in the region, and their presence remains significant. Cement, copper, nickel and gold industries have also played a role in the region's development, with the tourism industry increasingly playing a part (King, 2003).

3.5 Population

The main population centres of the region are Townsville, Thuringowa and Bowen. In 2001, Townsville was recorded in the Australian Census 2001 as having a population of 94,739 people while Thuringowa City had 51,140 people (King, 2003) and Bowen had 13,698 people recorded (Australian Bureau of Statistics, 2001). Both Townsville and Thuringowa have experienced high rates of population growth since the 1996 census (average annual growth rate of 1.4% and 2.9%, respectively) (King, 2003). Bowen, however, has a declining population as a result of the direct and flow-on effects of the closure of its meatworks in 1996 (MWREDC, 2003a).

3.6 Employment

Employment structures are diverse within the region. There is relatively high percentage employment in government administration/defence in the Townsville region compared to surrounding regions and the Australian average due to the large military bases located in the Townsville area (King, 2003). Areas out of the major population centres, as expected, have much higher employment in agriculture than the higher density residential areas. Other industries that provide significant levels of employment include retail trade, which is likely to be related to the tourism industry and education, due to James Cook University and the area's TAFE facilities (ABS, 2001).

In Bowen Shire the horticulture industry is the largest employer, followed by fishing. Other key industries in Bowen include wholesale and retail trade, education, and health and community services, which is similar to surrounding regions (MWREDC, 2003b).

The workforce participation rate (calculated by dividing the number of people employed by the number of people over the age of 15) shows that there are a greater proportion of people employed in the Townsville statistical division (65%) than in the

Thuringowa statistical division (61%), the Burdekin statistical division (58%) and the Bowen statistical division (54%).

3.7 Services

The region is well serviced by educational facilities with both public and private primary and secondary schools, special schools, support centres, open learning centres, a TAFE college and university campus (James Cook University) located within the region. The Australian Institute of Marine Science and the Great Barrier Reef Marine Park Authority main offices are situated in Townsville. Ambulance, police, fire, hospital and air sea rescue services are also located within the region.

Further information on the social and economic profile of the region can be found in Section 6.6.

3.8 Industrial and Urban Development

The coastal areas within the Burdekin Dry Tropics are more highly populated than inland regions and are dominated by urban, industrial and irrigated agriculture land-uses. Major industries in the coastal region include Townsville Port, Abbot Point Port, fisheries, agriculture and tourism. An aquaculture industry is also developing in the region.

The region has access to a good regional road and rail network as well as transport links to Townsville Port. This allows easy movement of goods, raw materials and bulk products throughout the region as well as nationally and internationally. The port is the third largest, and one of the fastest growing, ports in Queensland. It is managed by the Townsville Port Authority, which has a land and sea jurisdiction of 400 km^2. Ten million tonnes of cargo passed through the port in 2003/2004. Seven hundred and fourteen cargo ships docked at the port in 2003/2004 with most being bulk carriers (262), general cargo (191) and tankers (109) (Port of Townsville, 2004).

The mining industry contributes significantly to the Gross Regional Product of the region and has stimulated the development of three mineral processing plants in Townsville, making it a major industry centre. These are the Townsville Copper Refinery owned by MIM, Yabulu Nickel Refinery owned by BHP Billiton and the Sun Metals' Zinc Refinery (King, 2003).

Agriculture is another significant industry in the Burdekin Dry Tropics coastal region, producing capsicums, beans, sugarcane, mangoes, tomatoes and rockmelons. The contribution of agriculture to the local economy is immense, with a total gross value of production for the Townsville ($10.6 m), Thuringowa ($13.6 m), Burdekin ($192 m) and Bowen ($204 m) local government areas of $420.2 million (ABS Agriculture Census, 2001). Most of the agricultural production (80.6%) was derived from crops, with livestock comprising the remaining 19.4%.

Tourism is a major industry in the Burdekin Dry Tropics coastal region due to its proximity to the Great Barrier Reef, the World Heritage listed Wet Tropics rainforest and Magnetic Island and its warm, tropical climate. Townsville has been recognised as one of the top four tourist destinations in the State (EPA, 2003a). Tourism invigorates the local economy significantly and can account for approximately 5% of the Gross Regional Product in the Townsville region (Tourism Queensland, 2004).

The Burdekin Dry Tropics coastal region supports a strong commercial fisheries industry. The species of focus for the industry are prawns, shark, mud crab, bugs, mackerel, barramundi and coral trout.

There has been growing concern over the potential environmental impacts, such as the clearing of vegetation and stormwater run-off, associated with increasing industrialisation and urbanisation of the region.

3.9 Resource Assets

3.9.1 Land and coastal resources

The Burdekin Dry Tropics coastal landscapes are based on acid volcanic, acid igneous, sedimentary rocks and quaternary coastal plain formed from superficial sand, gravels and silt deposits. The lowlands of the lower Burdekin River are comprised of alluvial levees, floodplains and the Burdekin delta. Coastal hills, rocky capes and offshore continental islands are formed by granite rock outcrops. Important coastal resources such as marine plains, estuaries, dune systems, beaches, sand spits, shallow embayments, continental islands with fringing reefs and the Great Barrier Reef lagoon also occur in the region (Burdekin Dry Tropics Board, 2004).

Soils of the coastal lowlands are of variable age and nature as they are deposited during flood events. Soils include sands, black cracking clays, silts and a range of duplex and sodic soils. Generally the younger alluvial soils of active river deltas are more fertile than older, less active floodplains. Humic gleys and acid sulphate soils are present in coastal areas (Burdekin Dry Tropics Board, 2004).

3.9.2 Ecosystems and biodiversity

The Burdekin Dry Tropics coastal region is a unique area with considerable diversity of marine and terrestrial species and habitats. The Great Barrier Reef (GBR) region lies off the coast with the GBR World Heritage Area boundary starting at low water mark on the mainland. Great Barrier Reef Marine Park zoning in the region includes zones for conservation, marine national park, general use, habitat protection and scientific research (Map 3).

There are 14 marine bioregions (both reef and non-reef) occurring off the coast of the Burdekin Dry tropics. They are: NA3 – high nutrient coastal strip; NB5 – inner mid shelf lagoon; NB7 – mid shelf lagoon; NL3 – outer shelf inter reef – central; NL4 – outer shelf inter reef – southern; X7 – central inter reef; RA3 – outer shelf reef; RA4 – strong tidal outer shelf reef; RE3 – coastal central reefs; RE4 – coastal southern reefs; RF2 – central open lagoon reefs; RG2 – exposed mid shelf reefs; RHC – high continental island reefs; and RHW – strong tidal mid shelf reefs (Map 4).

Under the Representative Areas Program initiated by the Great Barrier Reef Marine Park Authority these bioregions form the basis for identifying areas for management and protection (GBRMPA, 2003b).

The terrestrial coastal region is comprised of the Brigalow Belt North and Wet Tropics bioregions (Map 5). Within these bioregions are a high diversity of vegetation types and landscapes that form regional ecosystems of which approximately 6 (~1,550 ha in total) are listed as 'endangered' and 30 (~235,200 ha in total) as 'of concern' (Map 6).

Eucalypt woodlands to open forests dominate the coastal terrestrial landscape with some non-eucalypt coastal communities and heaths. Coastal dune communities, mangrove systems and saltmarshes dominate the coastal and island interface with the sea. Further inland vegetation classes are primarily non-remnant in the Burdekin Haughton Water Supply Scheme area with eucalypt woodlands and open forests dominating in the southern areas. The northern areas have a greater range of vegetation types with *Melaleuca* sp. low open woodlands and rainforest and scrubs. Remnant riparian/floodplain eucalypt open forest and woodlands areas are far more abundant inland than near the coast (see Map 7).

Areas of State significance have been mapped by two methods, firstly using diagnostic data such as vegetation and species of conservation value mapping, and secondly, by a panel of experts. This mapping emphasises the importance of coastal vegetation in the Burdekin Dry Tropics region as a large portion of the coastal region is considered to be of State significance (Map 8). A large portion of Magnetic Island is also considered to be of State significance. For a description of 'State significance' criteria see EPA (2002). Areas of State significance within the Wet Tropics bioregion (i.e. the northern portion of the Burdekin Dry Tropics coastal region, see Map 5) have, at present, not been mapped.

Approximately 1,900 terrestrial plant and approximately 800 animal species have been recorded within the region. Of these, 27 plant and 58 animal species are of conservation significance. The area is important for migratory shorebird species and marine mammals with extensive areas of seagrass incorporated in the dugong sanctuaries. The vast areas of sheltered shoreline, creeks and inter-tidal wetlands provide significant spawning, nursery and juvenile habitats for many key commercial and recreational fisheries species. However, removal of estuarine habitat, changes to the freshwater flow regime and declines in water quality have all adversely impacted on fisheries productivity with the region.

The ecosystem types occurring within the area covered in this report include coastal plains, saltmarsh, seagrass meadows, mangroves, macroalgal beds, estuaries, wetlands, rocky shores, sandy shores, marine waters, inter-tidal mudflats, beaches, sandy shoals and dunes, sub-tidal sand/mud substrates, reefs, islands and riparian vegetation (Fig. 3).

3.9.3 __Water__

The availability of a reliable water supply is a matter of concern for many parts of Australia. Most of the freshwater used within the region comes from the Burdekin Falls Dam (Lake Dalrymple) on the Burdekin River. This dam has a capacity of 1,860,000 ML and provides a secure water supply to irrigated farms in the Burdekin Haughton Water Supply Scheme.

Lake Ross/Ross River Dam provides water to the Townsville-Thuringowa area and is connected to the Haughton Balancing Storage for emergency supply. Water is also piped to Townsville and Thuringowa from Paluma Dam on the Burdekin River system.

A large alluvial aquifer system is present in the Burdekin delta from which approximately 330,000-550,000 ML/year of groundwater is extracted for irrigated agriculture production.

A good clean and reliable water supply in the region is an important aspect for future growth of the region.

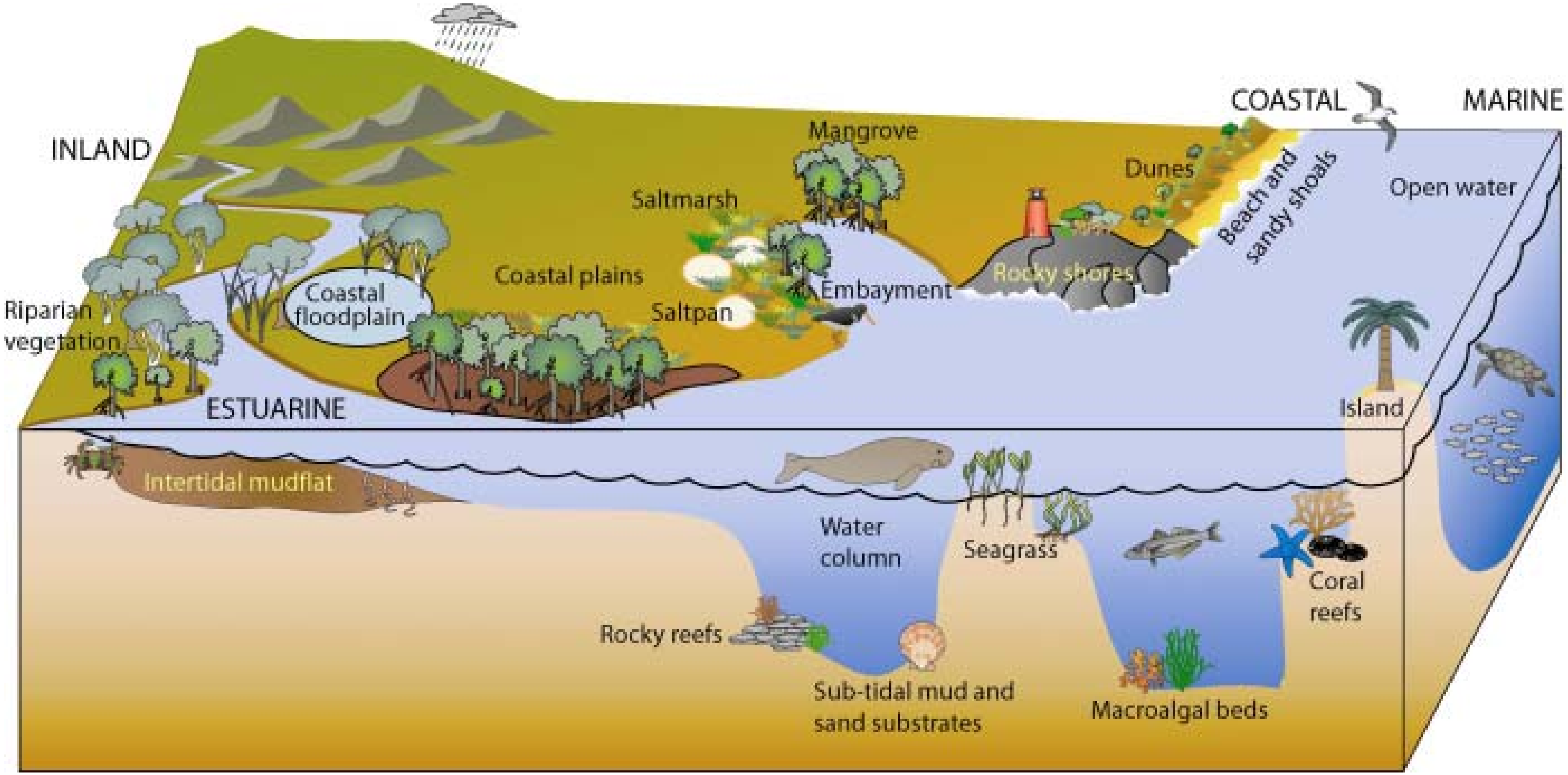


Figure 3. Ecosystems occurring in the Burdekin Dry Tropics coastal region.

4 Resource Management

4.1 Integrating Existing Legislation, Policy, Strategies and Plans

"The management of the coastal zone is complicated by overlapping and adjoining boundaries between many government agencies, legislation and plans" (EPA, 2003a, pg. 6.7). Due to this complex relationship the way coastal resources are managed and developed is influenced by Commonwealth, State and local government legislation. The State of the Environment Queensland 2003 report (EPA, 2003a) provides a graphic that displays the key Queensland legislation and jurisdictions relevant to the coastal zone (Fig. 4).

Local governments regulate land-use and development within their area and thus have an important role in coastal management and planning. They play a major role in the day-to-day management (i.e. funding, construction, acquisition, maintenance) of coastal infrastructure, waterways, foreshores and lands.

A regional NRM plan is designed to focus on significant catchment assets and pressures. It is part of an integrated larger picture of planning and management for the region's natural resources and environment. The plan operates with regard to other local, regional, State and national planning processes (legislation, policies and strategies) and industry codes-of-practice. The plan also has the capacity to influence, inform and complement government and industry planning and policy.

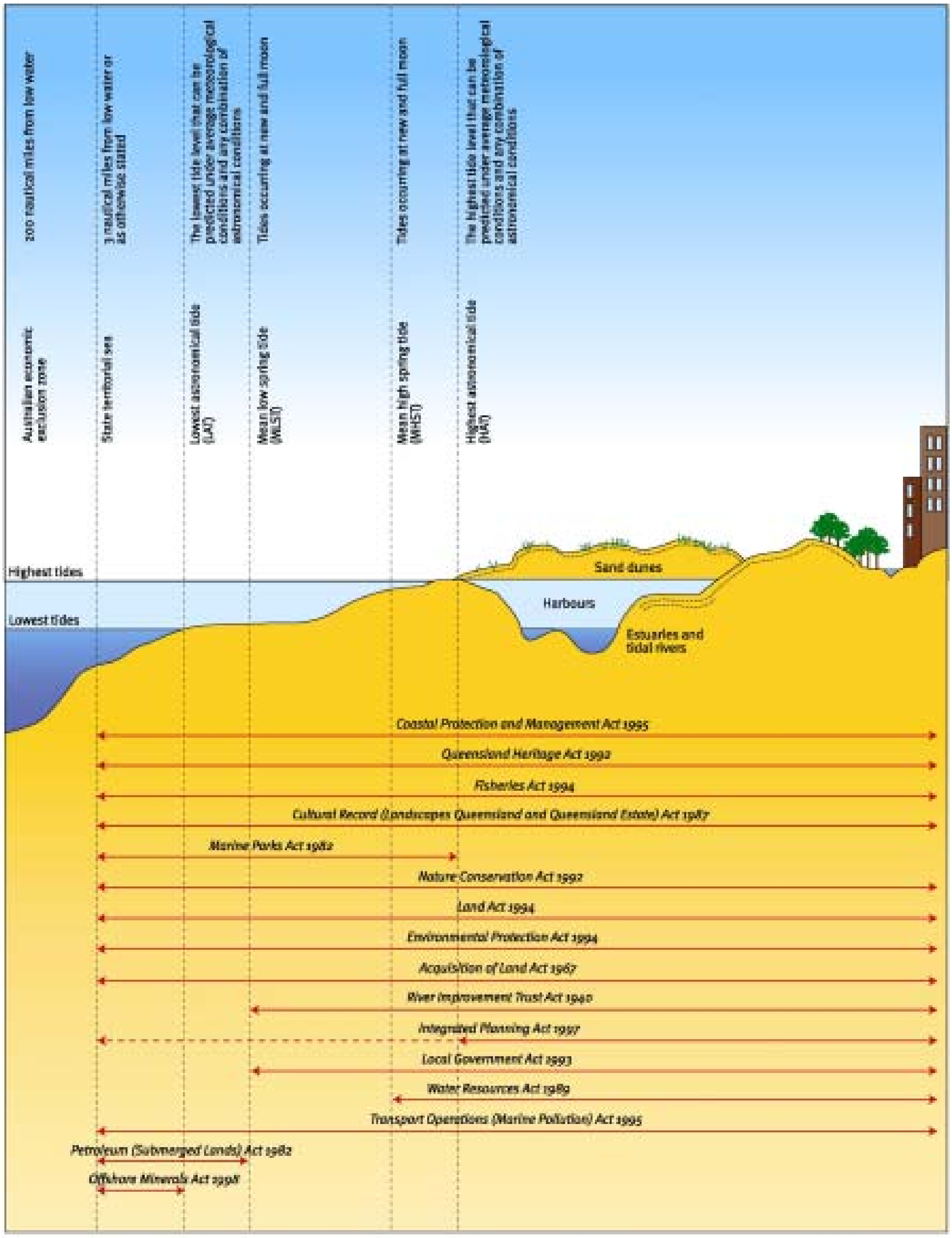
It is recognised that the plan operates within this broader planning context and, as such, has been aligned with other strategic planning activities, which operate at various geographic scales. This plan helps to bridge local and sub-regional community planning and action with regional, State and national planning and management activities. It does not override other plans, nor should it duplicate them. It is intended that this plan will complement other planning activities.

4.2 Commonwealth and Queensland Government Acts

Acts are enforceable by law. Several Commonwealth and State Acts prescribe the development of management plans and govern development activities. Natural resource management on a regional scale is influenced by Commonwealth and State legislative documents. Key examples include:

- *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth);
- *Great Barrier Reef Marine Park Act 1975* (Cwlth);
- *Native Title Act 1993* (Cwlth);
- *Fisheries Management Act 1991* (Cwlth);
- *Vegetation Management Act 1999* (Qld);
- *Transport Infrastructure Act 1994* (Qld);
- *Environmental Protection Act 1994* (Qld);
- *Fisheries Act 1994* (Qld);
- *Marine Parks Act 2004* (Qld);
- *Integrated Planning Act 1997* (Qld);
- *Nature Conservation Act 1992* (Qld);
- *Water Act 2000* (Qld); and
- *Coastal Protection and Management Act 1995* (Coastal Act) (Qld).

Figure 4. Key Queensland legislation and jurisdictions relevant to the coastal zone.



Source: *The State of the Environment Queensland 2003* (EPA, 2003a).

4.3 International Agreements Influencing NRM

Conventions and treaties signed at the international level are likely to be incorporated into the actions/strategies derived at the national level and so on down to the property level. They aim to provide a consistent, equitable and sustainable approach to managing the Earth's natural resources – particularly those that tend to stretch across national boundaries. Key examples include:

- International Agreement for Greenhouse Gas Emissions;
- The Ramsar Convention on Wetlands;
- JAMBA – Japanese Australian Migratory Bird Agreement;
- CAMBA – Chinese Australian Migratory Bird Agreement;
- The Convention on Biological Diversity; and
- The World Heritage Convention.

4.4 Commonwealth Initiatives

Planning at the Commonwealth level provides a framework for achieving a nationally consistent approach to natural resource management in those areas under Commonwealth jurisdiction. These plans and their actions are quite often driven by the need for Australia to meet certain obligations under international treaties or conventions. Decisions made at this level will have a flow-on effect and can drive the decisions made at the State, regional and local levels.

The Commonwealth Government introduced the National Action Plan for Salinity and Water Quality (NAP) and the extension of the Natural Heritage Trust (NHT2) to motivate and enable regional communities to use coordinated and targeted action to address natural resource management issues.

A *Framework for a National Cooperative Approach to Integrated Coastal Zone Management* (http://www.deh.gov.au/coasts/publications/framework/) has been developed to help protect coastal and estuarine water quality, coastal biodiversity and the economic base of coastal areas around Australia. This framework sets out implementation objectives and actions to address coastal issues of national importance and is intended to integrate with regional natural resource management planning under NAP and NHT2.

Key examples of other Commonwealth initiatives include:

- National framework for NRM standards and targets;
- Threatened species recovery plans;
- Weeds, pests, ferals of national significance;
- National objectives and targets for the conservation of Australia's biodiversity 2001-2005;
- National water quality management strategy;
- National system for prevention and management of introduced marine pests;
- EPBC – marine threatened species recovery plans (e.g. sea turtles, dugong);
- Oceans policy; and
- Coastal catchments initiative.

4.5 State Policies, Plans and Strategies

State planning policies describe the State government's interests in development related matters. The main purpose of State planning policies under the *Integrated Planning Act 1997* is to shape local government planning schemes to ensure that the State's interest is being integrated and coordinated with all levels of government. Areas of interest include:

- coastal management (including Regional Coastal Management Plans);
- planning and development involving acid sulphate soils;
- the development and conservation of agricultural land;
- protection of extractive resources; and
- fish habitat management operational policy.

Plans and strategies relevant to natural resource management at the regional level include:

- Reef Water Quality Protection Plan: for catchments adjacent to the Great Barrier Reef World Heritage Area (2003); and
- Strategy for the Conservation and Management of Queensland Wetlands (1999).

The Australian and Queensland governments have devised the Reef Water Quality Protection Plan in an attempt to halt the decline in the quality of water entering the Great Barrier Reef. A timeframe of 10 years has been set and the Great Barrier Reef Marine Park Authority is working with the Queensland Government and regional natural resource management groups to develop mechanisms for the identification and implementation of water quality targets for all catchments adjacent the Great Barrier Reef World Heritage Area (GBRMPA, 2001).

The State Coastal Management Plan (EPA, 2001) describes how Queensland's coastal zone is to be managed, and must be appropriately considered in relevant decisions. It attempts to supply ways to protect and manage both natural and cultural coastal resources which have ecological, economic and social values. These values, and associated pressures, are listed in the plan (EPA, 2001; see Table 1). The Burdekin Dry Tropics Regional Coastal Management Plan is currently under development.

4.6 Local Government Acts and Strategies

In practical terms, coastal land is managed by local government throughout much of Queensland. Local government planning schemes outline a number of policies and codes-of-practice for activities (e.g. developments and recreational activities) in the coastal zone.

Local Government Planning Schemes are statutory plans under the *Integrated Planning Act 1997*. By developing and implementing a planning scheme, a local government aims to manage growth and change in their local government area while coordinating and integrating State and regional planning at the local levels. These schemes aim to achieve ecological sustainability.

In addition, local government authorities have a number of strategies that influence natural resource management. Key strategies for the Dry Tropics region include:

- Management/Operational Plans;
- Revegetation Strategy;
- Townsville-Thuringowa Strategy Plan;
- Council of the Shire of Burdekin Corporate plan 2000 – 2005;
- Urban Stormwater Quality Management Plan;
- Soil Erosion and Sediment Control Policy; and
- Beach Management Plans.

4.7 Industry Codes-of-Practice

Industry Codes-of-practice are voluntary rules or procedures drafted in response to s.436 of the *Environmental Protection Act 1994*. Compliance with the codes is voluntary, but provides a defence against a charge of failure to comply with the general environmental duty under the *Environmental Protection Act 1994*.

4.8 Regional Catchment Plans

Planning processes in this category are generally undertaken on a voluntary basis, though usually coordinated under legislative instruments, by participating organisations and individuals who see the need to coordinate natural resource management to achieve common goals. Regional plans focus on specific issues and provide direction for the management of natural resources at a regional level.

The primary delivery mechanism developed for the implementation of on-ground works supported by the Burdekin Dry Tropics Board is through sub-regional groups. Each sub-region has a multi-stakeholder NRM steering group with a coordinator as well as specific sub-regional NRM Plans. This delivery mechanism encourages partnership among primary producers, industry bodies, Landcare and sub-regional groups, agriculture consultants and government agencies to identify, test and improve sustainable production systems and adoption of strategies in coordination with other land-uses and values.

4.9 Property Management Plans and NRM Planning

A property management plan is a tool used by landholders to document property resources and management practices and to design property and management changes. Property plans can have three main purposes:

- a strategy to meet financial, production and personal goals;
- a management tool to develop a property in a sustainable and profitable manner; and
- a record to demonstrate that a landholder is meeting their environmental obligations in natural resource management.

There are now a multitude of management plans that cover different issues such as land management, water conservation, vegetation, biodiversity and pest control. These plans may be voluntary, a regulatory requirement or needed to support an application for financial assistance. The contents of a property management plan will be specific to each individual landholder.

4.10 Protection/Conservation Areas

The Burdekin Dry Tropics NRM coastal region encompasses internationally significant wetlands, commercially and ecologically valuable animals and plants, and part of the Great Barrier Reef World Heritage Area. The exceptionally high conservation value of this coastline and the human related pressures it is experiencing has prompted the development of a variety of estuarine, coastal and marine management and protection measures. Sections of the region have been classified as State and/or Commonwealth marine parks, Ramsar sites, Fish Habitat Areas, Directory of Important Wetlands and Dugong Protection Areas (Maps 9 and 10).

4.10.1 Marine Parks

Tidal lands and waters can be designated as marine parks in an effort to protect and conserve areas of high ecological value while allowing the controlled use of marine resources. The flora and fauna within the marine park fall under the protection of the marine park management (EPA, 2004m). Zoning plans are created within Marine Parks to allow multiple-use of the area under a strategic framework of management (GBRMPA, 1998a).

The Great Barrier Reef (GBR) Marine Park follows the entire coastline of the Burdekin Dry Tropics region. With the exception of some nearshore areas, such as port areas, the GBR Marine Park starts at low water mark on the mainland and includes all waters within the limits of this report. State government typically administers marine parks from high water out to 3 nautical miles while the Commonwealth manage the waters beyond this range out to the limit of the Australian Exclusive Economic Zone, approximately 200 nautical miles from the land (DEH, 2004a). However, the GBR Marine Park is an exception as it is managed by a Commonwealth body, the Great Barrier Reef Marine Park Authority. The Queensland Government still plays a strong role in the day-to-day management of the park through the National Parks and Wildlife Service (DEH, 2004a). Coastal waters of the Burdekin region are predominately classified as general use zones, with five marine national parks, seven conservation parks, 14 habitat protection areas and two scientific research zones (Map 3).

4.10.2 Ramsar Sites

Wetlands that are internationally significant in terms of ecology, botany, zoology, limnology and/or hydrology can be placed on the List of Wetlands of International Importance under the Convention of Wetlands (DEH, 2003; Ramsar Convention Secretariat, 2004). Also known as the ‘Ramsar Convention’ this convention aims to promote the conservation and, where appropriate, the wise use of wetlands amongst signatories through a series of commitments, obligations and guidelines (Ramsar Convention Secretariat, 2004). The Burdekin Dry Tropics coastal region includes the 35,000 ha Bowling Green Bay Ramsar site, selected as a representative Queensland coastal wetland due to its rich variety of flora and diversity of wetland type which provides a seasonal habitat to large populations of all Australian waterbird groups (Blackman and Spain, 1999). Vulnerable species such as dugongs, estuarine crocodiles and green turtles also utilise the area for feeding and nesting. As well as being ecological rich, the Ramsar site has significant economic value as a habitat for critical life stages of commercially important fish and crustaceans and for coastal protection against erosion caused by cyclones. The site primarily consists of tidal mud-flats, mangrove forest and saltmarsh (Blackman and Spain, 1999).

4.10.3 Directory of Important Wetlands

Using Department of the Environment and Heritage field surveys and a range of other data sources, wetlands are reviewed and, if deemed as nationally ecologically valuable, are placed on the Directory of Important Wetlands and mapped in GIS (Blackman, 2001). This directory provides a useful source of information concerning wetland protection, restoration, rehabilitation and characteristics of specific wetlands (Blackman, 2001). Bowling Green Bay, Burdekin-Townsville Coastal Aggregation and the Burdekin Delta Aggregation are listed as nationally important wetlands in the Queensland component of the Directory of Important Wetlands (Blackman, 2001). This listing is due to their ecological significance as a habitat for many endangered and vulnerable fauna species and internationally protected migratory wader birds (Spain and Blackman, 1992). These sites are also regionally important breeding grounds for waterfowl and other waterbird populations and are vital for the sustenance of coastal and nearshore fisheries (both finfish and Crustacea) (Spain and Blackman, 1992).

Lake Ross (Ross River Reservoir) is also listed on the Directory of Important Wetlands. Being one of the few remaining large, permanent, freshwater wetlands in possibly the driest sections of Queensland's coast, this site provides an important refuge for local fauna, including the threatened Cotton Pygmy Goose and internationally protected waterbirds (Spain and Blackman, 1992).

Other wetlands occurring in the Burdekin Dry Tropics coastal region that are listed in the Directory of Important Wetlands are Abbot Point – Caley Valley wetlands, Southern Upstart Bay and a portion of the Bambaroo Coastal Aggregation (Map 9).

4.10.4 Fish Habitat Areas

Fish Habitat Areas (FHAs) are inshore or estuarine areas protected under the *Fisheries Act 1994* due to their value in sustaining both local and regional fish stocks and fisheries. FHAs are managed, through a permit system, as multiple-use aquatic areas allowing legal fishing activities and community use. FHAs have a two-tiered management system allowing for very strict management arrangements under level 'A' and a more flexible approach under level 'B' (DPI&F, 2004b).

Three Fish Habitat Areas have been created in the Burdekin Dry Tropics coastal region, including Bowling Green Bay (Plan No. 007), Bohle River (Plan No. FHA-027) and the Burdekin Dry Tropics coastal region extending from Cape Upstart to Cape Bowling Green (Plan No. FHA-005). Bowling Green Bay is under a Management A system, while the other two are under Management B systems (DPI&F, 2004b).

Cleveland Bay, lying to the east of the Ross River mouth, is currently under investigation as a possible Fish Habitat Area.

4.10.5 Dugong Protection Areas

The Burdekin Dry Tropics coastal region encompasses the Cleveland Bay, Upstart Bay, Bowling Green Bay, and the northern tip of Edgecumbe Bay, which are classified as Dugong Protection Areas (GBRMPA, 2004a). Dugong Protected Areas

(DPAs) were established by the Commonwealth and Queensland Governments in 1997 under the *Nature Conservation Act 1992* and Queensland's *Fisheries Act 1994* in order to halt the dramatic decline in dugong numbers that has occurred over the last 40 years. DPAs allow the implementation of various restrictions on mesh netting. Zone 'A' DPAs prohibit the use of offshore set, foreshore set and drift nets and prescribe modifications for river set nets. Zone 'B' allows mesh netting within the area, however, only with a series of safeguards and restrictions (GBRMPA, 2004a). As Cleveland Bay is one of the most significant dugong habitats in the Southern Great Barrier Reef it has been classified as Zone 'A' while the remaining Dugong Sanctuaries in the region fall under Zone 'B' management (GBRMPA, 2004a). Dugong Protection Areas have also been commended for providing protection against by-catch mortality of cetaceans (Limpus *et al*., 2002a).

4.10.6 JAMBA and CAMBA

The Japanese Australia Migratory Bird Agreement (JAMBA) and Chinese Australia Migratory Bird Agreement (CAMBA) are treaties between the Government of Australia and the Government of Japan and China respectively for the protection of migratory birds in danger of extinction and their environment (Australian Government, 1995a,b). The agreement came into effect in 1981 for JAMBA and 1988 for CAMBA. The primary method for implementing agreed commitments is through domestic legislation, such as Australia's *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Ryan *et al*., 2003). Species listed in the appendices of the JAMBA and CAMBA conventions are also included in the protected migratory bird list of the EPBC Act meaning Commonwealth approval must be sought in order to conduct an activity that significantly impacts any of the species (Ryan *et al*., 2003).

4.10.7 Natural Heritage Trust

The Natural Heritage Trust (NHT) is a Commonwealth Government scheme to fund community group projects that conserve and restore the environment. NHT supported projects in the Burdekin Dry Tropics coastal region include an 'Integrated community education and involvement in total water cycle management' project which is part of the 'Creek to Coral' plan currently being implemented by stakeholders in the Townsville-Thuringowa coastal plain (NHT, 2004). This project aims to increase community empowerment and ownership of water-cycle issues through an education campaign. Another project focuses on the protection and restoration of degraded seasonal wetlands in Northern Australia through the development and promotion of fire and grazing guidelines to improve weed management. Further funding has also been allocated to extend the employment of the Burdekin Coordinator Facilitator (NHT, 2004).

4.10.8 World Heritage Areas

Great Barrier Reef

In 1981 the Great Barrier Reef was classified as a World Heritage Area as it met all four natural world heritage criteria by representing major stages of the earth's evolutionary history, being an outstanding example of ecological and biological processes, and containing superlative natural phenomena and important natural habitats for conservation of biodiversity (EPA, 2004a). The Commonwealth and Queensland Governments have been charged with the protection and management of the Reef's natural and cultural values (DEH, 2004a). The Commonwealth Government is represented in the form of the Great Barrier Reef Marine Park Authority (GBRMPA) and is responsible for the overall management while the Queensland Government, through the Queensland Parks and Wildlife Service is focused on the day-to-day management (DEH, 2004a). As the Burdekin Dry Tropics region lies adjacent to the Great Barrier Reef its coastal waters fall under the World Heritage Area.

Wet Tropics
North Queensland is highly valued for its terrestrial, as well as its aquatic, biodiversity. The Wet Tropics World Heritage area includes at least 13 endemic mammal species and at least 50 endemic plant species which, together with about 3,000 other plant species and a third of all Australian mammal species, comprise a unique, living record of the ecological and evolutionary processes that have shaped Australian wildlife over the past 415 million years (WTMA, 2002). The Wet Tropics World Heritage Area extends from Townsville to Cooktown, covering 894,420 ha and including some northern parts of the Burdekin Dry Tropics region. The World Heritage Area includes national parks, State forest, freehold and public land creating a complex mosaic of land tenure. In order to manage and protect the area as part of Australia's obligations under the World Heritage Convention the Commonwealth and Queensland Governments established the Wet Tropics Management Authority (WTMA). As with the Great Barrier Reef World Heritage Area the WTMA conducts the overall management while the Queensland Parks and Wildlife Service are responsible for day-to-day management (WTMA, 2002).

4.10.9 National Parks
Approximately 5% of the Burdekin Dry Tropics coastal region is protected by national park (Maps 10 and 11). These parks are selected and managed by the Queensland Parks and Wildlife Service as places of high ecological and recreational value (EPA, 2004c). The *Nature Conservation Act 1992* states that the preservation of the natural condition of parks is the fundamental principle for park management and to ensure this preservation, management plans are developed for each park and are enforced by rangers (EPA, 2004c).

Magnetic Island National Park encompasses just over half of the large, continental island off the coast of Townsville (EPA, 2004d). Ecologically, the area supports open eucalypt woodlands, hoop pine rainforest and mangroves and is fringed with reefs in marine park waters (EPA, 2004d). The area also has cultural significance for its Traditional Owners, the Wulgurukaba people, which can been observed through the presence of shell middens, stone tools and rock art sites on the island (EPA, 2004d).

The largest terrestrial park in the Burdekin Dry Tropics coastal region is Bowling Green Bay National Park, which protects an extensive network of coastal wetlands, saltpans, mangrove forests, tropical rainforests and granite mountains (EPA, 2004e). Rock art sites by the Wulgurukaba people are also present in the Bowling Green Bay National Park forming an important component of the region's cultural heritage.

Cape Upstart National Park covers most of the granite Cape Upstart headland, including beaches, dunes and a range of coastal vegetation types. The area is also culturally significant for the Juru people and is surrounded by Great Barrier Reef Marine Park waters (EPA, 2004f).

Holbourne Island National Park is relatively small at 0.34 km^2 and is highly valued for its function as a key nesting site for flatback turtles (*Natator depressus*), a turtle species endemic to the southern Great Barrier Reef region (GBRMPA, 2004b). The island is also a significant bird nesting habitat (GBRMPA, 2004b).

Paluma Range National Park is divided into two sections – the Mt Spec section and Jourama Falls. Mt Spec is the southernmost tip of the Wet Tropics World Heritage Area (EPA, 2004g). Both sections contain areas of tropical rainforest, dry vine forest, eucalypt woodland and riparian vegetation (EPA, 2004g). Paluma Range National Park is home to many bird species, including the Golden bowerbird, a species endemic to high altitude regions of far north Queensland (Slater, 2004). The endangered Mahogany glider, Green ringtail possum, Giant white-tailed rat and freshwater tortoises are also found in this national park (EPA, 2004g).

4.10.10 Conservation Parks

As with national parks, conservation parks are areas designated for environmental conservation and nature-based recreation. However, this classification allows a greater range of activities to be permitted within the site (QPWS, 2001). Conservation parks can be managed or co-managed by trustees, such as local government (QPWS, 2001). Conservation parks found within the Burdekin Dry Tropics coastal region are shown on Map 10.

Cape Pallarenda Conservation Park, a coastal park in Townsville, houses the remains of a former quarantine station and gun emplacements built during World War II. Ecologically the area is valued for its open woodlands, vine thickets and coastal bird-life (EPA, 2004h).

The Townsville Town Common Conservation Park protects mangrove-fringed estuaries, swamps, vine thickets, grasslands, woodlands and ephemeral wetlands (EPA, 2004i). This conservation park also includes the remnants of the Bohle River basin and provides important seasonal waterholes for birds when inland water sources are scarce (EPA, 2004i). Being proximate to the major population centre of Townsville the site is also very popular with local visitors and tourists (EPA, 2004i).

Horseshoe Bay Lagoon Conservation Park, found on Magnetic Island is a 4 ha park (DEH, 2005) which currently has no management plan (EPA, 2005). This park is known for its diverse bird community, featuring brolga, jabiru and the nankeen night-heron (Fairfax, 2005). Horseshoe Lagoon Conservation Park is located near Ayr and covers an area of 76 ha (DEH, 2005); a management plan has been developed for this park.

4.10.11 State Forests

Queensland Parks and Wildlife Service are the custodians for Queensland’s State forests, attempting to balance commercial pursuits for timber products, recreational activities and ecological conservation (EPA, 2004c). A permit system has been developed to allow managers to regulate the extent and type of activities occurring within the State forest boundaries (EPA, 2004c). Paluma State Forest, in the

Burdekin Dry Tropics region, houses valuable upland rainforest remnants along the Paluma and Seaview Ranges (EPA, 2004j). This State forest occurs in the Wet Tropics World Heritage Area and provides habitat to many species of birds, mammals and amphibians found only in the Wet Tropics (EPA, 2004j).

Approximately 4% of the Burdekin Dry Tropics coastal region is under State forest tenure (Map 11).

4.10.12 Statutory Covenants

Statutory Covenants are legally binding agreements that involve an act of parliament (Statutory Covenants Working Group, 2004). They are registered by the Department of Natural Resources and Mines and bind all current and future owners of the land to the agreement (Statutory Covenants Working Group, 2004). The use of statutory covenants to ensure the continued conservation of a parcel of freehold land has become increasingly popular and is currently being used in the Burdekin Dry Tropics region as a planning and natural resource management tool.

4.10.13 Nature Refuges

Areas of freehold or leasehold land providing habitat for threatened or endangered species, or containing remnant vegetation or regional ecosystems that are poorly represented in current protected areas, wildlife corridors and/or have significant cultural heritage can be nominated for the Nature Refuge program (EPA, 2004k). A landholder or local council owning a suitable area can enter into a Nature Refuge conservation agreement with the Queensland Parks and Wildlife Service in order to gain support for managing the land in an ecologically sustainable manner (EPA, 2004k). The support is in the form of reimbursement for land tax and transfer duty (EPA, 2004l), specialist management advice by QPWS and the possibility of applying for financial assistance from QPWS for certain management work (EPA, 2004k). Nature Refuges are voluntary conservation agreements and form a protected area category under the *Nature Conservation Act 1992* (EPA, 2004l). Agreements are tailored to suit the needs of the landholder and particular land management requirements of the area and are perpetual on freehold land and for the duration of the lease over leasehold land (EPA, 2004k). A perpetual agreement ensures the continuation of conservation work on the land even after its transfer to new owners (EPA, 2004l).

4.10.14 Land for Wildlife

Land for Wildlife is a scheme where landholders can voluntarily register their property, demonstrating their interest in wildlife-friendly land management (Townsville City Council, 2004b). The scheme is not legally binding and a property's registered status does not continue after it has been sold (Townsville City Council, 2004b). Upon registration the scheme provides landholders with recognition and support for their efforts to integrate the maintenance of wildlife habitats with other land-uses (QPWS, 1999).

Land for Wildlife area at Castle Hill, Townsville (David Scheltinga)

Landholders are also encouraged to share their ideas and experiences through publications and field days (QPWS, 1999). Both Townsville and Thuringowa City Councils are involved in the scheme, along with the North Queensland Afforestation Association. Natural Heritage Trust provides funding for the scheme (Townsville City Council, 2004b).

4.11 Traditional Owner Land and Sea Use

Traditional Owner interests in the coastal area arise from a long standing cultural association with, and use of, the estuarine, coastal and marine environments of the region. The social, cultural and economic values associated with resources such as dugong and turtle give strength to Traditional Owner culture and demonstrate connection with tradition and traditional areas. Traditional Owner groups have a native title right to undertake harvesting of marine resources in accordance with their custom and tradition. Currently, there are moves towards development of Traditional Use of Marine Resources Agreements (TUMRAs) between EPA, GBRMPA and Traditional Owner groups to support the protection and sustainable use of traditional resources.

5 ESTUARINE, COASTAL AND MARINE ECOSYSTEM INTEGRITY – ASSETS, CONDITION AND TREND

5.1 Estuarine, Coastal and Marine Ecosystems

The separation of the estuarine, coastal and marine ecosystems described below is fairly arbitrary. In reality these ecosystems, even those that are geographically distant, are all part of one dynamic system. Estuarine and coastal waters, besides being ecosystems themselves, provide a linkage between other ecosystems, transporting water, organic matter, sediment and nutrients from sources to sinks. Riparian vegetation ecosystems are intimately linked to the wetland and waterway ecosystems they fringe, all of which form part of the coastal floodplain ecosystem. Saltmarsh, saltpan and mangrove ecosystems often share the same topographical niche, with dominance fluctuating literally, with the weather (rainfall in particular). Coral and some macroalgae communities exist in a similar dynamic equilibrium determined by water quality properties like nutrients. Seagrass ecosystems are found interspersed in sub-tidal sand and mud substrate ecosystems, both of which are bathed in estuarine and marine water ecosystems. It is vital that the headings below are seen as different 'nodes' in a complex system rather than separate entities unto themselves.

Burdekin River delta and coastal floodplain (EPA)

5.1.1 Coastal Floodplains

Description

Coastal floodplains are areas associated with the lower reaches of rivers that are partially inundated by floodwaters and/or tides up to several metres above the high water mark. Large areas of low-lying floodplain are inundated in periodic floods, less extensive areas are inundated with king tides and a smaller proportion are inundated with regular tidal events. Nutrients and sediments transported by rivers are deposited onto floodplains during inundation events. Algae and bacteria that are present in soils become active when soils are hydrated and may contribute to the productivity of the floodplain food web (e.g. through nitrogen fixation). Receding floods following inundation events results in the formation of swamps and lagoons, including shallow marshes and deeper ponds and billabongs (Turner *et al*., 2004). These wetlands may be permanent, or may flood only on an intermittent basis and disappear entirely during dry periods. Salinity often increases from freshwater to brackish or saline throughout the year (Turner *et al*., 2004).

The coastal floodplain wetlands of the Burdekin Dry Tropics region are important as breeding areas, dry season refuges and migration stopover points for many bird species, with the Bowling Green Bay Ramsar site being a prime example. Floodplain communities are often bordered by eucalypt forests, woodlands, saltmarsh and/or mangrove vegetation. Vegetation types found on Burdekin coastal plains include aquatic grasslands, sedge, and melaleuca woods (consisting primarily of *Melaleuca dealbata*, *Melaleuca vidiflora* and/or *Melaleuca leucadendra*) and a variety of aquatic herbs (Townsville City Council, 1999a). The coastal floodplains of the Burdekin Dry Tropics coastal region provide important wader bird and duck habitat for local and migratory birds like Latham's Japanese Snipe (*Gallinago hardwickii*). Mammals such as the agile wallaby (*Macropus agilis*) and tortoises (*Chelodina rugosa*) are also found in the area (Townsville City Council, 1999a). Despite their high ecological value coastal floodplains are the most poorly ecologically understood of the coastal ecosystems (Turner *et al*., 2004).

Distribution

Coastal floodplains are found in the low and relatively flat areas adjoining river mouths and within deltas. The coastal floodplains of the Burdekin delta tend to be narrow and discontinuous, widening as the topography flattens out and lowers closer to the sea (BOM, 2004c). When the Burdekin River floods, water overflows into these surrounding areas before draining into Bowling Green Bay. Under extreme flood conditions the Burdekin River can flow overland, recharging ephemeral swamps and entering the sea at Cleveland Bay (EPA, 2003d). The Haughton River to the north of the Burdekin River also has extensive floodplains that are interspersed with many small creeks, which typically drain into Bowling Green Bay and, under, flood conditions can overflow into swamps and Cleveland Bay (EPA, 2003d).

Coastal floodplains have also been created by the Don River in the south. The Don River flows to the north of the town of Bowen, which is built on a floodplain and is therefore susceptible to damage by flood events. Smaller creeks in the region, such as Crystal Creek and Plantation Creek have also formed coastal floodplains. Agriculture is the most common land-use for the coastal floodplains of these smaller creeks (OzEstuaries, 2001).

Condition and Trend

“Many of the aquatic ecosystems on the coastal floodplain are currently in very poor condition. Factors such as clearing of riparian vegetation, introduction of exotic weeds, drainage alterations and hydrological modifications, combine to undermine natural ecological functions and increase the vulnerability of water bodies to water quality problems” (ACTFR, date unspecified).

Coastal floodplains, by their nature have rich alluvial soils and are situated around river mouths, making them prime areas for ‘reclamation’ for agricultural activities, port facilities and urban waterfront developments, all of which threaten their role as native habitats. Such land-use changes have occurred extensively on the coastal floodplains of the Burdekin Dry Tropics region. The Don River delta has experienced many changes to its coastal plains, due to extensive horticultural activities (BOM, 2003) and the expansion of the town of Bowen. The Burdekin River delta is also heavily modified for irrigated sugarcane cropping. While the coastal plains only constitute a small area of the Burdekin Dry Tropics they produce 25% of Australia’s sugar production, constituting a highly significant proportion of the region’s economy (approximately $300 million per annum) (Ash, 2001). The Burdekin River Water Supply Scheme recently expanded, resulting in further loss of natural floodplain habitats and significant modifications to their hydrological patterns (Danaher, 1995).

Like Bowen, Townsville is also situated on a coastal floodplain, in this case, the Ross River delta. Extensive urban development has occurred on this floodplain with agricultural activities playing a smaller role than in the Don River or Burdekin River floodplain areas. Although many significant wetlands on the Burdekin Dry Tropics region's coastal floodplains are protected, such as the Bowling Green Bay Ramsar site (Blackman and Spain, 1999), most have been either 'reclaimed', significantly altered for human use or are being threatened by human activities. Upstream dam construction impacts ephemeral wetland ecosystems by dissipating flood pulse flows. Reclamation of coastal floodplains for development and agricultural use degrades these ecosystems directly by vegetation clearing and habitat loss and indirectly by the input of pollutants like herbicides, pesticides, and fertilisers, increased soil erosion and consumption of water for irrigation.

Reclamation of coastal floodplains often involves infilling, drainage and/or vegetation clearing. The vegetation-clearing rate in sections of the Burdekin Dry Tropics' coastal floodplains has been estimated as part of the Land Cover Change surveys. The clearing rate for the area around Townsville is estimated to be 1,000 to <2,000 ha/year. South of this area, from Townville to Inkerman the clearing rate is reduced to 0 to >100 ha/year and rises again in the Don River catchment to 100 to >500 ha/year (Natural Resource Sciences, 2003).

Some coastal floodplains in the Burdekin River region have become infested by Cumbungi *Typha* sp., a native sedge. Nutrient loading and the construction of saltwater exclusion bunds in shallow ponds has altered previously diverse ephemeral or tidally influenced areas into waterbodies that have Cumbungi sedge as dense monotypic stands (Tait and Perna, 1999).

Earth works in coastal floodplains for development can potentially reveal Acid Sulphate Soil (ASS). Exposure of these soils to oxygen in the air results in a chemical reaction that produces sulphuric acid (battery acid with a pH of less than 2-3), which can acidify soils, groundwater and run-off. Not only can this acid be harmful to animals and plants directly, it can also reduce the oxygen of waterways and release heavy metals like aluminium from the soil in toxic quantities. Fish exposed to acidified waters are more susceptible to 'red spot' infection that causes large red lesions to appear on the fish's body and often results in death (Ahern *et al*., 2002). Although no comprehensive mapping of potential and actual acid sulphate producing soils has been conducted, the coastal floodplains of the Burdekin Dry Tropics coastal region are thought to be at high risk of developing ASS upon disturbance because their topography is relatively low lying with many drainage paths below 5 Australian Height Datum (AHD) (Sadler, date unspecified).

Salinisation of water and land is one of the most serious issues facing natural resource managers in Australia. There are three main types of salinity based on their different causes:

- dryland salinity, which results from saline seeps creating scalds on non-irrigated land;
- irrigation salinity, resulting from overuse of water and a subsequent water table rise; and
- saltwater intrusion, occurring in coastal aquifers when seawater replaces depleted groundwater flows (NR&M, 2004b).

These causes are closely related to land characteristics, human activities and climatic factors. Salinity hazard mapping has been conducted for the Burdekin River coastal region indicating a high risk of salinity for much of the Burdekin Haughton Water Supply Scheme area, the land surrounding Ayr and to the south of Upstart Bay. The coastal strip adjacent to Bowling Green Bay, which currently supports extensive wetlands, has been classified as a moderate salinity hazard (Map 12; see also Section 6.1.2).

Summary of major issues and knowledge gaps

Coastal floodplains are known to have a high ecological value, however, they are still one of the most poorly understood ecosystems of the coastal region. This is particularly true within the Burdekin region where there is a need for the detailed examination of the condition and trend of these important natural resources. Particularly, in light of the effects of flood mitigation and flow regulation of the region's rivers.

Presently, no comprehensive mapping of potential and actual acid sulphate producing soils has been conducted in the region. The coastal floodplains of the Burdekin Dry Tropics coastal region are thought to be at high risk of developing ASS upon disturbance.

Groundwater interactions in the coastal floodplain are of concern in the region. Groundwaters are highly regulated in terms of extraction but poorly understood in terms of monitoring changes and the interactions between aquifers. A lack of baseline sampling with regards to salinity has meant that the cause of the increased salinity of groundwaters remains unknown which has resulted in debate between various industries in the region as to who/what is causing it.

The clearing of riparian vegetation, introduction of exotic weeds, reclamation for development, input of pollutants (like herbicides, pesticides and fertilisers (nutrients)), increased soil erosion and consumption of water for irrigation, acid sulphate soils, drainage alterations and hydrological modifications (e.g. the Burdekin River Water Supply Scheme – resulting in loss of natural floodplain habitats and significant modifications to hydrological patterns, upstream dam construction – impacts ephemeral wetland ecosystems by dissipating flood pulse flows, the construction of saltwater exclusion bunds – altered previously ephemeral or tidally influence) and salinisation of water and land are all important issues occurring in the region which impact on coastal floodplains.

5.1.2 Saltmarsh and Saltpan

Description

Haughton River saltmarsh (Dieter Tracey)

Saltmarshes are communities of low-growing herbs, shrubs and grasses tolerant of high salinity and poorly aerated soils that occur in areas where tidal inundation is regular but infrequent. They often form a mosaic of vegetated, low-lying mounds bordering shallow pools or hypersaline saltpans and are sometimes drained by small creeks. Most saltmarsh plants belong to a few widespread families, including the grasses, saltbushes and their allies, rushes and sedges. There are about 25 different species of saltmarsh plants in the Burdekin Dry Tropics coastal region (Townsville City Council, date unspecified – Natural Assets Database). *Halosarcia* sp. is a very common saltmarsh in the area (Rob Coles and Jane Mellors, pers. comm.).

The plant communities of saltmarshes often occur in distinctive zones and smaller scale patches, determined by a range of interacting physical and biological factors. Saltmarshes help maintain estuarine water quality by filtering sediment from land-based run-off. They provide an important source of organic matter to estuarine food chains, but are not as productive as seagrass or mangrove areas; nor are the animal communities in saltmarshes as diverse as those of adjacent habitats. However, they provide important habitat for some fish and aquatic invertebrates and a range of terrestrial species including insects and their larvae, spiders and lizards (Turner *et al*., 2004). These attract waterbirds such as herons, bitterns and egrets, waders such as the rare eastern curlew (*Numenius madagascariensis*) and some bush birds. Saltmarshes are frequently covered by high tides and may support dense mats of algae that provide an additional food source for many fish and invertebrates. Shallow pools topped up intermittently by rain provide transitory feeding habitats for larval and juvenile fishes including several of importance to fisheries (Turner *et al*., 2004). Saltpans are hypersaline to the extent that even the most salt tolerant saltmarsh species cannot grow.

Distribution

The Queensland Department of Primary Industries and Fisheries has conducted a mapping project of Queensland's coastal wetlands. These maps show saltmarsh habitats (classified as saltpan, saline grassland and samphire-dominated grassland) interspersed with mangrove communities. Saltpans tend to be present on the landward edge of coastal wetlands and cover the greatest area of the saltmarsh types while samphire-dominated grassland is mostly found on the seaward edge. Saline grassland occurs less frequently in the region and are distributed in a variety of tidal and estuarine situations.

In the Burdekin Dry Tropics coastal region saltmarshes are found at Cape Cleveland (including Cungulla-Bowling Green Bay Coastal Complex), Magnetic Island, Mundy Creek, Pallarenda, Ross River, South Bank Coast, in the Cleveland Bay coastal complex (which includes Stuart, Alligator, Crocodile and Cocoa Creeks), Toomulla, Townsville Town Common and Cromarty Wetlands (Townsville City Council, date unspecified) and the Burdekin River delta, with extensive saltpans in the areas from Cape Upstart to the Don River delta (see Maps 13-23).

Condition and Trend

As the Burdekin Dry Tropics coastal region experiences a drier climate than the coastal regions to the north and south, there is a greater proportion of saltmarsh/saltpan than mangroves in the region's inter-tidal zones (Bruinsma, 2001). Surveys of the State's coastal wetlands concluded that many of the saltmarsh communities in the southern parts of the region are in a relatively pristine condition (Bruinsma *et al*., 1999). Saltmarsh communities in areas within, and proximate to, major harbour facilities and towns like Townsville have not fared as well and some have either been completely lost through reclamation or degraded by a range of threats (DPI&F, 1998).

Land reclamation has resulted in extensive areas of inter-tidal wetlands and saltmarshes being replaced by ports, marinas, canal estates, urban developments and industrial sites (DPI&F, 1998). Saltmarsh communities often bear the greatest impact of coastal development compared to other saline wetland communities as they grow on relatively high, waterfront land and are therefore very desirable for coastal development. Other threats that can degrade saltmarsh communities include, invasion by weeds (mainly around the margins), rubbish dumping, off-road vehicle traffic, cattle grazing, changes in hydrology and mosquito control programs that involve pesticide spraying or drainage. Changes in sea level from global climate change are also predicted to be a threat to saltmarsh areas (Zann, 1995).

Natural causes can be responsible for saltmarsh degradation/disturbance; these include catastrophic weather events and mangrove encroachment, which is stimulated by an increase in rainfall. In natural situations, mangrove encroachment is usually coupled with a recruitment of saltmarsh on the landward edge creating a new equilibrium between these neighbouring ecosystems. However, coastal developments often restrict landward recruitment of saltmarsh. Saltmarsh are therefore caught between a rock (coastal development) and a hard place (encroaching mangroves). This has proved to be the case in the Don River delta where agricultural fields extend to the upper inter-tidal limit and saltmarsh areas are relatively diminutive (Bruinsma *et al*., 1999).

Saltmarsh condition varies greatly within the region with sub-catchments such as Ross Creek exhibiting a generally poor condition of saltmarsh with at least some loss in most sections, whereas the adjacent Haughton sub-catchment contains less disturbed saltmarsh (Bruinsma, 2001). Trend data for saltmarshes in the region is scarce. However, comparison of topographic maps (1970s) with satellite images (1992) suggest that these areas are naturally in a continual state of flux (Danaher, 1995). Saltmarsh communities have the potential to recover from some forms of degradation.

Summary of major issues and knowledge gaps

Many of the saltmarsh communities in the southern parts of the region are in a relatively pristine condition. However, saltmarsh communities in areas within, and proximate to, major harbour facilities and towns like Townsville have not fared as well and some have either been completely lost through reclamation or degraded by a range of threats. There is a need for a new survey to be conducted to examine the extent and health of saltmarsh in the region as presently there is a lack of trend data for saltmarsh communities in the region.

Large saltmarsh areas occur in and around the Bowling Green Bay Ramsar site. There is a need for an evaluation of the Ramsar site to determine if it is actually protecting the resource it is there to protect, e.g. examine its ability to provide habitat to migratory birds. Currently, there is little stopping adjacent landholders from impacting on the Ramsar site through their land management practices, e.g. modifying water flow (David Foster pers. comm.).

Research into the possible impact of sea level change on coastal natural resources such as saltmarshes is needed.

Reclamation by ports, marinas, canal estates, urban developments and industrial sites, invasion by weeds (mainly around the margins), rubbish dumping, off-road vehicle traffic, cattle grazing, changes in hydrology and mosquito control programs that involve pesticide spraying or drainage, changes in sea level, natural changes caused by catastrophic weather events and mangrove encroachment are all important issues occurring in the region which impact on saltmarshes.

5.1.3 <u>Mangroves</u>

Mangroves near Alva (David Scheltinga)

Description

Mangroves are trees and shrubs that usually grow in soft sediments in the inter-tidal zone. They are specialised in a number of ways to cope with waterlogged soils deprived of oxygen and nutrients, and high levels of salt in the water. Extensive, though shallow, root systems help anchor the plant, and many mangroves have aerial roots that enable them to 'breathe'. Mangroves have the ability to transport oxygen to their root systems (Curran *et al*., 1986; McKee *et al*., 1988) and the leaking of this oxygen into the surrounding sediments has a significant effect on adjacent biogoechemical processes (McKee *et al*., 1988; Anderson and Kristensen, 1988). Each species differs in its ability to influence and cope with changes in sediment anoxia (McKee, 1993; Youssef and Saenger, 1996).

The seeds of many mangrove species germinate while still attached to the parent tree, which enables them to establish rapidly while some also have buoyant components that encourage long-distance dispersal (Tomlinson, 1994). Mangrove diversity in the Burdekin Dry Tropics coastal region is high, with about 17 species of mangroves and mangrove associates. The stilt rooted mangrove *Rhizophora* sp. dominates the mangrove canopy in the region, except from Bowling Green Bay to Cape Bowling Green where *Ceriops* sp. communities are more common and in the Burdekin River delta where mixed communities containing the cedar mangrove *Xylocarpus mekongensis* flourish. Other mangrove species such as *Avicennia marina*, *Bruguiera* sp., *Excoecaria agallocha*, and *Osbornia octodonta* can also be found in the region (Danaher, 1995).

Mangroves provide physical protection of the coastal fringe and riverbanks from erosion, and trap sediments from overland run-off. This function helps improve water quality and is therefore particularly important for the health of seagrass meadows and coral reefs of the Great Barrier Reef Marine Park (GBRMPA, 1998b; Alongi and McKinnon, 2004).

Mangrove forests are highly productive ecosystems, producing a considerable amount of litter (leaves, twigs, bark, fruit and flowers) that provides nutrients and organic material to the mangrove food web. Some organic material is eaten by crabs, but most is decomposed by bacteria and fungi. Larger particles are consumed by fish and prawns or contribute to sedimentation processes, while smaller particles are taken up by molluscs and small crustaceans. A considerable amount of detritus is also exported and provides a source of organic material to nearshore areas (Alongi, 1990; Alongi and McKinnon, 2004).

Mangrove forests provide habitat for numerous terrestrial and marine animals, and are important feeding areas for others. Polychaete worms and small crustaceans are common in the mud; bivalves, tubeworms and barnacles grow attached to wood; snails and crabs move about over the mud and in the trees, and fish move in with the tides to feed (Vance *et al*., 1996; Ronnback, 1999). The food and shelter provided by mangroves are vital for different life stages of many commercially caught fisheries species (Hatcher *et al*., 1989; Manson *et al*., 2005b). Because of their structural complexity and productivity, mangrove forests often support greater densities of fish than adjacent habitats (Robertson and Duke, 1987; Blaber *et al*., 1989; Morton, 1990; Vance *et al*., 1996; Ronnback, 1999; DPI&F, 2001). The catch of some fisheries species has been shown by several researchers to be correlated to the extent of mangroves in a region (see Baran, 1999; Manson *et al*., 2005a, b).

The coastal sheath tailed bat (*Taphozous australis*) and saltwater crocodile (*Crocodylus porosus*), which are listed as vulnerable under the *Nature Conservation Act 1992*, as well as the rusty monitor (*Varanus semiremex*), which is listed as rare are also all commonly found in the mangroves of the Burdekin Dry Tropics coastal region (Townsville City Council, date unspecified). The riparian mangroves on Ross River provide important habitat for a very large flying fox nursery (George Lukacs, pers. comm.).

Distribution

Mangrove forests are predominantly found on low energy (sheltered) shores and stream banks, under a range of salinities, from hypersaline to freshwater. In the Burdekin Dry Tropics region, mangroves are found fringing the coastal and estuarine areas throughout the region (e.g. Cape Cleveland, Cromarty Wetlands, Magnetic Island, Ross River, Bohle River, Burdekin River delta, Boling Green Bay and Cleveland Bay Coastal Complex (which includes Stuart, Alligator, Crocodile and Cocoa Creeks), Pallarenda, Ross Creek, South Bank, Toomulla, Upstart Bay, Cape Upstart, Abbot Bay and Edgecumbe Bay) (see Maps 13-23).

Species distribution seems to vary throughout the area. *Ceriops* sp. (Yellow Mangrove) species tend to dominate mangrove communities from Bowling Green Bay to Cape Bowling Green and are often adjacent to landward saltpans while *Xylocarpus mekongensis* (Cedar Mangrove) dominates the mixed mangrove communities around the Burdekin River delta. Further south, from the Burdekin River to Cape Upstart *Rhizophora* species take the dominant role (Danaher, 1995). In this part of the Burdekin Dry Tropics coastal region closed *Rhizophora* communities and *Avicennia* sp. establish along the foreshore and watercourses while closed *Ceriops* sp., and closed mixed communities typically dominate the landward fringe of the closed *Rhizophora* sp. communities (Bruinsma *et al*., 1999).

Table 2. Mangrove habitat area within the Burdekin Dry Tropics region.

Mangroves/habitat type	Area (hectares)[†]
Rhizophora (closed)	4,990
Ceriops (closed)	1,390
Avicennia (closed)	820
Avicennia (open)	460
Mixed (closed)	5,560
Total	**13,220**

Source: DPI&F (2000). [†]Data collected between November 1993 and August 1994.

Condition and Trend

Surveys conducted as part of the GBRMPA State of the Great Barrier Reef World Heritage Area Reporting suggest that no major declines of mangrove area have occurred in the region over the last 40 years (GBRMPA, 1998). However, localised loss and damage has occurred from extensive reclamation activities, undertaken in the construction of ports, marinas and the like. Although the waters of the Great Barrier Reef are fringed with mangroves, most mangrove communities are found outside the World Heritage Area. Mangroves in Queensland are afforded protection through the Queensland *Fisheries Act 1994* (GBRMPA, 1998b).

Mangroves are susceptible to a variety of natural and anthropogenic pressures. Clearing and disturbance for coastal development of urban, industrial and military areas is a major cause of mangrove decline in the Burdekin Dry Tropics region and elsewhere. Structures such as breakwaters that alter water flow and sediment deposition patterns can also stress and kill mangroves. This can be seen at Branch Creek on the western side of Abbot Point where a levee was constructed for recreational fishing access which isolated mangroves on the landward side from tidal inundation and resulted in their death (Bruinsma *et al*., 1999). Mangroves have been removed from 8.6 ha of tidal land near Townsville for the construction of a defence facility (Zeller, 1998). Similarly, pressures from urban population spread around Townsville and Thuringowa have seen mangrove communities impacted by coastal development and subsequent removal of mangroves for aesthetic purposes (David Foster, pers. comm.).

Toxic substances in water, either through a catastrophic event such as an oil spill or through chronic exposure to toxicants like herbicides from run-off for example, can also threaten mangrove ecosystems (Duke and Burns, 1999; Duke and Bell, 2005). Invasion by the noxious weeds, rubber vine (*Cryptostegia grandiflora*) and pond apple (*Annona glabra*) has also been identified as a significant threat to mangrove communities in the Burdekin delta region with rubber vine being observed covering mangrove trees (Danaher, 1995; Tony Grice, pers. comm.). Natural disturbances such as cyclones or dramatic changes in salinity, sedimentation or inundation regime can also impact on mangrove growth and mortality (DPI&F, 2001).

Heavy boat wash near ports and marinas and high groundwater tables can result in erosion and slumping of riverbanks, which threatens mangroves in these areas (Norm Duke, pers. comm.).

Summary of major issues and knowledge gaps

The most recent surveys of mangrove habitat extent in the Burdekin region are over a decade old and used interpretation of species composition from aerial photography.

There is a need for a more up-to-date survey with ground truthing to get a more accurate current assessment and to compare with past data.

Although it appears that the total mangrove area may be stable within the Burdekin region it is unknown if there has been a change in community structure. There has been suggestions that the area covered by *Avicennia* is increasing while that of other mangroves decreases. This requires investigation as mangrove communities support much of the region's fisheries resources. Additionally, different species have different characteristics in terms of the habitat that they provide for associated animals. As each mangrove species has different tolerances to salinity, sediment type, oxygen levels and wave action any changes to these parameters (i.e. through development, freshwater extraction and run-off) have the potential to change the structure of mangrove communities in the longer term which may in turn impact on nutrient cycling and animal communities.

The presence and effects of toxicants, particularly herbicides, on aquatic plant communities within the Burdekin region requires examination.

The long term monitoring of natural resources, such as mangroves and seagrass meadows, would be valuable to compare sites with and without human influences and to build a long term picture of change in natural resources of the region.

Toxic substances in the water/sediment, reclamation activities, clearing and disturbance for coastal development of urban, industrial and military areas, invasion by the noxious weeds, natural disturbances such as cyclones, dramatic changes in salinity, sedimentation or inundation regime, heavy boat wash particularly near ports/marinas and erosion and slumping of riverbanks are important issues occurring in the region which impact on mangrove survival.

5.1.4 <u>Seagrass Meadows</u>

Description

Halophila ovalis seagrass meadow with sea cucumber and dugong feeding trail (Chris Roelfsema)

Seagrasses are flowering plants (angiosperms) that grow rooted in soft sediments of marine and estuarine environments. They form a productive, widespread and ecologically important component of nearshore environments. Seagrass areas are highly productive, meaning that they produce a lot of new plant material that supports large populations of animals. Seagrass meadows are primary food sources for dugongs while marine turtles, sea urchins and other invertebrates (e.g. amphipods, snails and commercially important prawns), some fish species (e.g. garfish) and birds (black swans, ducks and geese) also regularly feed on seagrass at some stages of their development. Studies have found the large seagrass meadows in Cleveland Bay and Upstart Bay support large populations of commercial penaeid prawns during juvenile life stages (Coles *et al*., 1992).

The majority of organic matter and nutrients that supports seagrass food webs originates as detritus. The decomposition of seagrass litter is undertaken by vast populations of bacteria and fungi, which in turn are eaten by the small organisms that form the base of the predatory food web. Intact seagrass meadows help to stabilise the sea floor, slow currents and reduce water turbulence, thereby facilitating the deposition of suspended sediments, limiting erosion and providing a safe haven for fauna (Turner *et al*., 2004).

Seagrass stems and leaves provide hard surfaces in areas of soft sediment that are colonised by numerous organisms, such as algae, bryozoans and hydroids. Seagrass meadows support a great variety of invertebrates such as sponges, anemones, bivalves, polychaete worms, seastars, sea cucumbers and crustaceans, including crabs, shrimps and yabbies. Cuttlefish, squid and a large number of fish species are predators in seagrass meadows. By providing protection and food for juvenile fish and crustaceans, seagrass meadows are vital for a variety of coastal fisheries. Some fish live in seagrass meadows for their entire life cycle, some species spend their juvenile stage here and others come and go with the tides (Turner *et al*., 2004).

Distribution

Seagrasses can be found growing on sheltered inter-tidal and sub-tidal soft substrates such as sand and mud. In the Burdekin Dry Tropics region seagrasses have been surveyed growing at depths from mean sea level to 20 metres in coastal inlets and bays sheltered from the southeast trade winds (Danaher, 1995). Seagrasses around Townsville Port however, occur at a maximum 4 m depth due to high turbidity (Lee Long *et al*., 1996).

The only region-wide description of coastal seagrasses for the Burdekin seems to be the broadscale survey of the entire Queensland coast by DPI&F in the mid 1980s (Coles *et al*., 1992). The scale of information collected and accuracy of maps from this survey are not sufficient to provide a baseline from which to monitor condition and trend of seagrasses in the region. It does however, give a good indication of where seagrasses are likely to be and the types of species represented in the region. The total area of seagrass is likely to be substantially higher than that indicated in the broadscale survey.

Since the broadscale surveys were performed there have been some detailed information acquired on seagrasses in specific locations within the Burdekin. The information and mapping collected for these specific areas can be used as a baseline to asses change and was generally collected as part of specific issues arising in those areas, for example:

- Upstart Bay – Rasheed and Thomas (1999) – surveys done to determine seagrass status within declared Dugong Protection Areas;
- Townsville area – Lee Long *et al*. (1998) – part of an assessment of Port Hinchinbrook; and
- Abbot Bay and Port of Abbot Point – Rasheed *et al*. (2005) – a recent survey to assess likely impacts/suitable design of port expansions.

Seagrass meadows in the Burdekin Dry Tropics region have a relatively high species richness, though some species are much more prevalent than others. *Halodule uninervis*, *Halodule pinifolia* and *Halophila decipiens* are found in all major bays of the region (see Table 3). Table 3 highlights the areas where seagrass species are found in the Burdekin Dry Tropics coastal region.

Table 3. Seagrass species found in the Burdekin Dry Tropics region.

Coastal Area	*Halodule uninervis*	*Halodule pinifolia*	*Halophila decipiens*	*Halophila ovalis*	*Halophila ovata*	*Halophila tricostata*	*Halophila spinulosa*	*Cymodocea serrulata*	*Cymodocea rotundata*	*Thalassia hemprichii*	*Zostera capricorni*	*Halophila* sp.
Halifax Bay	x	x	x	x			x			x		
Cleveland Bay	x	x	x	x	x		x	x				
Bowling Green Bay	x	x	x								x	
Upstart Bay	x	x	x	x		x	x	x			x	
Abbot Bay	x	x	x	x	x		x					x
Palm Island Group	x	x		x	x		x	x	x	x		
Magnetic Island	x	x	x	x	x	x	x	x	x			x

Source: Coles *et al*. (1992).

In Upstart Bay seagrass meadows tend to comprise either low biomass mixed *Halophila* and *Halodule* species meadows, high biomass *Zostera capricorni* meadows or *Halophila tricostata* meadows (Rasheed and Thomas, 1999). Seagrass meadows at Abbot Port meanwhile, tend to consist of light *Halodule uninervis* (narrow or wide) and/or light *Halophila spinulosa* with other species like *Halophila ovalis* also present (see Table 4).

Table 4. Seagrass community types and area in Port of Abbot Point, March 2005.

Seagrass Community Type	**Area ± R (ha)**
Light *Halodule uninervis* (narrow)	190.1 ± 50
Moderate *Zostera capricorni* with *Halodule uninervis* (narrow)	22.0 ± 6.0
Moderate *Halodule uninervis*	125.8 ± 41.0
Light *Halodule uninervis* (narrow) with *Halophila ovalis*	1784.9 ± 912.4
Light *Cymodocea serrulata*	43.6 ± 14.8
Light *Halophila spinulosa*	3464.8 ± 1838.6
Light *Halodule uninervis* (wide)/ *Halophila spinulosa*	3189.9 ± 2055.1
TOTAL ALL AREAS	**8821.1 ± 4917.9**

Source: Rasheed *et al*. (2005).

Broadscale surveys of seagrass areal cover indicate that Palm Island Group, Halifax Bay, Cape Pallarenda, Cleveland Bay and Bowling Green Bay seagrass meadows have only sparse (<10%) and moderately dense (10-50%) cover while Upstart Bay in particular, as well as Magnetic Island and Abbot Bay have dense seagrass cover (>50%) as well as sparse and moderate areas (Lee Long and Coles, 1995). Diver observations in Halifax Bay, Bowling Green Bay and Upstart Bay have also found very patchy but extensive distributions of very low-density seagrass (<1% cover). Biomass comparisons have been conducted for some areas in the north of the Burdekin Dry Tropics coastal region with the results shown in Table 5 and see Table 6 for seagrass biomass information for Upstart Bay. There is very little specific information on the seagrasses in the region outside Upstart Bay. For example Bowling Green Bay is poorly surveyed for seagrass (Rob Coles and Jane Mellors, pers. comm.). Recent seagrass surveys have been conducted around Abbot Point, which found the distribution of seagrass was contained within the inshore half of the port limits, mostly inshore of the Abbot Point wharf and covered an area of 8821.1 ± 4917.9 ha (Rasheed *et al*., 2005).

Comparison of surveys conducted in different seasons and years indicate that although seagrass meadows can vary widely in area and biomass (Rasheed and Thomas, 1999; see Table 6) the distribution and location of seagrass meadows has remained relatively constant in Upstart Bay since initial surveys in 1992 (Rob Coles and Jane Mellors, pers. comm.).

Table 5. Average above-ground seagrass biomass and seagrass areal extent for selected locations, October, 1996.

Location	**Mean Biomass (g DW.m^{-2})**	**Area (ha)**
Palm Island Group	5.7 ± 1.2	336 ± 60
Townsville and Magnetic Island	17.2 ± 1.9	4,404 ± 331
Cleveland Bay	17.9 ± 1.9	8,394 ± 323

Source: Lee Long *et al*. (1998).

Table 6. Mean above-ground biomass, number of seagrass meadows identified and area for each seagrass bed type in May 1999 and October 1999 in the Upstart Bay Dugong Protection Area.

Bed type* (seagrass community)	**May 1999**			**October 1999**		
	Mean biomass ±SE (range) (g DW m^{-2})	**Number of meadows**	**Area (ha)**	**mean biomass ±SE (range) (g DW m^{-2})**	**Number of meadows**	**Area (ha)**
High biomass *Zostera capricorni* dominated	32.4 ± 6.0 (20.4-39.4)	5	538.9	47.9 ±2.4 (43.0-53.9)	4	1,227.0
Low biomass *Halophila* and *Halodule*	9.6 ± 0.5 (9.6-10.7)	2	1,694.3	6.9 ± 3.4 (2.5-17.0)	4	1,266.5
Halodule uninervis (wide) dominated	15.3	1	13.7	4.5	1	0.6
Halophila decipiens dominated	Not present	-	-	1.2	1	4.5
Low biomass *Zostera capricorni* and *Halophila ovalis*	Not present	-	-	0.2	1	17.3
Halophila tricostata dominated	Not present	-	-	22.9 ± 5.8 (13.3-33.3)	3	471.2
Total meadows	22.1 ± 5.4	8	2,246.9	21.0 ± 5.3	14	2,987.1

Source: Rasheed and Thomas (1999). *No seagrass was found at the deepwater sites (> 10 m) surveyed in May or October 1999.

Maps 13-23 show the extensive area of seagrass habitat in the Burdekin Dry Tropics coastal region and sub-regions. Large seagrass meadows grow on the eastern side of Cleveland Bay, Upstart Bay, fringing Cape Pallerenda, western Magnetic Island and sections of the Palm Islands Group. Smaller seagrass meadows can be found in Bowling Green and Abbot Bays, near Kissing Point, The Strand and Pallarenda Beach, and some bays of Magnetic Island (Kettle *et al*., 2002; DPI&F, 2004a).

Condition and Trend

The Seagrass Watch program has observed a recovery of seagrass meadows in the Townsville-Thuringowa area since Cyclone Tessie in 2000. The population has now recovered to a stage where it oscillates seasonally (Jane Mellors, pers. comm.).

Seagrass surveys in Upstart Bay found relatively extensive inter-tidal seagrass meadows but only limited sub-tidal seagrass growth. This narrowing of depth range of sub-tidal seagrass can be linked to water turbidity. This is likely to have flow on effects for species reliant on seagrass ecosystems, as inter-tidal seagrass meadows are much less accessible to dugongs than sub-tidal meadows (Rasheed and Thomas, 1999).

Seagrass-Watch surveys of Shelly Beach sites have found that though the sites appear to be following a typical seasonal pattern (with higher abundance in late spring-summer than winter) seagrass abundance in summer 2002 was considerably diminished. The cause of this decline was inferred to be high water temperatures and other climatic factors (McKenzie, 2004). Species structure and canopy height have continued to follow a typical seasonal pattern. Interestingly, one of the monitored sites at Shelley Beach has an exceptionally high *Halodule uninervis* seedbank, which is gradually declining. Seagrass-Watch monitors sediment characteristics as well as seagrass and have found a higher mud content at one of the sites. In assessing the seagrass resources of this area Seagrass-Watch notes that there is a substantial amount of data missing for 2003/2004 making it difficult to accurately assess condition and trend (McKenzie, 2004).

As part of the recently developed Reef Water Quality Protection Plan Monitoring Program, seagrass meadows will be monitored at Magnetic Island (information provided by Deb Bass, GBRMPA).

The GBRMPA State of the GBR World Heritage Area report found that the greatest threat to seagrass was run-off and its effect on water quality (GBRMPA, 1998b). Flood events in dry catchments such as those in the Burdekin Dry Tropics can cause a decline in water quality through increases in sediment load and toxicants or a sharp decline in salinity. An increase in sediment loads reduces light penetration, which can stress and kill seagrass. Nutrient levels have a similar effect by stimulating phytoplankton and epiphyte growth, also reducing light penetration. Run-off containing toxicants, such as herbicides, may affect seagrass though the exact impacts that these toxicants have on seagrass meadows is a knowledge gap. Seagrasses have a limited range of salinity tolerances and can become stressed when salt levels decline.

The impact of river plumes from flood events can be exacerbated by human-induced changes to the catchment, such as removal of vegetation, increased imperviousness of the catchment and the use of toxicants. Physical disturbance such as dredging and trawling can also threaten seagrass by direct removal and fragmentation and also by resuspending benthic sediments, impacting on the water quality of nearby seagrass meadows.

Summary of major issues and knowledge gaps

Recent work on seagrass at Abbot Point is the first time seagrass and benthic communities had been surveyed at this scale within the Burdekin region. Seasonal comparisons should be conducted and this work could act as a baseline for future surveys.

Compared with other regions of Queensland there is a relative lack of information on the condition and trend of seagrasses in the Burdekin. There are likely to be more areas of deep-water seagrass in the region that at present have not really been examined in detail. Large scale/long term monitoring of seagrass throughout the region is lacking. The establishment of new ‘long-term’ monitoring sites would provide information which would be very useful in determining a baseline from which to assess change and status of seagrass resources.

Run-off and its effect on water quality (i.e. turbidity (sediment) and nutrients) and physical disturbance such as from dredging and trawling (resulting in direct removal, fragmentation, resuspension of benthic sediments) are important issues occurring in the region which impact on mangrove survival.

5.1.5 Macroalgal Beds

Description

Macroalgae are found attached to hard substrates, unlike mangroves and seagrasses. There are three major types of algae, the reds, greens and browns. Filamentous and colonial cyanobacteria are often also included in the algae group as they often look similar and perform a similar ecosystem role though technically, this is not correct. A variety of growth forms can be seen in macroalgae communities, including the familiar large fleshy structures (such as *Sargassum* spp), encrusting calcareous algae (such as *Halimeda* spp) and algae turfs (GBRMPA, 1998b).

Red macroalgae *Laurencia* sp.
(Chris Roelfsema)

Algae play a major role in marine food webs and calcareous algae can also be important for reef growth in some areas. Macroalgae communities are a universal component of coral reefs and exhibit high biodiversity in the Burdekin Dry Tropics region (Qld Herbarium, 2004). A suite of specialised photosynthetic pigments allows many species of algae to grow in lower light conditions than seagrass and hard corals. Most algae have the ability to rapidly take-up and utilise nutrients for growth, allowing them to out-compete both seagrass and corals under high nutrient circumstances.

Distribution

Literature describing macroalgae communities in the Burdekin Dry Tropics region is very limited. However, a recent study of benthic communities in Abbot Point Port involved surveying the area for algae. This survey found that although algae were widely distributed the percent cover of algae was typically below 5% and no dense areas were detected. The most common algae types were mat-forming red calcareous algae and the erect calcareous algae *Halimeda* (Rasheed *et al*., 2005). This survey suggests that macroalgal beds, in this part of the Burdekin region at least, tend to be very sparse with calcareous algae dominating the community (Rasheed *et al*., 2005).

Algal growth is widespread and abundant in the estuarine and marine components of the Burdekin Dry Tropics region, particularly on rocky shores, reefs and rocky sub-tidal substrates. Reef areas exhibit extensive and diverse macroalgae growth and *Halimeda* beds can be found in regions of very deep water.

Surveys of Port of Abbot Point (see Rasheed *et al*., 2005) have found moderate densities (>20%) of erect calcareous red algae interspersed with erect macroalgae, offshore of the mouth of Euri Creek. A large area of low-density (1-5%) erect calcareous red algae is present to west, alongside Abbot Point. To the north of Abbot Point, including around the area of the existing wharf lies a very low-density mixed erect macroalgae/erect calcareous algae community. A similar community can also be found in the west of Abbot Bay, offshore of Branch Creek. *Halimeda* (an erect calcareous green algae) beds can be found in some offshore areas to the east of Abbot Point and north of the old spoil ground of the Abbot Point Port.

The distribution of macroalgae within estuaries is changeable due to seasonal variability in light, temperature and salinity. In general, macroalgal cover on coral reefs in the region is increasing (see Section 5.1.10).

Condition and Trend

Natural and human induced disturbances can impact on macroalgae communities. As with other plant communities in the region, algae can be affected by natural events such as cyclones, storm surges, floods and other extreme weather events. Natural algae communities are also susceptible to human induced changes in water quality which can interrupt and prevent their re-establishment following disturbances, or may cause a shift from a very biodiverse community to the dominance of only a few species, sometimes to the extent of creating a bloom. A bloom event occurs when one species of algae flourishes, rapidly dominating all species around it by blocking light and taking nutrients.

High nutrient levels in some estuarine and inshore areas have encouraged algae to flourish in these areas. Blooms of macroalgae have been recorded in the Ross River estuary (George Lukacs, pers. comm.).

Algal communities are naturally controlled to some extent by herbivorous fish and invertebrate grazing. When this natural pressure is reduced through extensive netting, trawling or collection, shifts in the species composition of algal communities can occur and blooms may become more frequent. Conversely, where line fishing (which targets carnivorous fish) is intense, herbivorous fish population may increase as there are less predators, and they consume greater quantities of algae. Physical disturbance such as trawling can also threaten deepwater, inter-reef macroalgae especially when conducted repeatedly on an area (GBRMPA, 1998b).

Monitoring data are sparse for macroalgae, and the relationship between algal cover and coral abundance is not clear. Consequently, the management status and trends are uncertain (GBRMPA, 1998b).

As part of the recently developed Reef Water Quality Protection Plan Monitoring Program, inshore reefs will be monitored at Orpheus Island, Lady Elliot Reef, Pandora Reef, Havana Island, Middle Reef and Geoffrey Bay, while seagrass meadows will be monitored at Magnetic Island. As part of these activities data on macroalgae will also be collected (information provided by Deb Bass, GBRMPA).

Summary of major issues and knowledge gaps

There is a need for research to detail the distribution and species composition of algal communities in the region. The long term monitoring of algal blooms, weather and water quality may help to reveal the cause of these blooms.

The impact of trawling and fishing specific to the region on macroalgal beds (as well as on other benthic habitats) requires examination as the level of physical disturbance, especially when trawling is conducted repeatedly on an area, is unknown. Potential releases of exotically sources micro-algae from aquaculture. Loss of estuarine environments and connectivity with saline environments has led to blooms of freshwater filamentous algae in rivers and creeks – this greatly exacerbates WQ fluctuations as macro algae sloughs off various substrates and decomposes in the river bed.

Monitoring data are sparse for macroalgae, and the relationship between algal cover and coral abundance is not clear. Consequently, the management status and trends are uncertain.

High nutrient levels in some estuarine and inshore areas have encouraged algae to flourish and overfishing which can cause changes in grazing pressure are important issues occurring in the region which impact on algae.

5.1.6 <u>Inter-tidal Mudflats</u>

Description

Inter-tidal mudflats are formed by long-term deposition of fine silt and clay particles eroded from catchments. Gradual accumulation of particles in sheltered areas results in an almost flat, muddy shore extending some distance seaward from the high water level. Mudflats are common in the Burdekin Dry Tropics coastal region where large river flows (like the Burdekin River) carry large amounts of fine sediments and organic material to the coast.

Inter-tidal mudflats (David Scheltinga)

Mudflats have very poor drainage and remain saturated with water at low tide. Bacterial decomposition of organic material depletes oxygen from all but the top few centimetres of sediment, below which the mud is black and sulphur-smelling due to anaerobic bacteria. Few animals are able to survive in these anoxic conditions and as a result most of the fauna of inter-tidal mudflats is found in the top few centimetres of sediment where oxygen is available. In this layer, a diverse range of tiny, mostly microscopic, animals inhabits the spaces between the sediments. The surface of the mud is also occupied by high densities of microscopic single-celled and filamentous algae and cyanobacteria, which can help bind and stabilise the surface sediments (Turner *et al*., 2004).

Larger invertebrates that construct and live in burrows and tubes, such as ghost shrimps (yabbies), soldier crabs and tubeworms, are able to live much deeper in the mud as these burrows are more readily flushed with oxygen-rich seawater. The larger animals living in mudflats are dominated by polychaete worms, small crustaceans, and snails, which feed mostly on detritus, algae and micro-organisms in the sediment (Turner *et al*., 2004). Inter-tidal mudflats are important feeding areas for birds, especially waders. Fish move onto mudflats at high tide to feed, but mudflats are not as important as mangrove and seagrass habitats for nursery areas. People also use mudflats as a source of food and bait.

Distribution

Inter-tidal zones are present in different forms along the entire Burdekin Dry Tropics coastline including Cleveland Bay, Bowling Green Bay (Rob Coles and Jane Mellors, pers. comm.) and Upstart Bay which has wide inter-tidal flats in the south and east (Rasheed and Thomas, 1999). Smaller mudflats can be found at Rowes Bay and at the mouth of the Bohle River (Rob Coles and Jane Mellors, pers. comm.).

Condition and Trend

Little mapping or habitat status information is available for inter-tidal flats even though it is acknowledged that they are at risk of reclamation and infrastructure development and associated changes to hydrology, which can result in erosion. Dredging also alters stream and riverbank profiles, often resulting in erosion of inter-tidal zones. Erosion of the inter-tidal zones in the mouths of the rivers and creeks between Ross River and Cocoa Creek has been attributed to past dredging activities. For example, between 1968 and 1970, about 2,319,660 m^3 of sand was pumped from inter-tidal sandbanks to the inter-tidal areas of Ross River at its mouth (Pringle, 1989). From 1979-80 approximately 400,000 m^3 of sand was removed from the Ross River streambed and dumped in an 8 ha reclamation site east of Townsville Harbour’s Eastern Breakwater (Pringle, 1989). The combined impact of many such past dredging operations has resulted in dramatic changes to the inter-tidal areas around the Townsville Harbour in Port Cleveland and the Bowen Harbour (Pringle, 1989). Dredging continues in several areas in the Burdekin Dry Tropics region, including Abbot Point Harbour and Platypus Channel for Townsville Harbour.

Catastrophic weather events like cyclones can also damage inter-tidal flats, causing erosion with storm surges and bank slumping with high rainfall. Poor water quality caused by increases in nutrients, acid run-off from ASS, herbicides, pesticides, and heavy metals can degrade inter-tidal ecosystems. Increased turbidity (sediment levels in the water column) is also recognised as a form of poor water quality and can smother and degrade inter-tidal organisms. However, high turbidity can be beneficial for the inter-tidal area itself by providing supplementary sediments and can even allow for the growth of inter-tidal areas. The condition and trend of seagrass and mangrove covered inter-tidal mudflats are described in those sections, respectively.

Testing of inter-tidal sediments at Pallarenda and Upstart Bay has detected the presence of dioxin congeners (Müller *et al*., 1999). The source of dioxins could be industrial chemical reactions, combustion or pesticides in run-off (ANZECC, 2000).

Summary of major issues and knowledge gaps

Little mapping or habitat status information is available for inter-tidal flats even though it is acknowledged that they are at risk of reclamation and infrastructure development and associated changes to hydrology, which can result in erosion.

Changes to sediment particle size of inter-tidal flats, as a result of human activities such as increased catchment erosion or change hydrology, may result in the community structure of tidal flats changing depending on the ability of its in-fauna to maintain a burrow in the new sediment type. Increases in nutrients (and carbon) may result in an increase in sediment Biochemical Oxygen Demand (BOD) and an associated change to in-fauna which can deal with the lower oxygen environments.

There is a large gap in our knowledge relating to the quality of inter-tidal mud flat sediments throughout most of the region, especially in light of research which reported the presence of dioxin congeners in Pallarenda and Upstart Bay sediments. Need to draw a link here between changes in sediment structure (particle size) and the consequences for community structure.

Reclamation activities, infrastructure development, changes to hydrology, dredging (which may alter stream and riverbank profiles, often resulting in erosion of inter-tidal zones), catastrophic weather events like cyclones, poor water quality (increases in nutrients, acid sulphate soil run-off, herbicides, pesticides and heavy metals) are important issues occurring in the region which impact on inter-tidal ecosystems.

5.1.7 <u>Rocky Shores</u>

Description

Rocky shores are common and are associated with a number of estuaries, particularly drowned river valleys and embayments. Sub-tidal rocky shores are characteristically colonised by macroalgae (seaweeds) such as kelps. Unlike mangroves and seagrasses, these plants attach with simple holdfast structures, which are unsuitable for anchoring in soft sediments (Turner *et al*., 2004).

Rocky inter-tidal zone near Toolakea Beach (David Scheltinga)

Rocky shores provide habitat for diverse flora and fauna. Well-lit sub-tidal and lower inter-tidal areas are dominated by macroalgae, such as *Sargassum* spp. Where light levels are lower, such as beneath *Sargassum* canopies, or at greater depths, red algae are more common. Shaded areas are dominated by sessile animals such as sponges, bryozoans, anemones and hydroids, ascidians (sea squirts) and barnacles. Many motile invertebrates are also common including molluscs, echinoderms (seastars, sea urchins, sea cucumbers), various polychaete worms and crustaceans (Turner *et al*., 2004). The lower nutrient waters around islands favour the growth of the larger macroalgae that make a more permanent habitat compared with the ephemeral macroalgae of the coastal zone.

The abundance and variety of food, and physical diversity of rocky shores enable an abundant and diverse fish fauna to inhabit these areas including larger juveniles of many species. Inter-tidal rocky shores are a much less favourable habitat. Exposure at low tide to desiccation, high temperatures and bright sunlight makes survival difficult. Moving up the shore, algae become smaller with only encrusting species present at the top of the tide. Many animals have adapted to inhabit rocky shores, such as crabs, predatory and grazing snails, flattened grazing molluscs (limpets, chitons), oysters and barnacles. Various birds feed on exposed rocky shores at low tide. Isolated coral communities can be found on rocky shores in the Burdekin Dry Tropics region (Baldwin, 1986).

Distribution

Cleveland Bay contains granite promontories, rocky coasts and interspersed headlands, mostly granite with volcanic outcrops near West Point (GBRMPA, 1998b). Erosion prone area mapping indicates sections of soft and rocky substrate along the Burdekin Dry Tropics coastline. Cape Cleveland has several rocky shores including Cape Woora, Cape Ferguson and Red Rock Point. Kissing Point, an area north of Cape Pallarenda, Douglas Hill (north of Toomulla), much of Curlewis including Cape Upstart, areas between Abbot Point and Mt Luce, sections of Cape Edgecumbe and much of Gloucester Island are also rocky shores (EPA, 1984). Magnetic Island and the Palm Island Group also have rocky headlands (Rob Coles and Jane Mellors, pers. comm.).

Condition and Trend

The condition and trend of rocky shore ecosystems has been largely undocumented except for a few minor studies. An aerial photography comparison between 1959 and 1985 for Cleveland Bay found little change in the rocky shore areas (Pringle, 1989). However, such a survey method could not have detected ecosystem changes on rocky shores.

It is possible that some rocky areas are experiencing degradation due to heavy foot traffic, over-collection of specimens, removal of vegetative cover, decline in water quality resulting in nutrient enrichment or increased turbidity, changes in tidal and groundwater hydrology which can affect salinity levels, and pollution from sewage and stormwater overflow. Coastal development can also drastically alter rocky shores (GBRMPA, 1998b).

Summary of major issues and knowledge gaps

Although the rocky areas of coastline have been mapped at a broad scale only very limited mapping of the habitat at finer scales has occurred (this is also related to macroalgae knowledge gaps).

The condition and trend of rocky shore ecosystems has been largely undocumented except for a few minor studies. An aerial photography comparison between 1959 and 1985 for Cleveland Bay found little change in the total rocky shore area. However, these survey methods can not detect ecosystem changes on rocky shores. This is particularly important as rocky shore plants and animals can respond to changes in the environment and be good indicators of change.

Heavy foot traffic, coastal development, over-collection of specimens, removal of vegetative cover, decline in water quality (nutrient enrichment, increased turbidity), changes in tidal and groundwater hydrology, and pollution from sewage and stormwater overflow are important issues occurring in the region which impact on rocky shore ecosystems.

5.1.8 <u>Beaches, Sandy Shoals and Dunes</u>

Toolakea Beach (David Scheltinga)

Description

Dunes are generally characterised by *Spinifex* grasses, pig face (Aizoaceae), beach bean (Leguminosae) and *Casuarina* trees growing on a relatively infertile sandy substrate. Survival is hard in these areas due to the high amount of wind and salt spray, sand remobilisation and the low water holding capacity of the sandy soils. Dunes often form important habitat for sea turtle and wader/shorebird nesting sites. They act as barriers to erosive on-shore wind and wave action and their vegetation helps to stabilise windblown sand. However, due to these high winds and loose sandy soils, dunes are vulnerable to erosion, particularly if vegetation is removed. Physical disturbance and construction on and around dunes will have serious impacts on the success on turtle/bird nesting (Turner *et al*., 2004).

Sandy shoals and beaches are characteristically found near estuary mouths where coastal wave energy is high and there is a sufficient supply of sandy sediment from terrestrial or marine sources. Because the size of sediment particles is related to the speed of water movement over the bottom, sandy shoals and beaches are much more dynamic habitats than muddy bottom areas (Turner *et al*., 2004).

Within sandy areas, particle size varies, affecting the tiny animals and plants that live amongst the sand. Larger particles are associated with larger spaces between adjacent particles, which provide habitat for many small species. Coarse sediments are also better flushed and oxygenated and animals are able to live deeper in the sediments. Sandy shoals and beaches tend to contain fewer (and different) invertebrates than mudflats. They are inhabited by microscopic plants that live on or near the surface of the sediment or migrate between the water column and the sand. Bacteria and fungi actively decompose organic material within the sand (Turner *et al*., 2004).

A diverse range of tiny, streamlined animals live between the sand particles. Larger invertebrates burrow into the sand, predominantly molluscs, polychaete worms and crustaceans. These animals are adapted to an ever-changing environment and are able to reburrow rapidly following disturbance, e.g. during storms. Extensive inter-tidal and shallow sub-tidal sandy shoals are also used by a variety of fishes such as flathead and sand whiting (Turner *et al*., 2004).

Vegetation types present on beaches and dunes in the Burdekin Dry Tropics coastal region include dune vine thickets, *Corymbia tessellaris* and *Melaleuca dealbata* woodlands and grasslands. These areas play an important role as habitat for approximately eight mammal species (including the vulnerable coastal sheath-tail bat (*Taphozous australis*)), 22 reptile and amphibian species, and approximately 32 bird species (including the rare square tailed kite (*Lophoictinia isura*)) (Townsville City Council, date unspecified).

Distribution

Beaches, sandy shoals and dunes occur throughout the Burdekin Dry Tropics coastal region. Dune vine thicket forest/woodland can be found on Cape Cleveland, Nelly Bay (Magnetic Island), Pallarenda, South Bank Coast and associated wetlands, and Townsville Town Common. Dune/swale *Corymbia tessellaris*/*Melaleuca dealbata* forest/woodland is present at Bush Garden near Ross River Creek, Cape Cleveland including Cungulla – Bowling Green Bay Coastal Complex, Castle Hill, Magnetic Island, Serpentine Lagoon, South Bank Coast and associated wetlands, Stuart Creek and Cromarty Wetlands at Cape Cleveland (Townsville City Council, date unspecified).

Foredune woodland/grassland/vineland is also present at Cape Cleveland, Nelly Bay, Magnetic Island, Pallarenda, South Bank (South Bank Coast and associated wetlands) and Toomulla (in Thuringowa Shire) (Townsville City Council, date unspecified).

Condition and Trend

Surveys of foreshores indicate several erosion prone areas in the region including Abbot Bay, southern Bowling Green Bay, Cape Bowling Green, western Upstart Bay, parts of Bushland Beach, beaches north of Rollingstone Creek and around Toomulla (EPA, 1984), the causes of which are multifaceted. For example, navigational dredging of the Platypus Channel has impeded the littoral sand drift process by causing sand to deposit in the channel; this has prevented the sand drift supplementing The Strand beach in Townsville. Another obstacle to replenishment of sand on The Strand beach by littoral sand drift was the construction of the breakwater marina. Dams and weirs on rivers in the region further exacerbated the problem by reducing natural sediment flow from these areas to the beach.

The recreational use of quad bikes on beaches and dunes in the Burdekin Dry Tropics coastal region, particularly on Alva Beach on Cape Bowling Green is damaging dunal vegetation, destabilising dunes and interfering with wildlife (Hansen, 2004). Erosion of the dunes at Alva Beach is also attributed to the movement of the Kalmia Creek channel, which may be a natural cyclic process, or due to coastal development and the damming of the Burdekin River (Raphael Wust as cited by Vern Veitch, pers. comm.).

Recreational use of quad bikes on Alva Beach (David Scheltinga)

Construction of urban developments and other infrastructure on the beach's dunes diminishes their role as a sand reservoir, and therefore restricts the ability of the beach to recover from extreme weather events. As cyclones are a relatively common occurrence in the area, dune development is particularly concerning. Beaches around Townsville were decimated by a recent cyclone, but after extensive engineering redevelopment, The Strand foreshore and the beaches at Pallarenda have been "rejuvenated", and the area has recently been awarded the cleanest beach award (Wilkie, 2000). However, while these beaches now look good, a poor understanding of the hydrodynamic forces that shift sediments within Cleveland bay has meant that the engineering activities have affected sand movement to and from The Strand which impacts on adjacent habitats.

Thuringowa City Council has adopted management plans for two of its northern beaches; Toomulla Beach and Balgal Beach. The plan focuses on dune protection through vehicle-access restrictions, revegetation and the establishment of defined walkways (Hansen, 2004).

Summary of major issues and knowledge gaps

Erosion prone foreshore information for the region is very old, needs to be updated. This may have resulted in development being permitted within erosion prone areas.

Dredging and breakwater construction, recreational use (which is damaging dunal vegetation, destabilising dunes and interfering with wildlife), construction of urban developments and other infrastructure on the beach's dunes and cyclones/storm surge/sea level rise are important issues occurring in the region which impact on beach and dune ecosystems.

Access to beaches in the region needs to be assessed as unregulated access to beaches in many areas has resulted in the compaction of sand and the loss of fauna which then has flow-on effects on feeding birds.

The building of structures to prevent erosion are now known to often exacerbate or transfer problems elsewhere. Therefore, good planning is needed for future development in the Burdekin Dry Tropics to reduce any impacts on these fragile environments.

5.1.9 Sub-tidal Sand/Mud Substrates

Description

Unvegetated, or 'bare' sand or mud substrates occupy the greatest sub-tidal area in most Burdekin Dry Tropics estuaries, but these areas are by no means uniform. Variation in the type of sediment (e.g. from marine sand to mud), salinity, water depth, water movement and position in relation to other habitat types all strongly influence the biota of these areas.

Sub-tidal sand substrate (Chris Roelfsema)

Sub-tidal sandy bottoms occur in more exposed areas, particularly in larger embayments. Muddy basins are associated with the sheltered conditions of many estuaries. Where light penetration is sufficient and the sediments sufficiently stable, a range of microscopic algae occupy the sediment surface. Many of these algae migrate up and down within the sediments to photosynthesise during the day and escape predation at night.

Scavengers and organisms that feed on surface deposits dominate in unvegetated areas. Common invertebrates living in unvegetated muddy areas include prawns, bivalve molluscs, polychaete worms and small crustaceans. Prawns are opportunistic feeders that ingest bacteria, algae and tiny animal species during their juvenile stages. As they mature, small molluscs, crustaceans and polychaete worms also form part of their diet. Prawns and other invertebrates are preyed upon by estuarine fish that live and feed in unvegetated areas. Juvenile fish also inhabit these areas, and may escape predation through schooling behaviour and camouflage, or because turbid conditions obscure them from predators.

A different range of invertebrates are found in sandy areas. These include hydroids, seapens, bryozoans, sponges and molluscs such as scallops, as well as polychaetes and crustaceans. Fish such as flounder, flathead, whiting and sharks are also found on sandy bottoms.

Sub-tidal substrates in Cleveland Bay vary from calcium carbonate rich sediments in the western bay influenced by Middle Reef and the reefal fringes of Magnetic Island to muddy sand in the centre of the Bay. Sediment in the centre of the Bay is largely derived from land-based sources imported through creeks and rivers (Anderson and Roche, 2002).

Distribution

Soft bottom sediments occupy approximately 85% of the Cleveland Bay area, with seagrass covering another 10% of the area (Kettle *et al*., 2002).

Condition and Trend

Data on the condition and trends of sub-tidal areas is sparse. Threats to these areas include dredging, natural impacts from cyclones and declines in water quality. Sediment testing for pollutants can provide some indication of condition.

Dieldrin has been detected in sediments collected from Halifax Bay (0.05 $\mu g\ kg^{-1}$). DDT and its metabolites (DDE) were detected in low concentrations at the mouth of the Burdekin River and in Halifax Bay (Haynes *et al*., 2000a). No organochlorine pesticides were detected in sub-tidal samples of Cleveland Bay (Haynes *et al*., 2000a), however, some inter-tidal sediment samples from Cape Pallarenda contained a range of dioxin congeners (Müller *et al*., 1999).

“None of Queensland’s major east coast rivers or estuaries are significantly contaminated by heavy metals from industry. In urbanised areas, treated sewage discharges may contribute small loads of metals, but the Queensland data indicate that urban stormwater is by far the most significant source of metals in urban areas” (Moss and Costanzo, 1998, pg. 2). The concentrations of cadmium, chromium, copper, lead, nickel and zinc in the sediments of the Bohle River are at levels at which there is a very low probability of the metals affecting biota (see Moss and Costanzo, 1998).

The maximum concentrations of copper, lead, mercury and zinc recorded in the sediments of Althaus Creek and the Bohle River were below the ANZECC (2000) interim sediment quality guideline (ISQG) (low) trigger values. The 90th percentile concentration of nickel in the sediment of the Bohle River was also below ISQG (low) trigger values, however, the maximum levels recorded for both waterways was above ISQG (high) trigger values. Cadmium concentrations in the sediment of both Althaus Creek and the Bohle River were found to be above ISQG (low) trigger values but below or equal to ISQG (high) trigger values. The maximum concentration of chromium in Althaus Creek was below ISQG (low) trigger values, as was the 90th percentile concentration found in the Bohle River. However, the maximum concentration of chromium found in sediments of the Bohle River was above the ISQG (low) trigger value but below ISQG (high) trigger value (see Table 7).

Concentrations above the ANZECC ISQG (high) trigger values have a high probability of having a toxic affect. Values between low and high trigger values have an intermediate probability of having toxic effects on benthic biota.

Table 7. Metals concentrations recorded in the sediments of waterways within the Burdekin Dry Tropics coastal region. Metals recorded as actual metal (mg/kg).

Metal	**Bohle River**[†] 90th percentile (max.)	**Althaus Creek**[†] 90th percentile (max.)	**Cleveland Bay*** average ± S.D. (max.)	**Cocoa Creek*** average ± S.D. (max.)	**Sandfly Creek*** average ± S.D. (max.)	**Ross Creek*** average ± S.D. (max.)	**Ross River*** average ± S.D. (max.)	**ANZECC ISQG**[‡] **trigger value** low : high
Cadmium	<3 (10)	<10 (10)	21±16 (68)	4±6 (19)	18±22 (61)	68±189 (838)	23±29 (143)	1.5 : 10
Chromium	50 (200)	40 (50)	-	-	-	-	-	80 : 370
Cobalt	20 (20)	-	-	-	-	-	-	-
Copper	20 (62)	18 (26)	6±4 (21)	9±4 (22)	18±7 (25)	39±63 (366)	16±4 (25)	65 : 270
Lead	20 (31)	20 (20)	10±4 (19)	12±4 (23)	15±3 (18)	49±67 (325)	18±4 (32)	50 : 220
Mercury	<0.1 (0.1)	<0.1 (<0.1)	-	-	-	-	-	0.15 : 1
Nickel	16 (310)	40 (90)	9±5 (24)	13±5 (29)	15±4 (19)	17±5 (27)	14±3 (22)	21 : 52
Zinc	76 (194)	68 (74)	26±14 (67)	38±10 (78)	48±14 (65)	168±273 (1532)	58±15 (94)	200 : 410

Source: [‡]ANZECC (2000); [†]Semple and Williams (1998); *Anderson and Roche (2002).

Analysis of Townsville Harbour (in Cleveland Bay) sediments found a general enrichment of cadmium, copper, zinc (Gibbs, 1993) and a nickel concentration that exceeded ANZECC ISQG (low) trigger values (Reichelt and Jones, 1994).

Average concentrations of nickel, lead, zinc and copper recorded in the sediments of Cleveland Bay, Cocoa Creek, Sandfly Creek, Ross Creek and Ross River were found to below ANZECC ISQG (low) trigger values. However, the maximum concentration of nickel found in the sediments of Cleveland Bay, Cocoa Creek, Ross

Creek and Ross were above ANZECC ISQG (low) trigger values but below ANZECC ISQG (high) trigger values. Maximum concentrations of copper, lead and zinc found in the sediments of Ross Creek were above ANZECC ISQG (high) trigger values. Enrichment of cadmium in the sediments was found in Cleveland Bay, Cocoa Creek, Sandfly Creek, Ross Creek and Ross River (Anderson and Roche, 2002).

Summary of major issues and knowledge gaps

The distribution of sub-tidal sand and mud areas has not been extensively surveyed except unintentionally through seagrass mapping. As a consequence accurate data on areal extent, and probably more importantly, data on the condition and trends of sub-tidal areas is sparse. Their health has only really been assessed through sediment toxicant testing, not extensively through biological indicators.
Dredging, natural impacts from cyclones and declines in water quality are important issues occurring in the region which impact on sub-tidal sand and mud ecosystems.

Baseline data on contaminants in sediments is very patchy and usually related to specific locations because of prescribed EPA monitoring which is usually associated with industry. Linking this data together with new sites to watch for the spread of contaminants into new areas would be an excellent tool – particularly given the potential changes to hydrology (with related sediment movement) as a result of modification to beaches and harbours.

5.1.10 Reefs

Description

The corals of the Burdekin Dry Tropics coastal region form part of the impressive Great Barrier Reef, an area of incredible natural beauty and diversity located in the Indo-Pacific. Corals are tropical organisms and are intolerant of freshwater, sensitive to turbidity, sedimentation and water temperature, and require a hard substrate to colonise. Most estuaries in the Burdekin Dry Tropics region present extremely unfavourable conditions for coral establishment and growth due to their high sediment loads and low salinities. Nearshore coral reefs along much of the Burdekin Dry Tropics region are also subjected to ‘estuarine’ conditions when rivers are in flood and carry freshwater, nutrients and sediments some distance offshore.

Reef with soft and hard coral, marine invertebrates, algae and fish (CRC Achives)

Coral reefs support unique and diverse fish and invertebrate communities. There are two groupings of corals. Hard corals consist of an animal component (the cnidarian host) and a microscopic algal component (a zooxanthellae) that live together in a mutually beneficial partnership on a skeleton of calcium carbonate that forms the reef’s structure. Soft corals consist solely of animal polyps connected together by fleshy tissue, only occasionally being associated with an algae partner (ReefED, 2004).

Distribution

The distribution of coral reefs in the Burdekin Dry Tropics coastal region can be seen in Maps 29 and 30.

Numerous reefs occur within the tropical water off the Burdekin Dry Tropics coast, being associated with islands (e.g. Fantome Island Reef) or in nearshore waters (e.g. Pandora Reef off Townsville and Stanley Reef off Cape Upstart).

Some reefs in the region have features notable in addition to their general distribution. Firstly there is an area of high soft coral abundance just north-east of Townsville with >60% cover and another ‘hot spot’ of soft coral abundance near Cape Upstart. Magnetic Island’s offshore reef community is notable for containing the Great Barrier Reef’s only population of the rare soft coral *Nephthyigorgia* sp. (Fabricius and De’ath, 2002) and, on the island’s leeward side grows one of the largest colonies of *Montipora digitata* recorded in the Great Barrier Reef.

Condition and Trend

Havannah Island Reef consists of a gentle reef slope with a benthic community dominated by coralline/turf algae with populations of macro-algae and soft coral. There are low levels of hard coral cover on Havannah Island Reef’s first flank which were mainly composed of *Porites* species. Massive corals are dominant on this reef but other forms such as tabulate corals were also present in surveys (AIMS, 2003a). Although no crown-of-thorns seastars were observed on the first flank of Havannah Island Reef, coral bleaching was present on a few individual colonies (AIMS, 2003a). Fish abundance on the first flank of Havannah Island Reef is moderate and is dominated by parrot fish and fusiliers (AIMS, 2003a).

Pandora Reef, off Townsville is an inner-shelf planar reef with an area of approximately 0.6 km^2 (AIMS, 2004d). The hard coral cover of Pandora Reef increased between 1993 and 1997 by approximately 11% to a maximum cover of 58% in 1997. However, moderate bleaching affected all abundant hard and soft coral families during 1998 (AIMS, 2004a). During this time the Townsville region experienced a major flood event and surveys a month after the flood found 80% of the corals had been bleached (Devantier, Fabricius unpublished). Coral cover recovered to 46% in 1999 with species in the Acroporidae family being most severely affected. Hard coral cover has since declined slightly, possibly because of the impact of Cyclone Tessie in 2000 (AIMS, 2004a). The reef monitoring program has noted a continual decline in soft corals, especially following Cyclone Tessie. Macroalgae cover of the reef is increasing (AIMS, 2004a). The Pandora Reef fish community has experienced a considerable decline in *Pomacentrus* species, probably related to the marked decrease in hard coral cover, which is their primary food source (AIMS, 2004b).

The Fantome Island Reef back is generally shallow, dropping off to a gently sloping reef base composed of sand, reef framework and algae. The benthic community consists of coralline and turf algae, and soft and hard corals. Hard coral cover on the reef back is low, composed mainly of *Porites* species with a massive life-form, though other digitate and branching corals are also present (AIMS, 2002a). This community structure is similar for the Fantome Island first flank. However, the first flank also has a strong presence of bottle-brush corals (AIMS, 2002b). The Fantome Island Reef front is also similar to the back, though it has lower levels of hard coral cover and other forms such as foliose and sub-massive corals are comparatively abundant (AIMS, 2002c).

Fantome Island Reef's second flank is similar to the front (AIMS, 2002d). Coral bleaching and crown-of-thorns seastar (COTS) are not observed on surveys of Fantome Island Reef (AIMS, 2002a,b,c,d). However, white band disease and shutdown reaction were present on some of the hard corals of the reef front (AIMS, 2002c). Fish abundance on the back and second flank of Fantome Island Reef is low and consists mainly of damselfish, parrotfish, fusiliers and pelagic predators (AIMS, 2002a). Fish abundance increases on the first flank and front of Fantome Island Reef are moderate and contain conspicuous groups of reef fishes including parrotfish and damselfish on the first flank (AIMS, 2002b) and sweetlip, fusiliers, damselfish, parrotfish and surgeonfish on the front reef (AIMS, 2002c).

Stanley Reef is situated off Cape Upstart and its back reef's benthic community are dominated by sand, coralline/turf algae, rubble, hard coral and soft coral. Hard coral cover on the reef back was low with no one coral genus dominant. Branching life-forms are dominant in the Stanley Reef back but massive and tabulate corals were also present in decreasing order of abundance (AIMS, 2001a). Stanley Reef's front and first flank are dominated by hard coral, but coralline/turf algae, soft coral, sand and macroalgae are also common (AIMS, 2001b,c). Unlike the reef back, hard coral cover on the reef first flank was high and composed mainly of *Acropora* species. The most abundant coral life-form is tabulate, though other forms such as branching, bottle-brush and massive corals are also present in decreasing order of abundance (AIMS, 2001b,c).

Stanley Reef's second flank was covered with coralline/turf algae and some hard and soft corals. Hard coral cover on the reef second flank is moderate and composed primarily of *Acropora* species. The dominant coral life-form is tabulate, but other forms such as digitate and encrusting corals are also present in decreasing order of abundance (AIMS, 2001d). Although some COTS were found on the Stanley Reef back, no coral bleaching was observed. White syndromes like white band disease and shutdown reaction were present on hard corals on the back and second flank of Stanley Reef and were common on the front and first flank (AIMS, 2001a). Stanley Reef has high fish abundance with sweetlip, coral trout, parrotfish, surgeonfish, sharks, baitfish and pelagic predators present (AIMS, 2001b,c,d).

There was widespread bleaching of both hard and soft corals on Middle Reef in 1998 and a gradual decline of hard coral cover has been observed since 1999, with a significant decline in soft corals since 2002 (AIMS, 2004c). The dominant soft coral family, Alcyoniidae, has declined from a maximum cover of 12.5% in 1998 to 1% in 2003. Extensive coral bleaching, was observed around Magnetic Island in 2002, and is thought to be the cause of coral decline at Middle Reef (AIMS, 2004c).

Coral Bleaching involves the rejection of the algal component of the coral from the coral tissue, leaving it colourless. Although recovery of the coral is possible, it can only occur under stress-free conditions. The cause of coral bleaching is thought to be related to an increase in water temperature and can be exacerbated by high light intensity, low salinity and pollutants (GBRMPA, 2004d,e). Coral bleaching status reports show that although elevated sea temperatures of the 2003/2004 summer caused patchy bleaching at numerous locations on the Great Barrier Reef, there was significantly less bleaching than the previous summer (GBRMPA, 2004d).

Long-term monitoring of hard coral coverage in the Burdekin Dry Tropics coastal region shows stable coral coverage for the inshore and offshore reefs from 1993 to 2003, with only mid-shelf reefs exhibiting a decline between 1996-97 (EPA, 2003a). Coral cover around Townsville however, has declined in both inshore and mid-shelf areas from 1994 to 2000 (EPA, 2003a).

As part of the recently developed Reef Water Quality Protection Plan Monitoring Program, inshore reefs will be monitored at Orpheus Island, Lady Elliot Reef, Pandora Reef, Havana Island, Middle Reef and Geoffrey Bay (information provided by Deb Bass, GBRMPA).

Another major threat to coral reefs is the crown-of-thorns seastars (COTS), which is a native seastar that preys on coral and can reach very high population numbers, creating an ‘outbreak’. The reason for COTS outbreaks is still being explored but it is understood to be a natural phenomenon that has increased in frequency due to nutrient enrichment of reef waters allowing increased larval survivorship (Hoey and Chin, 2004). COTS decimated coral cover in the Townsville region in the 1980s (Osborne *et al*., 1995) and have again increased dramatically in the Townsville region from 1998 to 2000, reaching one of the two highest levels in Queensland for this period. Conversely, Cape Upstart has shown a consistently low population of these seastars for the last 10 years (EPA, 2003a), highlighting the variation in COTS population trends in the region.

Great Barrier Reef corals, including those in the Burdekin Dry Tropics region experience a variety of threats both natural and man-made. Cyclones are one of the most common natural impacts on coral reefs with Townsville reefs in particular being hit hard and frequently with a cyclone coming within 100 km of the area 11 times over a 28 year period. The high rainfall associated with cyclones and summer wet seasons can result in rivers flooding and discharging large quantities of turbid freshwater into the coastal zone, creating a sediment-laden flood plume which can impact nearshore and even mid-shelf reefs (GBRMPA, 2004).

Coral adjacent to the Burdekin Dry Tropics region, especially those in the nearshore zone are likely to experience very high sediment loads during floods due to the typically dry nature of the catchment. Such an occurrence is a natural feature of the region. However, there is persuasive evidence to suggest that the sediment and pollutant load of flood plumes have increased fourfold since European settlement in the area (GBRMPA, 1998b). This increase in pollutant and sediment laden terrestrial run-off can be attributed to several factors including the removal of native vegetation cover and is considered by many to be the greatest potential threat to the survival of the Great Barrier Reef and nearshore coral communities.

Along with sediment plumes, heavy rainfall also washes dissolved and particulate nutrients from heavily modified Burdekin Dry Tropics catchments into the adjacent Great Barrier Reef lagoon. High nutrient levels stress corals because they are adapted to low nutrient conditions. If nutrient levels in the water column are high for an extended period of time a community shift from corals to organisms that can survive high nutrient conditions better than corals, like macroalgae and sponges, can result (GBRMPA, 1998b). The increase in nutrients and sediment in the water column may at least partially explain the decline in coral cover in the inshore and mid-shelf reefs.

Physical disturbance can also be a significant threat to corals in the Burdekin Dry Tropics region and is primarily associated with tourism, boat anchorage in heavily visited areas, damage by divers and reef walkers, construction and operation of tourist facilities and ship groundings (GBRMPA, 1998b). Boat traffic can also damage reefs through minor and major oil leaks. Dredging for boat navigation can cause the re-suspension of benthic sediment that potentially impacts corals hundreds of metres away while the dumping of dredge spoil on or near reefs (such as Middle Reef off Townsville) is likely to have impacted corals in the past. Coral diseases, such as white band disease, have only recently been identified in the area and have increased dramatically following the high water temperatures in 1998. Monitoring studies are currently underway to assess their distribution and potential threat to corals (Baird, 1999).

The status and trend of soft coral communities in the Burdekin Dry Tropics coastal region (like many areas in the Great Barrier Reef) is largely unknown.

Summary of major issues and knowledge gaps

There has been widespread bleaching of both hard and soft corals on several reefs in the region with a gradual decline of hard coral cover and a significant decline in soft corals during recent times. The cause of coral bleaching is thought to be related to an increase in water temperature and can be exacerbated by high light intensity, low salinity and pollutants, however, most aspects of coral bleaching are not well understood.

As part of the recently developed Reef Water Quality Protection Plan Monitoring Program, inshore reefs will be monitored at Orpheus Island, Lady Elliot Reef, Pandora Reef, Havana Island, Middle Reef and Geoffrey Bay.

The reasons behind COTS outbreaks in the region are still being explored.

Coral diseases, such as white band disease, have only recently been identified in the area and are currently being monitored to assess their distribution and potential threat.

The impact of climate change (e.g. increased temperature, more severe weather patterns) on reef ecosystems is uncertain and requires study.

The status and trend of soft coral communities in the Burdekin Dry Tropics coastal region is largely unknown.

Crown-of-thorn seastars, sea temperature change, bleaching, turbidity and sediment settling, dredging, low salinity, nutrient levels, toxicants and physical disturbance (primarily associated with tourism, boat anchorage in heavily visited areas, damage by divers and reef walkers, construction and operation of tourist facilities, ship groundings and natural events such as cyclones) are important issues occurring in the region which impact on reef ecosystems.

5.1.11 Islands

Description

Magnetic Island (David Scheltinga)

The Burdekin Dry Tropics region encompasses several continental islands such as Magnetic Island (north of Townsville) and the Palm Island Group (north-west of Townsville). Magnetic Island has a population of approximately 2,500 residents as well as a variable number of tourists. Although the Palm Island Group is composed of 16 separate islands, including Great Palm, Orpheus, Pelorus, Fantome and Curacoa, only two of these islands are permanently inhabited with a combined population of approximately 2,305 residents (as of June 2001). About 93% of the total population are of Aboriginal or Torres Strait Islander origin, many of which identify as Malanbarra and Bwgcolman people, the Traditional Owners of the area (Queensland Government, 2003).

Both Magnetic Island and the Palm Island Group are relatively mountainous and rugged. These islands form part of the continental shelf and during periods of lower sea level, may have been contiguous with the mainland. Palm Island Group is noted as being geomorphologically unique. Landforms present on the granitic Magnetic Island include saddles and perched valleys, captured watercourses, boulder screes and talus slopes (Magnetic Island Community Development Association Inc., 2004). Alluvial and coastal aeolian landscapes are also present as well as tidal flats, reef flats, beaches and wetlands.

These islands also harbour an impressive array of habitat diversity both terrestrial and marine. The Palm Island Group marine environments vary dramatically, with clear water of the Palm Passage on the eastern side of the islands and sheltered and muddy coastal habitats on the protected, western side, with channels of fast currents between the islands (GBRMPA, 2004f). Within this range of marine environments grows an impressive array of fringing reefs, where “more [coral] species have been recorded than anywhere else in the world” (Veron, 1986, cited in Hopley *et al*., 1990).

These reefs have developed on Permo-Carboniferous granite and are sufficiently close to the mainland to be impacted by catchment run-off. Islands of the Palms Island Group generally have a small fringing reef on the windward side and a more extensive reef flat on the leeward side. The extensive reef flat on the leeward side of Fantome Island is over 600 m wide and 5 km long (Johnson, 1985). Outcrops of the rare brain star coral (*Goniastrea* sp.) can be found on these reefs, along with sponges, algae and seagrasses. Habitats present on the islands include beaches, eucalypt and other species woodlands, grasslands, mangroves and rocky headlands.

Magnetic Island also has distinctive and ecologically valuable coral features including the Great Barrier Reef’s only population of the rare soft coral *Nephthyigorgia* sp. (Fabricius and De’ath, 2002) and, on the island’s leeward side grows one of the largest colonies of *Montipora digitata* recorded in the Great Barrier Reef. Magnetic Island also contains 22 terrestrial species of plants and animals listed as endangered, vulnerable or rare under the Queensland *Nature Conservation Act 1992*.

The ecosystems found on Magnetic Island most closely resemble those of the mainland, especially Cape Cleveland, Cape Upstart and Mount Elliot. Five hundred and seventy-eight native plant species have been recorded on the island, as well as 146 native bird species, 16 native mammal species, 34 native reptile species and 13 native amphibian species (Magnetic Island Community Development Association, 2004). Several species found on the island are considered disjunct from their normal range or at the extremity of their range, such as, the rare ‘common’ death adder (*Acanthophis antarcticus*). There are approximately ten endemic species of plants and one species of endemic lizard (Sadliers dwarf skink (*Menetia sadlieri*)). Lowland vegetation types that occur on the island include saltmarsh, mangrove forest, *Melaleuca* woodlands and *Elaeocharis* sedgelands. Magnetic Island has also been recorded as having the third greatest number of known rare vascular plant taxa (11 species) of the Great Barrier Reef islands (Batianoff and Dillewaard, 1995). Approximately 5,200 ha of Magnetic Island is listed as national park. Magnetic Island also contains a variety of culturally and historically important features such as shell middens, stone artefacts, rock paintings and fish traps (Magnetic Island Community Development Association, 2004).

Orpheus Island, part of the Palm Island Group, is surrounded by fringing reefs, with a range of mid-shelf reefs located nearby which are separated by sand and mud substrates. Queensland Parks and Wildlife Service manages most of the island, with the exception of the small Orpheus Island Resort (30 rooms) located on the western side of the island at Hazard Bay. A research station is located at Pioneer Bay, which contains an inter-tidal reef flat supporting a diverse fauna. The Island’s shoreline includes *Rhizophora*-dominated mangrove forests, sandy beaches backed by dune vegetation and rocky shores. The island is dominated by eucalypt forest interspersed with patches of other forest types and grassland (AuseMade, 2004).

Surveys by IPSTCG (Indo-Pacific Sea Turtle Conservation Group) have found turtle tracks and evidence of possible nesting on Rattlesnake Island (Hazel, 2003).

Distribution

There are 20 major islands located within State waters (i.e. within the 3 nautical mile limit) off the Burdekin Dry Tropics coast (Table 8; Map 1). The main inhabited islands in the region include Magnetic Island (located 8 km off the coast of Townsville) and the Palm Island Group (20 km east of Ingham, ~80 km north-west of Townsville), both in the Coral Sea.

Condition and Trend

Of the 26 major islands within the study area, eight are under a Deed of Grant in Trust under Palm Island Aboriginal Council, eight are wholly or partly within national parks, six are controlled by the Department of Defence while the remaining four have a variety of other land tenures. A management plan is in place for the Holbourne Island National Park and Orpheus Island National Park. Magnetic Island National Park and Gloucester Island National Park do not have management plans (Table 8).

The geology and vegetation of many of these islands has not been mapped and they lack fauna records. Of the islands that have been mapped and/or fauna recorded, several contain ‘of concern’ regional ecosystems and/or endangered, rare or vulnerable animal species.

Although most of the islands are small, remote and under some form of protection, some of the islands are not entirely within protected areas and are used for grazing (e.g. Rita Island) and/or, residential areas, tourism and recreation; Magnetic Island, Rita Island, Peters Island and the western side of Great Palm Island are inhabited, while Orpheus Island has a resort and research station and Stone Island has a Tourist Leasehold (Table 8). The extent of these pressures on islands along the Burdekin Dry Tropics coast, as well as the potential future pressures, has not been fully assessed.

Table 8. Major islands within State waters included in the Burdekin Dry Tropics NRM region.

Island name	Land tenure
Pelorus* (North Palm or Yanooa)	Reserve for recreational purposes under Hinchinbrook Shire Council Lot 3 SP.133155
Orpheus* (Goolboddi)	National park including a parcel for S34 lease to JCU Research Station; and a resort special lease (latter is not national park). There is a national park management plan for Orpheus.
Curacoa* (Noogoo)	Deed of Grant In Trust under Palm Island Aboriginal Council
Fantome* (Eumilli)	Deed of Grant In Trust under Palm Island Aboriginal Council
Falcon* (Carbooroo)	Deed of Grant In Trust under Palm Island Aboriginal Council
Esk* (Soopun)	Deed of Grant In Trust under Palm Island Aboriginal Council
Brisk* (Culgarool)	Deed of Grant In Trust under Palm Island Aboriginal Council
Havannah*	Deed of Grant In Trust under Palm Island Aboriginal Council Lot 43
Eclipse* (Garoogubbee)	Deed of Grant In Trust under Palm Island Aboriginal Council
Great Palm*	Deed of Grant In Trust under Palm Island Aboriginal Council
Acheron	Commonwealth Dept of Defence (Lot 187)
Herald	Commonwealth Dept of Defence (Lot 186)
Rattlesnake	Commonwealth Dept of Defence (Lot 124)
Cordelia Rock	Commonwealth Dept of Defence (Lot 220)
Little Cordelia Rock	Commonwealth Dept of Defence (Lot 221)
Bramble Rocks	Commonwealth Dept of Defence (Lots 222, 223, 224)
Magnetic	Free hold, also Magnetic Island National Park, and unallocated state land (no management plan)
Rita	Many leases on this island – other tenure type unsure, no national park.
Peters	Many leases on this island – other tenure type unsure, no national park.
Camp	National park Lot 135 MPW 463, but also has lease issued (originally Ariadne /Bruce Judge since resold) which is Lot 142 SP.7
Stone	Tourist leasehold land Lot 246 Plan HR1226
Middle	Part of Gloucester Island National Park
Gloucester	Gloucester Island National Park, no management plan
Thomas	Part of Gloucester Island National Park, no management plan
Poole	National park Lot 54 HR735
Holbourne Island[†]	Holbourne Island National Park, has a management plan

*form the Palm Island Group. [†]Not with State waters.

The overall condition of Magnetic Island is thought to be relatively good. Compared to the mainland there has been less impact of weeds and feral animals and it has in the past only experienced light grazing by cattle in a limited number of areas. Magnetic Island is home to nine conservationally significant plants and 13 conservationally significant animals.

A trend of increasing, inappropriate development in the unprotected regions of Magnetic Island is stimulating concern amongst residents and scientists. This development is particularly prevalent in the unprotected lowland areas (Magnetic Island Community Development Association, 2004). Weed dominance is also a concern as mint weed (*Hyptus suaveolens*) and lantana (*Lantana camara*) have a significant foothold on the island while rubber vine (*Cryptostegia grandiflora*) has also been recorded recently and could prove to be a threat to coastal vegetation. Numerous 'naturalised' ornamental plant species, such as yellow oleander, mother-in-law's tongue, mother-of-millions, Singapore daisy, broad-leaved pepper tree and yellow bells are deemed weeds on Magnetic Island. Feral animals such as cats and cane toads, if kept unchecked, could also threaten the island's biodiversity. Feral animals (goats in particular) are also a problem on Esk Island, in the Palm Island Group (Parkes *et al*., 1996).

A community project has been devised on Rita Island to develop an evolving ownership of environmental management to reduce the impact of coastal erosion on Rita Island's beach front and delta mouth. Although a lack of rainfall has hampered revegetation efforts, monitoring studies are underway and community capacity is growing (Bosel, 2004). Chital deer are known to occur on Rita Island and there are concerns that these pests may move off the island and into surrounding areas (including Bowling Green Bay National Park).

Little is known about the terrestrial fauna on most of the islands in the region, particularly with respect to insects, but also in regard to reptiles, amphibians and smaller mammals.

Summary of major issues and knowledge gaps

The geology and vegetation of many of the islands located within the Burdekin NRM region have not been mapped and they lack records of what animal inhabit them. This is particularly important in light of the fact that of the islands that have been examined, most contain 'of concern' regional ecosystems and/or endangered, rare or vulnerable animal species. This baseline information of what is present on an island is essential for their management.

Of the islands that have been examined, little is known about the ecology of the terrestrial fauna inhabiting them, particularly with respect to insects, but also in regard to reptiles, amphibians and smaller mammals.

Increasingly, inappropriate development in the unprotected regions of Magnetic Island is stimulating concern amongst residents and scientists.

Population growth, weed and pest animal invasion, extraction of marine resources, coastal erosion and development are important issues occurring in the region which impact on island ecosystems.

5.1.12 Marine Waters

Description


Marine waters, Toolakea Beach (David Scheltinga)

The majority of life inhabiting the open waters goes completely unnoticed by the casual observer. In fact, these waters are teeming with life, but most of it is too small to be seen with the naked eye. The millions and millions of tiny organisms that inhabit open waters are collectively known as plankton. These include microscopic bacteria, plants and animals, and a range of single-celled organisms (protists) that are often something in between an animal and a plant. The phytoplankton (plant plankton), which includes cyanobacteria and photosynthetic protists, use light energy and simple chemicals in the water to grow and multiply. These are then eaten by a range of tiny animals and protists (the zooplankton), which provide food for larger zooplankton and so on up the food chain. In this way, phytoplankton form the basis for the productivity of estuarine waters. The zooplankton includes larval forms of many familiar animals including sea urchins, snails, crabs, lobsters and fish, as well as many species that spend their entire life in the plankton. These open waters serve as feeding grounds for pelagic fish such as tailor, fish-eating birds such as sea eagles, terns, gulls and cormorants, and mammals such as dolphins and whales (Turner *et al*., 2004).

Distribution

The marine waters of the Burdekin Dry Tropics coastal region fall within the High Nutrient Coastal Strip Marine Bioregion (Map 4) of the Coral Sea.

Condition and Trend

Long-term water quality monitoring of the GBR has found relatively low concentrations of nutrients and pollutants in the Coral Sea; however, recent data indicates a decline in inshore water quality (GBRMPA, 2001). This decline can be attributed to increases in sediment and nutrient input by rivers, such as the Burdekin, especially during flood events. A substantial increase in fertiliser use in catchments is linked, through erosion and transport via rivers, to increases in nutrient indicators in adjacent marine waters (GBRMPA, 2001).

Water quality monitoring of Cleveland Bay and Bowling Green Bay show relatively high levels of dissolved inorganic nitrogen (0.1 to 1.2 µM), phosphate (0.2 to 0.3 µM) and suspended solids (3 to 5 mg/l) compared to the average values of the Great Barrier Reef World Heritage Area. Water quality in this area has also proved to be highly variable and strongly influenced by flood events which can create peaks in suspended sediment concentrations as high as 200 mg/l (Anderson and Roche, 2002). A water and sediment quality monitoring program has recently been devised for the southern Halifax Bay area focusing on creek discharges and points around the Yabulu Nickel Refinery (JCU, 2005).

During dry years Cleveland Bay can experience levels of chlorophyll *a*, dissolved ammonium, dissolved nitrate, dissolved organic nitrogen (DON), and total nitrogen

(TN) at levels that exceed the ANZECC water quality guidelines for coastal and marine waters. Levels of dissolved inorganic phosphate can also exceed ANZECC guidelines at times. Such high nutrient levels can stimulate phytoplankton blooms (particularly *Trichodesmium* sp.) which may disrupt ecosystems, sequester large amounts of dissolved oxygen, pose a human health hazard and impact on visual amenity when washed up in large quantities on local beaches (Anderson and Roche, 2002). Surveys conducted in 2000 show chlorophyll *a* levels (a proxy for nutrients) have doubled in Cleveland Bay since 1988 and the mid to late 1970s (Anderson and Roche, 2002).

The cyanobacteria *Trichodesmium* is notorious for blooming in areas around Townsville, forming what is known locally as a ‘red tide’. During the peak tourist season of 2003, The Strand, Horseshoe Bay and the Rock Pool were closed to the public due to the human health risks of a particularly large bloom that washed up on these popular tourist and recreation areas (Mancuso, 2003).

Sediment inputs into marine waters are also increasing, with models estimating a three to five fold increase in sediment flux since European settlement (GBRMPA, 1998). Erosion and land-use models indicate that large, dry catchments, where considerable land is used for cattle grazing, are responsible for the greatest inputs of nutrients and sediment into marine waters. The Burdekin River catchment fits this description precisely and is one of the major point sources of sediment into Great Barrier Reef waters (Danaher, 1995). Flood events also discharge enormous amounts of freshwater into adjacent marine waters, creating reduced salinity levels that can impact on organisms living in this environment, particularly coral.

Some marine waters in the region (particularly those in Cleveland Bay) experience frequent resuspension of particles due to shallow bay depths and wind and wave action. This natural process can further exacerbate the impact of high sediment loads coming from the human-modified catchment (Anderson and Roche, 2002).

The maritime industry can threaten water quality through oil spills and leaks, waste disposal and the use of antifouling paints such as tributyltin (AMSA, 2001). Pollutants such as organochlorine pesticides and heavy metals are also known to be issues in marine waters close to large urban and industrial centres. However, monitoring research has not detected concerning levels of these pollutants in the Burdekin Dry Tropics coastal region (GBRMPA, 2001).

Summary of major issues and knowledge gaps

There is limited knowledge of the marine area affected by discharge from rivers in the region, particularly the area effected by discharge from the Burdekin River. How far flood plumes carry sediments, pollutants, etc. along the coast or into the GBR lagoon, and what effect it has on different ecosystems, is a knowledge gap for the region. Different ecosystems will have different exposure risks to contaminants and different contaminants (dissolved versus particulate) will travel different distances.

The large seasonal differences of water flow result in highly fluctuating water quality parameters of the region. This complicates monitoring efforts and means that long term regular monitoring is essential to detect between seasonal variation and human induced change.

Polluted run-off from the land, plumes of sediment, pollutants, nutrients and freshwater, resuspension of particles due to shallow bay depths and wind and wave action (exacerbate the impact of high sediment loads coming from the human-modified catchment), maritime industries and algal blooms are important issues occurring in the region which impact on marine water ecosystems.

5.1.13 Estuaries

Description

Ross River estuary, Townsville (David Scheltinga)

Estuaries are a transition zone where water flowing off the surface of the land meets the regular ebb and flood of the tides. Surrounding mainland features or barrier islands help block freshwater flows and create a fertile mixing zone where organic and mineral nutrients from the land and sea accumulate. Estuaries of the Burdekin Dry Tropics region reflect the area's climatic extremes. During dry seasons freshwater flows can be ephemeral or even non-existent while floods can create freshwater flows to the mouth and beyond (Turner *et al*., 2004).

Estuaries are a highly variable environment and species living here must be able to tolerate continuous changes in numerous factors such as temperature, salinity, nutrients and turbidity.

Estuaries provide sheltered habitat, nursery and spawning areas for fish, crabs, prawns and shellfish. They help filter pollutants, act as buffers to protect shorelines from erosion and flooding, and provide essential food and habitat for birds, fish and other wildlife. Estuaries within the Burdekin Dry Tropics region support riparian vegetation, mangrove forests, seagrass meadows and macroalgal beds. These areas within the region have been recognised for their high value to fisheries both inshore and offshore, most notably to the popular barramundi fishery by providing nursery areas. Burdekin Dry Tropics estuaries are also important dugong and loggerhead turtle habitat (OzEstuaries, 2001).

Distribution

Estuaries occur where rivers and creeks meet the sea. The most notable estuaries in the area include the Burdekin River, Haughton River, Ross River, Ross Creek, Bohle River, Black River and Don River estuaries (Map 1).

Condition and Trend

Twenty-six estuaries within the Burdekin Dry Tropics region were examined as part of a condition audit of Australia's estuaries performed as part of the National Land and Water Resources Audit (see OzEstuaries, 2001 and Appendix B for more detail). Just under half of the estuarine systems in the region are river dominated with a wave-dominated delta and therefore have naturally low turbidity and salt wedge/partially-mixed circulation. The estuarine systems of the Bohle River, Ross River, Sandfly Creek, Alligator Creek, Crocodile Creek, Haughton River, Barramundi

Creek, Q195, Barratta Creek, Burdekin River, Rocky Ponds Creek, Nobbies Creek, Elliot Creek and Euri Creek are tide-dominated estuaries and generally have naturally high turbidity and well-mixed circulation. With the exception of the Don River, all estuaries in the region have low sediment trapping efficiency and a low risk of estuarine habitat loss due to sedimentation. The Don River is wave dominated and has a high sediment trapping efficiency, naturally low turbidity and salt/wedge/partially-mixed circulation. Therefore, this system has a high risk of sedimentation.

Of the 26 estuaries examined, seven are classified as 'near pristine', 11 as 'largely unmodified' and eight as 'modified' (Table 9). None were found to be in the poorest condition category of 'extensively modified'. However, later reworking of the data, new information and local knowledge suggests that some of these estuaries may be in a lower condition classification (e.g. the Ross River has been report as being in a severely (= extremely) modified condition and Leichhardt Creek as largely unmodified (Page and Hoolihan, 2002). The current condition of some of the estuaries in the region, particularly those impacted by the Burdekin Haughton Water Supply Scheme, require reassessment.

Table 9. Condition of estuaries in the Burdekin Dry Tropics region.

Estuary name	Condition
Crystal Creek	Largely unmodified
Ollera Creek	Largely unmodified
Rollingstone Creek	Largely unmodified
Leichhardt Creek	Near pristine; Largely unmodified†
Sleeper Log Creek	Largely unmodified
Bluewater Creek	Largely unmodified
Althaus Creek	Largely unmodified
Black River	Modified
Bohle River	Modified
Ross River	Modified; Extensively modified†‡
Sandfly Creek	Modified
Alligator Creek	Largely unmodified
Crocodile Creek	Near pristine
Haughton River	Modified
Barramundi Creek (also known as Morrison Creek)	Largely unmodified
Q195 (Unnamed estuary)	Largely unmodified
Barratta Creek	Modified; Extensively modified‡
Mud Creek	Largely unmodified
Plantation Creek	Largely unmodified; Extensively modified‡
Burdekin River	Modified
Rocky Ponds Creek	Near pristine
Nobbies Creek	Near pristine
Elliot Creek	Near pristine
Branch Creek	Near pristine
Euri Creek	Near pristine; Not a correct assessment‡
Don River	Modified

Source: Condition reported is from OzEstuaries (2001) unless otherwise indicated; †Page and Hoolihan (2002); ‡Comments provided by George Lukacs (2005).

Many estuaries in the Burdekin Dry Tropics region have had their connectivity with upstream areas and wetlands removed due to barriers such as dams, weirs and bund walls (see Section 5.3.1). This has subsequent effects on migratory fish species (see Section 5.2.4).

Weed species covering an estuarine waterbody in Ayr (David Scheltinga)

The dominance of exotic weeds, such as lantana, water hyacinth, cabomba, salvinia, hymenachne and rubber vine, has had a significant affect on waterway health in the region. This has been particularly important in areas within the Burdekin River floodplain where many waterways, such as Plantation Creek and Sheepstation Creek, now flow continually throughout the year as they are used to distribute irrigation water as part of the Burdekin irrigation project. The lack of a dry period, normal for many of the ephemeral coastal streams, results in aquatic weeds overgrowing the surface of waters. This results in less, little or no sunlight reaching submerged aquatic plants and due to decreased oxygen production and increased oxygen use may result in anoxic conditions, which have local and downstream impacts (Perna *et al*., 2004; Perna and Burrows, 2005). Small-to-moderate rainfall events can result in this anoxic/hypoxic water being pushed downstream into estuarine waters and resulting in animal kills.

The Barratta Creek system, which previously would stop flowing during the summer months, leaving a series of permanent lagoons, now also flows throughout the year due to tailwater releases. These tailwaters add variable amounts of nutrients to the system, though the effects of these nutrients on the estuary, including their supply during the dry season when previously inputs would not have occurred, remains unknown. There is also a high potential for these tailwaters to contain toxic substances, such as pesticides, herbicides and heavy metals, or be anoxic/hypoxic. The actual concentrations of these substances entering estuaries and their effects on the ecosystem remains unknown (ACTFR, date unspecified).

Oxygen concentrations in Leichhardt Creek, Stuart Creek, St. Margaret Creek and Piccaninny Waters, Haughton River do not comply with ANZECC (2002) guidelines. However, this may be indicative of a need to develop local guidelines as opposed to a sign of water quality problems. Phosphorus and lead concentrations in all monitored estuaries were higher than the ANZECC default trigger value for tropical aquatic ecosystems. The cause of contamination has not been determined (Faithful, 2002).

Monitoring (generally monthly) of two sites in the Ross River estuary by RIVER and Burdekin Waterwatch members between June 2000 and early 2003 showed pH, dissolved oxygen and turbidity levels to be within ANZECC (2000) guidelines for tropical aquatic ecosystems with only the occasional sample being outside guideline levels (data supplied by David Reid, 2005).

Most estuaries in the region have a moderate level of habitat diversity and support mangroves, saltmarshes and inter-tidal mud/sand flats, a few support additional ecosystems such as seagrass meadows (e.g. Nobbies Inlet) or coral reefs (e.g. Leichhardt Creek and Sleeper Log Creek) (Page, 2002).

There has been very little research into the impacts of catchment run-off on estuaries themselves with most research looking at catchment impacts on the GBR lagoon. Long-term and interpretable ambient water quality data for estuaries in the Dry Tropics is very limited and an important knowledge gap. This is despite the fact that estuaries are at a higher risk of damage from poor water quality inputs and are placed under more pressure from land-use than marine waters (ACTFR, date unspecified).

Summary of major issues and knowledge gaps

The authors of this report have noted disagreement over the condition attributed to some estuaries in the region by the National Land and Water Resources Audit (examined in 2000). Reworking of the data, new information and local knowledge suggests that some of these estuaries may currently be in a lower condition classification. The current condition of some of the estuaries in the region, particularly those impacted by the Burdekin Haughton Water Supply Scheme, require reassessment.

Estuaries have become a diminishing ecosystem type in the Burdekin. They may have become entirely fresh from water distributed from elsewhere or fully marine (even hypersaline) due to the addition of bund walls. The ecological implication of this is poorly understood.

The effects of more subtle changes to flows on the estuarine portion of the river system is a major knowledge gap. Several estuaries currently have freshwater input all year round, including during the dry season when previously inputs would not have occurred, others receive little or no flow throughout the entire year, while many do not receive the annual flushing due to summer flood waters they once did – the affect of these alteration on the estuarine ecosystem remain unknown and requires investigation.

The effects of changes to the fresh/saltwater interface because of dredging, bunding and water extraction on invertebrate populations in particular needs close examination. It can be expected that a change from estuarine condition to purely freshwater means a significant change in community structure (especially for sessile organisms) – this has huge implications for nutrient cycling and the food chain. A greater understanding of this is needed and should be factored into the impacts of these operations.

Oxygen concentrations in Leichhardt Creek, Stuart Creek, St. Margaret Creek and Piccaninny Waters, Haughton River do not comply with national guidelines. However, this may be indicative of a need to develop locally specific guidelines as opposed to a sign of water quality problems. Phosphorus and lead concentrations in all monitored estuaries were higher than the ANZECC default trigger value for tropical aquatic ecosystems. The cause of this contamination needs to be determined.

There has been very little research into the impacts of catchment run-off on estuaries themselves with most research looking at catchment impacts on the GBR lagoon. Long-term and interpretable ambient water quality data for estuaries in the region is limited and an important knowledge gap.

Drainage alterations and hydrological modifications (e.g. the Burdekin River Water Supply Scheme – resulting in loss of natural floodplain habitats and significant modifications to hydrological patterns, upstream dam construction – impacts ephemeral wetland ecosystems by dissipating flood pulse flows, the construction of saltwater exclusion bunds – altered previously ephemeral or tidally influence, loss of connectivity with upstream areas and wetlands), exotic weeds, alterations to flows, tailwater inputs, low oxygen concentration, high nutrient levels are important issues occurring in the region which impact on estuarine ecosystems.

5.1.14 __Wetlands__

Description

Wetlands can be defined as “areas featuring permanent or periodic/intermittent inundation, whether natural or artificial, static or flowing, fresh, brackish or saline, including areas of marine water, the depth of which at low tide does not exceed 6 m” (Ramsar Convention Secretariat, 2004).

Haughton River wetlands (Dieter Tracey)

The Burdekin Dry Tropics coastal region contains a variety of habitats, which can be classified as wetlands, including streams, mangrove forests, saltmarsh areas, freshwater ponds and swamps. Wetlands are described as the ‘kidneys of the natural system’ as they act as water filters, removing non-flood levels of silt, nutrients and other pollutants (McPhail, 1998). Wetlands can also protect coastal areas against the erosive effects of cyclones (Spain and Blackman, 1992) and reduce the resuspension of sediments deposited at river deltas. These properties, combined with their importance as bait fish, fin fish and crustacean habitat, confer major economic value to wetland areas.

Bowling Green Bay and other wetlands in the Burdekin Dry Tropics coastal region also provide important services (e.g. feeding grounds) for conservationally and internationally significant species such as dugong, saltwater crocodiles, green turtles and wader birds. Several wetlands in the Burdekin Dry Tropics coastal region have been identified as having significant ecological value and have been placed on the Australian Directory of Important Wetlands (see Section 4.10.3). One, Bowling Green Bay, is listed as on the Ramsar list of Wetlands of International Importance.

Bowling Green Bay was selected as a wetland of international significance as it is representative of the richest coastal wetland habitat types found in the coastal tropics of north-eastern Australia. Habitat types found in this diverse wetland complex include mangrove and saltmarsh communities growing in highly saline areas, brackish to freshwater marshes, coastal sand dunes dominated by *Eucalyptus tessellaris* and *E. tereticornis* with *Melaleuca dealbata* and *M. leucadendra* and other aquatics in the swales (Spain and Blackman, 1992).

The Burdekin-Townsville Aggregation is one of the most extensive wetland systems on the east coast of Queensland covering approximately 149,198 ha and listed on the Directory of Important Wetlands of Australia (Environment Australia, 2001). Ecosystems in this wetland aggregation include floodplain sedge swamps, *Melaleuca* paperbark forests and coastal, estuarine, mangrove-salt flat complexes. Up to 40 species of fish have been recorded in these habitats as well as breeding groups of waterbirds and migratory wading birds (Tait and Perna, 1999).

Distribution

Maps 13-23 show the extensive area of wetland habitats in the Burdekin Dry Tropics coastal region and sub-regions. Inter-tidal wetlands feature prominently in the area, fringing Cleveland, Bowling Green and Upstart Bays. Large freshwater swamps can be found adjacent to inter-tidal wetlands at Bowling Green Bay, Upstart Bay, Cape Upstart and Abbot Point.

Wetlands listed under the Directory of Important Wetlands in the coastal region include Abbot Point – Caley Valley wetlands, Bowling Green Bay, Burdekin-Townsville Coastal Aggregation, Burdekin Delta Aggregation, Southern Upstart Bay, Ross River Reservoir and a portion of the Bambaroo Coastal Aggregation.

There are numerous locally important wetlands distributed throughout the Burdekin Dry Tropics coastal region. A large freshwater wetland extends north of the Elliot River mouth for approximately 11.5 km, following the coastline of Cape Upstart. A smaller wetland also exists to the south of the Elliot River wetland. Two small wetlands exist to the south west of the Branch/Mt Stuart Creek wetlands. A large ephemeral swamp environment exists to the south of Abbot Point becoming brackish to fresh during the wet season and reduced to a saltpan in the dry (Bruinsma *et al*., 1999).

Condition and Trend

Most of the freshwater habitats adjacent to tidal areas in the Burdekin Dry Tropics coastal region have been substantially modified by human activity (Danaher, 1995). Many of the *Melaleuca dealbata*, *M*. *leucadendra* and *M*. *viridiflora* lowland swamps that once extensively covered the coastal floodplains of the Burdekin Dry Tropics region have been cleared for agriculture and urban development (Johnson *et al*., 1998). Large-scale reclamation of other wetland types has also occurred throughout the area, leaving only remnant areas.

Exotic pasture grasses, which have become weeds, particularly paragrass (*Brachiaria mutica*) and hymenachne, have proved to be a threat to the condition of wetlands in the Burdekin Dry Tropics coastal region (Townsville City Council, 1999a). Exotic pasture grasses, such as *Panicum maximum*, have also been known to invade and dominate freshwater wetlands in the region (Spain and Blackman, 1992).

Altered hydrological regimes, caused by developments such as the Burdekin Haughton Water Supply Scheme, have impacted on wetlands associated with Barratta Creek, Haughton River and, of course, the Burdekin River by either diverting water away from, or into them, via irrigation supply channels and as tail water (Spain and Blackman, 1992).

Eutrophication of freshwater wetlands is also occurring in the region, most notably in the Bowling Green Bay wetland complex, creating a favourable environment for weed invasion. The source of nutrients is thought to be fertiliser applied to agricultural areas and run-off from developed areas (Spain and Blackman, 1992).

Drainage depressions and lowland areas that support ephemeral wetlands and native sedge communities have been converted into stock dams in the past, removing these habitats and providing a favourable environment for exotic ponded pasture species to out-compete native vegetation (Spain and Blackman, 1992).

Seven hundred hectares of wetlands in and around Townsville are subject to regular aerial and ground spraying of larvicides and pesticides as part of the city's Mosquito Prevention Program (Townsville City Council, 2004e). Although environmental factors have been considered in the Program's application, the potential for detriment to the receiving environment by the chemicals and equipment used remains (Townsville City Council, 2004e).

Growth of urban, aquaculture and agricultural development in the Burdekin Dry Tropics coastal region is expected to further threaten the condition of wetlands through clearing, pollution, weed invasion and hydrological changes. Wetlands that fall outside national park and other protected area boundaries are only partially protected by the Marine Parks legislation or by the *Fisheries Act 1994* if they are marine plants (Johnson *et al*., 1998). Even wetlands in protected areas can still be negatively impacted by activities in surrounding and upstream areas.

Water quality monitoring of Inkerman Lagoon and Swans Lagoon found these water bodies in a highly vulnerable state in terms of oxygen levels. Wet season recharge events coincide with unusually high levels of fine organic sediment, resulting in severe oxygen decreases in these lagoons; however, this is not uncommon in dry tropics water bodies. Water quality monitoring also found phosphorus concentrations were higher than ANZECC default trigger values for tropical aquatic ecosystems. Sediment testing showed concentrations of cadmium in fine benthic sediment from Swans Lagoon and the concentration of lead in sediments from both lagoons exceeded EPA guidelines. The cause of contamination has not been determined. It is predicted that disturbance of these areas would result in severe water quality degradation (Faithful, 2002).

Surveys of lagoons adjacent to the Burdekin River during 2000-2003 found that weed infested lagoons were virtually anoxic with very few fish species present. The fish communities that were present were dominated by those species that could breathe by gulping air from the surface. After the lagoons were cleared of weeds they were rapidly recolonised by fish from nearby remnant lagoons (Perna *et al*., 2004).

Wetlands in the Don River delta and Abbot Bay areas tend to contain less species than others (e.g. at Edgecumbe Bay). Despite the lower number of species, all areas are recognised as important commercial and recreational fishing grounds by the DPI&F (Bruinsma *et al*., 1999).

Summary of major issues and knowledge gaps

Wetlands are experiencing a range of human related threats (e.g. reclamation practices) which need to be more closely examined to access their level of impact. Following on from this is the need for information on future threats to wetlands and the vulnerability of specific wetlands to these threats.

The cause of cadmium contamination in Swans Lagoon and lead contamination in Swans and Inkerman Lagoons has not been determined and requires examination.

Clearing and reclamation, weeds, altered hydrological regimes, eutrophication, conversion of wetlands to stock dams, aerial and ground spraying of larvicides and pesticides, coastal development and low oxygen levels are important issues occurring in the region which impact on wetland ecosystems.

5.1.15 <u>Riparian Vegetation</u>

Description


Riparian vegetation near Alva (David Scheltinga)

Riparian vegetation refers to the habitat that grows on the banks of streams and rivers. In the Burdekin Dry Tropics coastal region this vegetation is present in a variety of forms, including *Melaleuca leucadendra* and *Eucalyptus tereticornis* stands, riparian vine thickets and mangrove forests (Townsville City Council, 1999a). Not only do they provide wildlife habitats for frogs and other animals, riparian vegetation plays a key role in the health of aquatic ecosystems, stream water quality and downstream ecosystems. These areas are noted as being particularly important as habitat and nursery areas for several commercially important fish species such as barramundi (Johnson *et al*., 1998).

Riparian vegetation also provides shade for the stream, reducing heat and light penetration, and providing cover from predators, features valued by fish and other aquatic organisms. Other important ecological 'goods and services' provided by riparian vegetation include the maintenance of bank stability through the binding and consolidating action of roots on bank materials (Johnson *et al*., 1998). Vegetated banks are therefore less likely to slump and the stream is therefore less likely to become turbid through bank erosion.

Riparian vegetation also reduces stream turbidity by acting as a filter trap for sediment from terrestrial and upstream sources by baffling the water column creating sites of deposition and by physically and biologically trapping terrigenous sediment. Riparian areas are also able to buffer the effect of flood flows following heavy rains on surrounding areas providing a benefit to both nearby organisms and artificial infrastructure (Johnson *et al*., 1998).

Distribution

Riparian *Melaleuca leucadendra*/*Eucalyptus tereticornis* forest/woodland can be found on Magnetic Island, Mt Elliot, Ross River, Stuart Creek, Toomulla and in Cromarty Wetlands (Townsville City Council, 1999a). Riparian vine thicket forest is present at Bush Gardens Ross Creek in Ross River catchment, Magnetic Island, Mt Elliot, Cape Cleveland, Mundy Creek in Pallarenda, Ross River, Stuart Creek, Toomulla, Cromarty Wetlands.

Riparian/floodplain eucalypt open forest and woodlands areas are better represented inland than on the coast (Map 7). Map 24 shows that waterways in the Burdekin Haughton Water Supply Scheme area have experienced the greatest loss of riparian vegetation. Riparian vegetation loss has also occurred near Townsville and to the west and south of Bowen with much of this loss occurring on freehold land (compare Map 25).

See also information on mangrove distribution in Section 5.1.3.

Condition and Trend

The condition of mangrove riparian vegetation is described in the mangrove ecosystem section.

Riparian areas in the Burdekin Dry Tropics coastal region have experienced significant clearing and reclamation reducing their distribution to narrow, sparsely vegetated remnant stands (Johnson *et al*., 1998). This clearing has a strong historical basis with substantial loss of riparian vegetation occurring in the Burdekin delta during 1940s and 1950s due to the perception (admittedly with some justification) that they provide a refuge for the pest cane beetle (Tait and Perna, 1999). The condition of many of the remnant riparian stands in the Burdekin Dry Tropics coastal region is further degraded by the invasion of exotic weeds, particularly paragrass, guinea grass and, though more restricted, hymenachne (Johnson *et al*., 1998; Tait and Perna, 1999). Other weeds that threaten riparian communities in the region include rubber vine, guinea grass, lantana and bellyache bush (Tony Grice, pers. comm.) (see Appendix C for a list of weeds found in the Dry Tropics region).

These exotic weeds also inhibit some of the ecosystem goods and services offered by native vegetation such as the provision of habitat for terrestrial species and frogs. Riparian areas are also at risk of pruning for ‘views’, changes to hydrology and sedimentation, the construction of dams and weirs, boat wash, changes in tidal regime, changes in salinity, invasion by feral species and poor water quality. Protection of riparian areas (excluding mangroves and other marine plants which are

Aquatic weed infestation of a small freshwater coastal waterway between Alva and Ayr (David Scheltinga) protected by the *Fisheries Act 1994*) is virtually confined to those in national parks and reserves (Johnson *et al*., 1998).

Considerable decline of riparian vegetation at 'Round-waterhole' on Sheep Station Creek, a distributary channel on the Burdekin River northern delta has occurred since 1970 and is thought to be primarily due to waterlogging related to sustained high water levels due to pumped irrigation and aquifer recharge flow. The loss of riparian trees has attributed to the invasion of exotic grasses in the riparian zone (Tait and Perna, 1999). Dense stands of invasive, exotic pasture grasses like guinea grass have flourished over recent decades in the emergent zones of most riparian zones in the Burdekin delta. There is evidence to suggest that these weeds exclude native sedges and grasses and reduce the recruitment of riparian tree species (Tait and Perna, 1999).

Intense, hot, cane harvest fires and clean up 'burn-offs' fuelled by exotic, pasture grasses have also be recognised as a threat to riparian vegetation and soil banks proximate to cane farms in the Burdekin region (Tait and Perna, 1999). Saline groundwater intrusion resulting from intense irrigation in some Burdekin Dry Tropics coastal areas threatens riparian vegetation species that are adapted to freshwater conditions (Tait and Perna, 1999).

The *Melaleuca* sp. and *Casuarina* sp. riparian vegetation surrounding Leichhardt Creek is considered to be generally intact with only minimal disturbance by stock and pigs. Riparian vegetation is also recorded as being intact for sites along the Haughton River, Inkerman Lagoon and St. Margaret Creek. Swans Lagoon and Stuart Creek sites are recorded as having cleared riparian zones (Faithful, 2002).

The riparian zone along the lower Ross Creek has been the focus of over 20 community group's rehabilitation efforts. Weed removal, tree planting, fire fighting and seed collection have been conducted in an effort to improve the area for wildlife habitat and erosion prevention (Townsville City Council, 2002).

Remnant riparian/floodplain eucalypt open forest or woodland vegetation in Bluewater Paluma National Park is classified as endangered under the *Vegetation Management Act 1999*. Sections of riparian vegetation along the lower Burdekin River are also classified as endangered (see Map 6).

Legislation administered by the Department of Natural Resources and Mines, EPA, DPI&F and local governments, like the specific Buffer Zone Guidelines (FHG 003), aims to protect and manage riparian vegetation (Bavins *et al*., 2000).

Summary of major issues and knowledge gaps

Past heavy clearing of riparian vegetation has not only reduced the distribution of this ecosystem but also impacted on downstream water quality and stream habitat. There is a need for specific on-ground verified data for the condition of riparian areas within the region.

The mapping and protection of remnant vegetation in the region is needed.

Weed invasion, clearing and reclamation, changes to hydrology and sedimentation, the construction of dams and weirs, boat wash, changes in tidal regime, changes in salinity, poor water quality, changes to groundwater levels and saline groundwater intrusion are important issues occurring in the region which impact on riparian ecosystems.

5.2 Estuarine, Coastal and Marine Species

5.2.1 <u>Birds</u>

Distribution

Due to the typically dry nature of the Burdekin Dry Tropics region birds tend to congregate around water holes, making fresh, brackish and saltwater wetlands hotspots for both local and migratory bird-life. To highlight the importance of wetlands for a large proportion of the area's bird-life it can be noted that the Bowling Green Bay Ramsar wetland frequently hosts at least 20,000 waterbirds, including 10,000 magpie geese (*Anseranas semipalmata*), various species of the bird family Anatidae (which includes ducks, geese and swans) and over 4,000 brolgas (*Grus rubicunda*) (Blackman and Spain, 1992).

The Burdekin Dry Tropics coastal region seasonally hosts over 50% of the migratory bird species listed in both the Japan Australia Migratory Bird Agreement (JAMBA) and China Australia Migratory Bird Agreement (CAMBA) (Blackman and Spain, 1992). Another hotspot for bird-life is South Bank, a 45 ha site on the Ross River bounded by Stuart Creek. This site is home to significant, seasonal populations of Australian white ibis (*Threskiornis aethiopica*), straw-necked ibis (*Threskiornis spinicolils*, great egret (*Ardea alba*), intermediate egret (*Ardea intermedia*), little egret (*Ardea garzetta*) *a*nd cattle egret (*Ardea* ibis) (Townsville City Council, 1999a). Other habitats that are rich in bird-life include saltmarshes, mangroves, islands and dune vegetation. Some birds, such as the rare black-chinned honeyeater (*Melithreptus gularis*) are habitat specialists living only in a particular habitat type (in this case *Melaleuca viridiflora* low woodlands) while others such as the sulphur-crested cockatoo can be found in a variety of habitats. Townsville Bird Observers Club compiles species lists of Townsville Common and Ross River Bush Park on a monthly basis.

The Burdekin Dry Tropics coastal region includes important raptor habitats attracting hawks, goshawks (such as the endangered red goshawk and rare grey goshawk), eagles and kites (such as square tailed kite which is listed as rare) (Wildnet, 2004).

Condition and trend

The Burdekin Dry Tropics coastal region supports a large and diverse bird population. The Queensland EPA's WildNet database estimates that there are approximately 437 species of birds in the region with 27 being of high conservation significance. Under the *Nature Conservation Act 1992*, four species are classified as endangered, 11 species as vulnerable and 13 as rare (See Appendix D).

Monitoring of a large bird colony at Southbank has provided vital information about the local populations of Australian white ibis (*Threskiornis aethiopica*), straw-necked ibis (*Threskiornis spinicolils*), great egret (*Ardea alba*), intermediate egret (*A*.

intermedia), little egret (*A. garzetta*) and cattle egret (*A. ibis*). A significant decline in roosting bird numbers was recorded in 1999 though the cause has not been accurately determined. Previous monitoring data showed large, seasonal variations in population size so it is possible that such a decline is part of the natural fluctuations of this colony (RIVER Group, 1999).

Coastal development places direct and indirect pressures on the area's bird communities. Loss and fragmentation of habitat is a major threat to birds, reducing nesting site availability and food sources. Predation by feral animals like cats, foxes and feral pigs is also a threat, especially for birds that nest and/or forage on the ground. Feral birds, like the common myna (*Acridotheres tristis*), can also threaten native birds as they can aggressively compete for nesting space and food (Pell and Tideman, 1997). Vehicles, boats, dogs and recreational activities, such as kite surfing, disturb bird roosting/nesting sites and disrupt feeding birds. Constant disruption can reduce weight gain prior to migration and reduce the chance of successful migration. The loss of inter-tidal mudflats is also a concern for wader birds.

Summary of major issues and knowledge gaps

The loss and fragmentation of habitat, coastal development, vehicles, boats, dogs and recreational activities and pest animal invasion are all important issues occurring in the region which impact on bird survival.

5.2.2 Mammals

Distribution

Marine mammals have been divided up for the purposes of this report into three sub-categories, cetaceans (whales), dugongs and dolphins due to their differences in distribution, condition and threats.

The migratory nature of cetaceans creates a very extensive distribution of animals throughout the world's oceans. Within the Burdekin Dry Tropics coastal region, humpback whales (*Megaptera novaeangliae*) can be found in the Coral Sea from the start of winter for breeding. Sperm whales, 'dark shoulder' and dwarf minke whales also visit the area regularly (GBRMPA, 1998; EPA, 2004o). Most whales seasonally migrate from the southern seas up to the Great Barrier Reef.

Three species of dolphin are found in the inshore/coastal areas of the region, the irrawaddy dolphin (*Orcaella brevirostris*), the indo-pacific hump-backed dolphin (*Sousa chinensis*) (both classified as rare under the *Nature Conservation Act 1992*) and the common bottlenose dolphin (*Tursiops truncates*). Although these dolphins are typically found inshore, their populations are highly mobile. Offshore bottlenose dolphin populations can also be found in the region.

Dugongs are large herbivorous marine mammals commonly found feeding on coastal seagrass meadows. Cleveland Bay, in the Burdekin Dry Tropics coastal region, is one of only two core areas for the entire Great Barrier Reef dugong population. Bowling Green Bay also consistently contains high levels of dugongs and is thought to be tightly linked to the core area (Preen, 1994).

Terrestrial mammals can be found in a variety of habitats, including grasslands, rainforest, wetlands and woodlands. Most terrestrial mammals prefer undisturbed areas, with access to water and essential habitat. Some, however, like the brush tail possum are able to survive in heavily modified environments like residential areas. Habitats that are particularly high in mammal species are rainforests, which provide habitat for the rare leaf nosed bat (*Hipposideros diadema reginae*), and Clarkson's bloodwood (*Corymbia clarksoniana*) open woodlands (Townsville City Council, date unspecified).

Condition and trend

One hundred and forty-one mammal species (both marine and terrestrial) have been recorded in the Burdekin Dry Tropics coastal region including 13 species with high conservation significance and 14 animal species introduced to Australia. Of the 13 species with high conservation significance two dolphin species are listed as rare (the Irrawaddy dolphin and the Indo-Pacific hump-backed dolphin) while humpback whales and dugong are listed as vulnerable (EPA, 2004o).

Population studies and stranding reports suggest that the condition of the cetaceans is good and is likely to be continuing the recovery process from the whaling operations that decimated their numbers ~50 years ago. Conversely, the rare inshore dolphins have been found in a disproportionate number of strandings, prompting experts to call for a reassessment of their conservation status (Limpus *et al*., 2002b).

Dugongs are threatened worldwide, however, the Townsville-Cardwell dugong population, which includes approximately 49% of the entire dugong population between Cooktown and Hervey Bay, is the only significant dugong population which has not exhibited a decline in numbers (Preen, 1994). There has also been a significant reduction in dugong strandings in the Townsville region from 2001 to 2002 (Limpus *et al*., 2004a). To protect dugongs and their habitat in Upstart Bay, the area was declared a level ‘A’ Dugong Protection Area (DPA) in January 1998, restricting commercial fish netting (Rasheed and Thomas, 1999) (see Section 4.10.5).

Most marine mammals, especially great whales and dugongs have a relatively slow rate of increase with late sexual maturity and low fecundity. Therefore, even a slight decline in adult survival can result in a chronic population decline (Marsh, 1996). Some threats are common to all marine mammals while others tend to impact most heavily on species that frequently utilise certain areas. Threats experienced by all marine mammals include entrapment in shark control nets, which caused over a third of the whale and dolphin mortalities in Queensland in 2002 (Limpus *et al*., 2002a). Shark control nets have been identified as the cause of death for at least one rare irrawaddy dolphin in Upstart Bay in 2002 (Limpus *et al*., 2002a).

Boat strikes are another significant threat as they cause direct damage through injuries and also deter dugongs from entering important grazing areas through boat noise and disturbance. The impact of boat traffic, from whale watching operations, on humpback whales has also been identified as being negative, however, the long-term effects remain unstudied (GBRMPA, 1998b).

Dugongs and the two species of rare dolphin live predominately in coastal waters, and are therefore exposed to the greatest level of chronic water pollution and resultant habitat degradation. Boat disturbance and nets of inshore gill-net fisheries can also negatively impact marine mammals in coastal waters.

As seagrasses are essential for food a decline in seagrass biomass or distribution will affect dugong populations. Factors that severely degrade seagrass meadows, such as decreased light penetration due to increased sediment loads from the catchment or epiphyte growth stimulated by nutrient enrichment, or physical or chemical disturbance, therefore indirectly threaten dugong populations. This factors can limit the growth of seagrass to shallow areas, which are more difficult for dugongs to access. Another unquantified threat is the impact of Traditional Owner hunting on dugong populations (Marsh, 1996).

In terms of terrestrial mammals, six species of bats have high conservation significance; with the bare-rumped sheathtail bat listed as critically endangered under the *Environmental Protection and Biodiversity Conservation* (*EPBC*) *Act 1999* and endangered under the *Nature Conservation* (*NC*) *Act 1992*; the horseshoe bat listed as endangered under both Acts; the coastal sheathtail bat listed as vulnerable and two other species are listed as rare and one as conservation dependent. Both the Mahogany Glider (*Petaurus gracilis*) and Sharman’s rock wallaby (*Petrogale sharmani*) are listed under the *NC Act 1992* as endangered and the lemuroid ringtail possum (*Hemibelideus lemuroids*) is listed as rare under the same Act. Australia’s largest bat, the grey-headed flying-fox (*Pteropus poliocephalus*) is listed as vulnerable under *EPBC Act 1999*.

Habitat loss, degradation and fragmentation caused by coastal development are major threats to terrestrial mammals in the Burdekin Dry Tropics coastal region. Such development disrupts ecosystems and creates a mosaic of isolated remnants of suitable habitat which are often unconnected and interspersed with a range of land-uses that are unsuitable for habitat. Remnant habitat patches are also more susceptible to invasion by feral animals and weeds, which can compete with, or prey on, terrestrial mammals or, in the case of weeds, degrade their habitat or food sources for herbivores.

Road traffic can also be a threat to terrestrial mammals causing high mortality in the form of road-kill and further fragmentation of habitats. Mammals that are most commonly killed on roads on Magnetic Island are possums and wallabies (Townsville City Council, 2004c). Predation by introduced animals like foxes and cats are also a threat to terrestrial mammals, especially small, ground dwelling species. Foxes can be found throughout the region, including at Cape Bowling Green, Mt Stuart and Rocky Springs, while feral cats are can be predominately found in the Pallarenda region (Townsville City Council, date unspecified).

Summary of major issues and knowledge gaps

Terrestrial mammal distribution within the region is unclear, as is population size which is usually assessed at a broader scale than the region.

The conservation status of some mammals in the region has been questioned and requires investigation (e.g. the rare inshore dolphin).

The impact of boat traffic on marine mammals has been identified as being negative, however, the long-term effects remain unstudied.

Another unquantified threat requiring examination is the impact of Traditional Owner hunting on dugong populations. However, during 2003-04, the Great Barrier Reef Marine Park Authority Board approved a five-year Traditional Use of Marine Resources Agreement (TUMRA) Program for the Gudjuda region. Through the Gudjuda TUMRA Traditional Owners have now voluntarily committed to not taking more dugong in the BDT region (David Foster, pers. comm.).

Habitat loss, degradation and fragmentation caused by coastal development, invasion by feral animals and weeds, and road and boat traffic are all important issues occurring in the region which impact on mammal survival.

5.2.3 Reptiles

Distribution

The Queensland EPA's WildNet database reports that 149 reptile species are found in the Burdekin Dry Tropics coastal region. This includes marine reptiles such as turtles and sea snakes that are found throughout the Coral Sea area with turtles also using beaches in the area to lay eggs. Saltwater crocodiles are found in the estuarine regions while freshwater crocodiles prefer inland, freshwater streams. Terrestrial reptiles have variable distributions within the region; for example, the rare rusty monitor (*Varanus semiremex*) is present on the South Bank Coast and associated wetlands and Magnetic Island, and the rarely seen northern crowned snake and eastern taipan, to water pythons, keelbacks, common tree snakes and death adders which are found throughout the region (Townsville City Council, date unspecified). Some animals are nationally rare but are common in small patches within the Burdekin Dry Tropics coastal region, e.g. Sadliers dwarf skink (*Menetia sadlieri*) which is endemic to Magnetic Island. Terrestrial reptiles inhabit native bushlands and waterhole areas, preferring areas undisturbed by humans.

Condition and trend

Eight reptile species are listed as rare under the *Nature Conservation* (*NC*) *Act 1992*, including the rusty monitor and robust burrowing snake (*Simoselaps warro*). Three reptile species are listed as vulnerable under both the *NC Act 1992* and the *Environmental Protection and Biodiversity Conservation* (*EPBC*) *Act 1999*, these are the single-striped delma (*Delma labialis*) a legless lizard found on Magnetic Island, and two marine turtles, the flatback turtle (*Natator depressus*) and the green turtle (*Chelonia mydas*). Hawksbill and loggerhead turtles (listed as vulnerable and endangered, respectively, under the *EPBC Act 1999*) have also been sited foraging in the region (Tim Harvey, pers. comm.).

The conservation status of turtles has been of concern to the World Conservation Union (IUCN) who have listed the green turtle as endangered, the hawksbill and leatherback turtles as critically endangered and the flatback turtle as data deficient. Queensland Parks and Wildlife Service Turtle Monitoring programs have found that loggerhead turtles seem to be experiencing the most significant decline in numbers (Tim Harvey, pers. comm.). The estuarine crocodile (*Crocodylus porosus*) is listed as vulnerable on the *NC Act 1992* though not on the *EPBC Act 1999*. The status of sea snake populations is largely unknown (GBRMPA, 1998b).

Threats to marine turtles are well documented. By-catch of marine reptiles in fisheries nets has been a serious threat in the past. However, the implementation of Turtle Excluder Devices (TEDs) is expected to reduce the impact of this industry on turtles and other large marine animals. Drum lines, however, still pose a threat to loggerheads in particular (Haines and Limpus, 2000). Captures of small turtles in collapsible crab pots is increasing dramatically (annual increase from 2001 to 2002 of 37%) in Queensland. Consumption of plastics, fishing line ropes and bags is also a threat to marine turtles as is entrapment in these items and in shark control nets (Haines and Limpus, 2000).

Boat strikes by commercial and recreational vessels are a major cause of carapace fractures and death, with this threat being blamed for approximately 43% of the turtle strandings in Queensland (Haines and Limpus, 2000). Traditional Owner hunting is a largely unquantified threat.

Predation of turtle eggs and hatchlings on beaches by native and introduced animals such as feral pigs and foxes has been identified as of particular concern at Cape Upstart (Tim Harvey, pers. comm.).

Coastal development impacts on marine turtles mainly through reclamation of dunes, degradation of natal beaches by pollution, increased four wheel drive traffic (which can crush eggs) and the use of unnatural lights which confuse hatchlings and draws them inland instead of out to sea (Haines and Limpus, 2000).

The fibropapilloma virus is an increasing threat to the region’s turtle population with recent surveys finding an increase in the numbers of juveniles exhibiting large tumour growth around their eyes, mouth, flippers and internal organs. The tumours can affect an infected turtle’s foraging ability, occasionally resulting in mortality and are thought to be exacerbated by poor water quality (Dobbs, 2001).

As mature turtles require seagrass and macroalgae beds for grazing, threats to these habitats indirectly threaten turtle populations. These threats are described in more detail in the macroalgae and seagrass ecosystem sections.

Sea snakes are threatened by many of the processes that impact turtles, such as degrading water and habitat quality, and entrapment in fishing lines and nets. Some threats specific to sea snakes include illegal collection for aquarium trade (especially of the olive sea snake). By-catch from trawling is also a major threat to sea snake populations. It is estimated that in the Gulf of Carpentaria in 1991 between 30,000 and 67,000 sea snakes were killed as a result of commercial prawn trawling (GBRMPA, 1998b). The effect of prawn trawling on populations of sea snakes in the Burdekin Dry Tropics region is a knowledge gap.

Though specific studies are not available, it is expected that terrestrial reptiles in the Burdekin Dry Tropics region are particularly threatened by habitat loss (Cogger *et al*., 1993). This involves both vegetation clearing and the invasion of natural habitat by weeds. There is concern that some introduced pasture grasses like Indian couch cannot provide adequate shelter for ground dwelling reptiles therefore reducing their already threatened habitat areas (Grice, date unspecified). Other threats to terrestrial reptiles include overgrazing by stock of essential habitat, cropping, urban development, and predation by introduced mammals (principally foxes, cats and rats) (Cogger *et al*., 1993). There are eight terrestrial reptile species that are classified under the *Nature Conservation Act 1992* as rare and one, the stripe-tailed delma, is classified as vulnerable. See Appendix D for a list of rare, endangered and vulnerable reptiles.

Summary of major issues and knowledge gaps

The status of sea snake populations is largely unknown and requires investigation.

Captures of small turtles in crab pots is increasing dramatically throughout Queensland. Research is needed to determine what impact crab pots are having on turtle numbers in the region and if it is a threat, then how to alleviate the impacts.

As part of the Commonwealth's *National Policy on Fisheries Bycatch* individual fisheries have been addressing bycatch issues through the development of bycatch action plans.

Traditional Owner hunting of marine reptiles is a largely unquantified threat.

Predation of turtle eggs and hatchlings on beaches by pest animals such as feral pigs and foxes has been identified as of particular concern at Cape Upstart. It seems likely that this would be the case throughout the region but research is need to confirm this and look into ways of reducing pest impacts on turtles.

While informal agreements with community groups and Traditional Owners have been developed to help protect specific beaches from vehicle traffic. These agreements need to be formalised and beach management plans developed by local government authorities. These beach management plans enable local laws to protect resources from inappropriate activities.

Viruses, water quality, coastal development, habitat loss and degradation, lights, feral pigs, entrapment in fishing equipment, boat strikes are all important issues occurring in the region which impact on turtle survival.

5.2.4 Fish

Distribution

Fish are found in a variety of aquatic habitats from marine habitats such as reefs, seagrass meadows and macroalgae beds, to estuarine habitats, freshwater streams and wetlands. Great species diversity exists within these categories, especially for reefs, which are thought to support the greatest diversities in fish species.

Fish play an important ecological role as grazers, predators and scavengers, and they are the basis of recreational and commercial fishing industries. Important commercial fisheries operating in the area include reef (line) and inshore fin-fishing (estuarine and net). Commercial fishing tour operations and recreational fishing are also important industries in the region. Recreational fishing for barramundi is so popular in the region that 100,000 barramundi fingerlings have been released into the freshwater reaches of the Ross River (Townsville City Council, 2004a). Other waterways in the Burdekin Dry Tropics coastal region that have been stocked with barramundi include: the Burdekin Falls Dam and the Bowen River Weir (which is also stocked with sooty grunter). For more information on fisheries see Section 6.4.

Condition and trend

No fish in the Great Barrier Reef area associated with the Burdekin Dry Tropics region have been identified as threatened, vulnerable or endangered (Stokes and Dobbs, 2001). Limited regionally specific information is available for inshore and estuarine fish population condition and trend, even for commercially important species. Even less is known about the population condition and trends of pelagic fish species in the region. It is thought that fish harvesting levels are sustainable at the current level of exploitation and that the resource is presently fully utilised (GBRMPA, 1998; see also ecological assessments of Queensland fisheries – http://www.deh.gov.au/coasts/fisheries/qld/index.html).

The introduction of 'green zones' where activities such as line and bait fishing are not permitted is expected to reduce the harvesting pressure on local populations. However, this may have an adverse affect on some species by concentrating effort into smaller areas, thus increasing harvest pressure in areas close to urban centres.

Overall, the commercial fishery's catch in the Burdekin Dry Tropics coastal region has varied considerably in the past but in terms of both tonnes and gross value of production (GVP) ($), appears to be currently equivalent to 1988 values despite a decrease in effort over recent years (see Fig. 5, Section 6.4). The rate and impact of recreational catch is difficult to estimate, however it is thought to be relatively low compared to commercial fishing. More information about fisheries in the region is described in Section 6.4.

A comparison between beam trawls in northern Burdekin Dry Tropics creeks in 1987 and 1999 found a similar diversity of species (approximately 24 species) (Rasheed and Thomas, 1999). However, surveys of lagoons adjacent to the Burdekin River in 2000-2003 found a severe reduction in species diversity and potential productivity resulting from a loss of estuarine connectivity. It is therefore expected that the fisheries value of these water bodies would be significantly increased by restoring estuarine connectivity (Perna *et al*., 2004).

In 1999, fish surveys conducted in the upper reaches of Ross Creek and its associated stormwater drainage system found a total of 39 fish species present, with the greatest number of species found below the tidal gates of Ross Creek (Webb, 1999).

Environmental needs of fish vary greatly according to species and life-stage. However, several elements are important for a large proportion of species, such as, adequate water quality, high dissolved oxygen levels, the provision of food and essential habitats such as mangroves for juvenile stages, and the passage between important habitats (e.g. between breeding grounds and foraging sites).

A perceived threat facing the region's fish populations is that of unsustainable fishing practices, which may result from the lack of accurate stock data. However, recent DPI&F ecological assessments and their ensuing DEH accreditation (against the *Guidelines for the Ecologically Sustainable Management of Fisheries*) have demonstrated sustainable management of the fisheries in Queensland (see http://www.deh.gov.au/coasts/fisheries/). Declining water quality is also an issue for fish, directly impacting their health and degrading their seagrass, mangrove, macroalgae and coral habitats. Loss or modification of riparian vegetation threatens fish species that require these areas for breeding, shelter or as a nursery sites, such as mangrove jack (*Lutjanus argentimaculatus*). Studies conducted in the Burdekin River found that the relative abundance of adult fish species correlated with root mass abundance and other properties associated with riparian vegetation, (Pusey *et al*., 1998) highlighting the importance of riparian vegetation for freshwater fish in the region.

Declining water quality can result from coastal development exposing acid sulphate soils that, through a decrease in pH, cause a dramatic increase in aluminium concentrations which can lead to 'red spot' disease (epizootic ulcerative disease), potentially causing mass fish kills (Clarke, 1998). As with coral, reef fish can also be sensitive to temperature, becoming stressed and more susceptible to disease during high water temperature periods (GBRMPA, 1998b). Algal blooms in waterways threaten fish by causing a decrease in dissolved oxygen. Terrestrial weed species can also 'bloom' in riparian areas, choking creeks and reducing light penetration to also affect fish populations (see Perna and Burrows, 2005).

Inappropriately managed aquaculture operations can threaten native fish populations by increasing nutrient levels, introducing diseases and new foreign genetic material, and through habitat removal. Stringent management by local and State authorities attempts to ensure these potential impacts are minimised (Rob Coles and Jane Mellors, pers. comm.). Nutrient waste discharge from aquaculture facilities may result in algal blooms causing anoxia and sub-sequential fish kills and are another threat to fish populations of freshwater and marine environments. Freshwater fish populations are threatened by the construction of impoundments as they can alter flow regimes and restrict fish migration. Species which require access to freshwater, estuarine and/or saltwater at different stages of their lifecycle are particularly threatened by the construction of artificial barriers like weirs, bund walls, drop boards, culverts and poor water quality barriers in the Burdekin Dry Tropics region (Perna *et al*., 2004). Sufficient environmental flows are also vital for certain fish species.

Analysis of fish muscle tissue in Cleveland Bay in 1975 (7 µg/g wet weight) and 1999 (4.83 ± 2.82 µg/g) has found a slight decline in the zinc concentration in fish (Anderson and Roche, 2000). Zinc concentration in shark and ray tissue were also measured in 1999 but not in 1975 so a trend cannot be determined. However, zinc tends to be higher in sharks and rays (3.5-7.2 mg/g wet wt) than for fish but lower than squid and cuttlefish and crustaceans. Zinc levels in Cleveland Bay seafood consistently fall below the ANZECC maximum limit for zinc in seafood (Anderson and Roche, 2002).

Fish kill incidents for 2003 reported nine significant fish kills, including one that consisted of approximately 3,600 fish, in the Burdekin Dry tropics coastal region. Six incidents were attributed to very low dissolved oxygen content of waters in Ross River, Ross Creek, Curralea Lakes, Haughton River channel and 3 Mile Creek near Bowen, while three incidents have been the result of discarded by-catch in Paluma, Ross River and the beach between Blind Creek and Althaus Creek (EPA, 2003e). These fish kills have mostly occurred in artificially constructed waterways in residential developments. These waterways are often poorly designed for fish and have very high nutrient adjacent land-uses. Low dissolved oxygen levels therefore results from several causes such as nutrient stimulated algal blooms, elevated temperatures resulting from a decline in riparian vegetation shading, impoundments that limit water flow and cause stagnation, and high levels of organic content in waterways.

Infestations of noxious fish (such as *Tilapia*) have occurred in the region, most notably in Ross Dam but also in Ross River, Alligator Creek, Louisa Creek, Rowes Bay drainage system, Healey Creek and the Bohle River. There have been unconfirmed sighting of tilapia populations in Townsville Common and the Burdekin River (DPI&F, 2005a).

Summary of major issues and knowledge gaps

Limited regionally specific information is available for inshore and estuarine fish population condition and trend, even for commercially important species. Even less is known about the population condition and trends of pelagic fish species.

Environmental flows, obstructions to fish passage, fishing sustainability, dissolved oxygen levels in creek resulting in fish kills are all important issues occurring in the region which impact on fish survival.

5.2.5 Amphibians

Distribution

There are approximately 50 species of frogs known to occur in the Burdekin Dry Tropics coastal region (see Appendix D). As most frogs rely on access to freshwater to complete their lifecycles they are typically found inhabiting wet areas such as stream banks, swampy, flooded wetlands or stream channels. Species like the graceful tree frog (*Litoria gracilenta*), marbled frog (*Limnodynastes convexiusculus*) and the spotted marsh frog (*Limnodynastes tasmaniensis*), prefer swampy wetlands and marshlands while the chirping froglet (*Crinia deserticola*) inhabits creek beds. The endangered torrent tree frog (*Litoria nannotis*) has very specific habitat requirements and is virtually restricted to cascades and splash zones of fast-flowing streams at altitudes between 180 and 1,300 m. This endangered species is found in and north of Paluma (DEH, 2004). Another endangered frog, the Australian lace-lid (*Nyctimystes dayi*) has a similar distribution, being found preferentially in fast-flowing rocky streams in and north of Paluma (EPA, 2003b). Both species are present at Paluma National Park. The Mount Elliot nursery frog (*Cophixalus mcdonaldi*) is restricted to the Mount Elliot range and is therefore endemic to the region (Shoo and Williams, 2004).

The introduced cane toad (*Bufo marinus*) is also distributed throughout the region and tends to favour open lagoon environments as found in Magnetic Island, Mundy

Creek and Cromarty Wetlands (Townsville City Council, date unspecified) and areas where human disturbance has occurred.

Condition and Trend

There are four species of frogs in the Burdekin Dry Tropics coastal region that are listed under the *NC Act 1992*. These are the rare robust whistle frog (*Austrochaperina robusta*), the rare Mount Elliot nursery frog (*Cophixalus mcdonaldi*) and the endangered Australian lace-lid (*Nyctimystes dayi*) while the torrent tree frog (*Litoria nannotis*) is listed as endangered on both the *NC Act 1992* and *EPBC Act 1999* (EPA, 2004o).

The torrent tree frog is experiencing dramatic population declines in most parts of its range and especially at altitudes above 300 m. This population decline trend and resulting range contraction has been noted since 1990 (Northern Queensland Threatened Frogs Recovery Team, 2001). The Australian lace-lid has also undergone a substantial population decline, especially in the higher altitude areas of its range, since 1989. Populations at lowland sites remain stable, however, these sites are few in number (EPA, 2003b). Research on frog population declines has focused on rainforest stream species with little systematic surveying of species in other habitats (Northern Queensland Threatened Frogs Recovery Team, 2001). Monitoring projects around Townsville have found some frog population declines relating to habitat clearing (Northern Queensland Threatened Frogs Recovery Team, 2001).

Threats to the Burdekin Dry Tropics coastal region's frog population are varied and complex. A virulent pathogen, most likely a chytrid fungus has been proposed as the cause of many of the high altitude frog population declines and is supported by observations of sick and dying specimens (Northern Queensland Threatened Frogs Recovery Team, 2001).

Drought is another natural threat to frog populations. The artificial construction of dams and weirs has been recognised as a substantial threat to the region's frog populations as these large-scale impoundments result in the direct loss of important aquatic and riparian habitats and the imposition of barriers to frog movement. Such hampering of movement interferes with reproductive cycles and juvenile recruitment into adult habitats. Dams and weirs can also substantially alter stream flow patterns and channels may become chocked with sediments or weeds as a result, making them less suitable for frog inhabitance (Northern Queensland Threatened Frogs Recovery Team, 2001).

'The Action Plan for Australian Frogs' (Tyler, 1998) has identified aerial spraying of agricultural chemicals, particularly insecticides, as a major threat to frog populations. Habitat loss, through vegetation clearing, drainage of wetlands for land reclamation and the conversion of ephemeral ponds to dams for stock use causes obvious population declines. The introduced mosquito fish (*Gambusia holbrooki*) poses a threat to frog populations because it preys on frog eggs and tadpoles.

Threats to water quality such as acidification from acid sulphate soils, sedimentation, nutrient enrichment and pollution also threaten frogs. Potential threats include an increase in UV exposure from ozone layer depletion and global changes to air and water quality (Tyler, 1997).

Summary of major issues and knowledge gaps

Although there has been some research looking into the decline of frog populations within rainforest streams, there has been little systematic surveying of species in other habitats.

Habitat clearing, pathogens, environmental flows and connectivity of waterways, aerial spraying of chemicals, water quality degradation, global climate change and loss of ozone layer are all important issues occurring in the region which impact on frog survival.

5.2.6 Invertebrates

Distribution

The marine waters off the Burdekin Dry Tropics coast are home to a huge diversity of invertebrate organisms. These organisms can be found from inter-tidal zones to sub-tidal depths on almost every substrate and habitat type, including rocky, muddy and sandy substrates, reefs, seagrass and algae beds, parasitising other organisms and some are even small enough to live between sand grains.

Types of marine invertebrates present in the Burdekin Dry Tropics coastal region, with some examples, include:

- ascidians (sea squirts), which filter significant quantities of water through their tube-like bodies, straining plankton out of the water column;
- protozoans, single-celled and sometimes colonial organisms, exhibiting a huge diversity of forms and sizes. These microscopic invertebrates can be found in all habitats, from the water column and on substrates or other living organisms;
- cnidarians are marine invertebrates like jellyfish, coral, sea anemones, sea fans and hydroids. These organisms live in a variety of habitats and often utilise very different habitats for different stages of their life cycle;
- a huge variety of polychaete and oligochaete worms also live in Burdekin Dry Tropics marine habitats, including platyhelminths (flatworms), ribbon worms, round worms (nematodes), peanut worms and spoon worms;
- molluscs including clams, oysters, squid, octopus, nudibranchs, snails and shellfish live on soft and hard substrates, reefs, in underwater caves, on mangrove sediments and on mangrove trees themselves;
- crustaceans such as crabs, lobsters, prawns, barnacles and copepods are also present in the region, frequently found in supratidal to sub-tidal ecosystems and include several commercially important species (e.g. tiger prawns, mud crabs and blue swimmer crabs). The distribution of juvenile, penaeid prawns can be closely correlated with the distribution of seagrass meadows, to the extent that the dominant prawn species can even be correlated to the species and type of seagrass present with high biomass seagrasses like *Zostera* species supporting a greater diversity and abundance of prawns than lower biomass species (Rasheed and Thomas, 1999). In the past, seagrass meadows in Upstart Bay were particularly abundant in prawns, exhibiting significantly greater numbers than Cairns and Bowen seagrass meadows (Coles *et al*., 1992 cited in Rasheed

and Thomas, 1999). However, a more recent survey is needed to confirm if this is still the case and to allow for a trend to be detected;
- echinoderms found in the Burdekin Dry Tropics coastal region include seastars (starfish), sea cucumbers, brittle stars and sand dollars and
- Sponges, which are soft bodied organisms that filter their microscopic food from the water column.

Another type of marine invertebrate, adding to the dazzling array of types, colours, shapes and forms present, are the bryozoans, which are superficially similar to coral colonies but exhibit a much more complex microscopic structure (GBRMPA, 1996).

Exotic marine invertebrates have been known to enter Australian waters through the transfer and dumping of ballast water. Some of these pests have the potential to out-compete native species, bloom and even threaten human health with toxins. Surveys of invertebrates were recently conducted in the Port of Townsville as part of the Introduced Marine Pests Program which found several native crustaceans that were new to science, highlighting the need for a comprehensive survey of the region's invertebrates (Townsville City Council, 1999a).

The distribution of most of these organisms is yet to be comprehensively studied and attempts to do so have focused only on species of significant commercial value such as prawns or notorious pest species like the crown-of-thorns seastar.

Common terrestrial invertebrate groups include insects and spiders, worms and micro-organisms. Many of these terrestrial invertebrates inhabit soils, creating a wealth of often-overlooked biodiversity. Insects and spiders live in a vast array of habitats, and often require different habitats for different life stages.

As with marine invertebrates, there is very little precise data available concerning species lists, distribution, conditions and threats for most species with only the pest species receiving significant attention. One exception to this rule is butterflies, which have been surveyed around the greater Townsville area (including Paluma, Bluewater and Mt Elliot). Butterflies and other insects have been observed in gardens, native bushlands, wetlands and agricultural areas. Within these broad areas 'hot spots' of species diversity exist, including Mt Elliot, which is home to several endemic insect species. Surveys of flightless insect endemicity in the Wet Tropics region found the Elliot Uplands contained one of the greatest percentages of sub-regional endemism. Mt Spec and Halifax Bay Uplands were also noted for their importance as endemic flightless insect refugia, prompting calls for special attention to be paid for their conservation (Yeates *et al*., 2002).

A survey of the ant fauna of the Bowen Basin found 96 different ant species from around 28 genera in the area, most of which were common to semi-arid eastern Australia (Andersen and Spain, 1996).

Mosquitos can be a vector for blood-borne diseases such as Ross River Virus, Barmah Forest Virus, Encephalitis and Dengue Fever and therefore pose a human health risk. There are approximately 25 common species of mosquitos in the region, many of which are capable of transmitting diseases, especially the *Ochlerotatus vigilax* and *Culex annulirostris* species. There are also five mosquito species that are identified as being nuisance species: *Culex sitiens*, *Ochlerotatus vittiger*, *Ochlerotatus alternans*, *Verrallina funereal* and *Mansonia uniformis*. Areas in Townsville shire that tend to experience high mosquito populations include Rowes Bay, Pallarenda and Cungulla (Townsville City Council, 2004e). Aerial spraying programs have been developed by councils in an attempt to control the populations of disease-carrying and nuisance mosquito species.

Though occasionally pests, insects play a valuable role in ecosystem function as pollinators, scavengers, in aiding soil aeration, predating other insects that could otherwise reach plague proportions, and as a food source for many species of reptiles, birds and mammals. Spiders are also important for ecosystem function due to their role as predators, regulating the numbers of insect populations. An example of such a spider is the true Australian bird eater spider (*Selenotypus plumipes*), which is a very large tarantula that was first described at Major's Creek, south west of Townsville (Raven, 2004).

Condition and trend

Of the rich diversity of terrestrial and marine invertebrates mentioned above only a very small percentage of species have been studied for their population condition and trend and even then, much remains uncertain. Even as a broad group there are many knowledge gaps. No historical scientific monitoring data exist describing the species make-up and abundance or even the position and size of marine invertebrate communities, making it virtually impossible to detect ecosystem changes and trends. For instance, as no comprehensive data exists describing the communities before the advent of trawling it is difficult to determine and quantify the effects of such a pressure on the community's condition.

Only the status of a small number of commercially important species and some pest species have been documented. This includes the crown-of-thorns seastar (COTS), which has been the focus of an Australian Institute of Marine Science (AIMS) long-term monitoring program that surveys the Great Barrier Reef for the pest seastar. Recent surveys found that the highest numbers of COTS occurred in the mid-shelf reefs of the Townsville region and that new outbreaks had been detected in the Cape Upstart area early in 2004 (GBRMPA, 2004).

Data for commercial species exists in the form of fisheries catch information. See Table 10 for information concerning invertebrate trawling.

Table 10. Information on trawler catch of some marine invertebrates from the Burdekin Dry Tropics region.

Species	Tonnes	Boats	Days	GVP (Aus $)
Prawns	1,795	4,031	31,503	$22,414,300
Bugs	385	1,676	15,406	$4,538,800
Crabs	228	937	15,038	$2,159,500
Scallops	24	288	1,623	$482,400
Squid	9	455	2,473	$46,900
Cuttlefish	6	343	2,060	$29,600
Octopus	2	174	1,112	$12,500

Source: DPI&F (2004a) – see Appendix F.

Disturbance by trawling and pollution from run-off from the urbanised and agricultural catchment are thought to be the major threats to marine invertebrates (GBRMPA, 1996). Trawling is a fishing method that captures not only target species (like prawns and scallops) but also many nearby plant and animal species. These captured, non-target species are referred to as by-catch and often collectively weigh eight to ten times more than the weight of the targeted species haul. The by-catch is discarded at sea where the vast majority of the organisms die (GBRMPA, 2003). As marine invertebrates make up a significant but largely unquantified proportion of by-catch they are particularly at risk from trawling, especially if it occurs repeatedly at the same site. Trawlers are required to use by-catch reduction devices on trawl nets.

Research has shown inter-reef and lagoonal areas that are trawled regularly have significantly altered seabed communities. Areas that are trawled for 13 passes in a year (which is normal for high yielding areas) lose between 70% and 90% biomass of the seabed community annually (GBRMPA, 2003). Trawling also results in habitat fragmentation and even though many marine invertebrates are capable of long distance dispersal, habitat fragmentation has been identified as a major threat to the biodiversity of these organisms in the Great Barrier Reef (Australian Museum, 2002).

Physical disturbance through tourist activities, anchoring and dredging can also pose a threat to marine invertebrates. Increased sediment, nutrients and pollutants in run-off threaten estuarine and coastal invertebrate species, especially sessile species and those that feed by filtering particles from the water column. Damage from run-off can be caused directly by sediment smothering or by the long-term accumulation of toxicants in organisms. Damage can also be caused indirectly by degradation and loss of coral, seagrass and macroalgae, which are important habitats for a variety of invertebrate and vertebrate species.

Changes in sea temperature have also been recorded as causing stress, reproductive failure and the reduction of survival of marine invertebrates. A final factor, identified by the Independent Scientific Steering Committee for the Great Barrier Reef Marine Park which is not, of itself a threat, but is an issue nonetheless, is that current zoning regimes are not able to provide sufficient protection for the biodiversity and conservation of inter-reefal and lagoonal areas, which are prime habitat areas for marine invertebrates (GBRMPA, 2003).

Only a few terrestrial invertebrate species can be adequately discussed here due to a lack of information concerning the condition and trend of most terrestrial invertebrates. These species include mosquitos, butterflies and pests.

The prevalence blood-borne diseases in the region, such as Ross River Virus and Dengue Fever, has prompted Townsville City Council to implement an aerial spraying program. Triggers for the spraying program are environmental factors such as rainfall events, wind direction and velocity and 3.48 m tides. The actual mosquito or potential mosquito population number and conditions are not directly measured (Townsville City Council, 2004d). It is expected that due to their strong ability to recover, the populations of mosquitos are relatively healthy, though they do follow a ‘boom and bust’ cycle.

Anecdotal evidence suggests that butterfly populations are increasing in the area due to the re-establishment of native plants in restoration areas and gardens (Valentine, 1998).

Crazy ants, a potentially harmful exotic ant species, have been detected at the Townsville Port. Fortunately, a Queensland Government-led response has since eradicated the species, with the area now being declared crazy ant free (Queensland Farmers Federation, 2003).

The sugar growing areas regularly experience outbreaks of pest insects such as the grey-backed cane grub – chemical pesticides are often ineffective on this pest due to a build up of resistance (Taylor, 1998). Silverleaf whitefly is a major cotton pest in the region (Australian Cotton CRC, 2004).

The most significant threats to the terrestrial invertebrates are habitat loss and fragmentation through urban development, mortality of non-target species by agricultural and mosquito control program pesticides, competition from invasive species and, in some cases collection and trafficking by the pet or collection trade. A greater understanding of the status of terrestrial invertebrates is essential for their condition and trend to be determined.

The pesticides DDT (and its metabolites), dieldrin and heptachlor epoxide have been detected in crabs from the Ross River and Ross Creek estuaries. Concentrations of copper, cadmium, mercury and lead were also relatively high in crabs from Ross Creek compared to other estuaries along the Queensland east coast (Mortimer, 2000).

Summary of major issues and knowledge gaps

The distribution of most marine and terrestrial invertebrate animals is yet to be comprehensively studied and attempts to do so have focused only on species of significant commercial value such as prawns or notorious pest species like the crown-of-thorns seastar.

Of the rich diversity of terrestrial and marine invertebrates occurring in the region only a very small percentage of species have been studied for their population condition and trend and even then, much remains uncertain. Even as a broad group there are many knowledge gaps. No historical scientific monitoring data exist describing the species make-up and abundance or even the position and size of marine invertebrate communities, making it virtually impossible to detect ecosystem changes and trends.

As marine invertebrates make up a significant but largely unquantified proportion of by-catch they are particularly at risk from trawling, especially if it occurs repeatedly at the same site. However, the exact impact and level on risk remains unknown, though individual fisheries have been addressing bycatch issues through the development of bycatch action plans.

Sea temperature change, habitat loss and fragmentation through urban development, mortality of non-target species by agricultural and mosquito control program pesticides, competition from invasive species, collection and trafficking by the pet or collection trade, and the loss of estuarine ecosystems due to altered flow regimes are all important issues occurring in the region which impact on invertebrate animal survival.

5.2.7 <u>Plants</u>

Distribution

The plants of the Burdekin Dry Tropics coastal region can be divided into a number of types based on their distribution. Marine plants include seagrasses, mangroves and saltmarsh. There are about 25 different species of saltmarsh plants in the coastal region (Townsville City Council, date unspecified – Natural Assets Database) with samphire, ruby saltbush, sedges such as the saltwater sedge (*Cyperus scariosus*), and salt tolerant grasses like saltwater couch (*Sporobolus virginicus*) featuring prominently in these habitats.

Mangrove diversity in the Burdekin Dry Tropics coastal region is high, with about 17 species of mangroves and mangrove associates present (Qld Herbarium, 2004). Generally, the stilt rooted *Rhizophora* dominates the mangrove canopy, especially on the foreshore edge of waterbodies. *Avicennia* sp. also tend to be found colonizing the foreshore edge of waterbodies. Further landward other species such a *Bruguiera* sp., *Excoecaria agallocha*, *Xylocarpus mekongensis*, *Ceriops* sp. and *Osbornia octodonta* can also be found (Danaher, 1995).

Seagrass species found in the region include *Zostera capricorni*, *Halophila tricostata* and *Halodule uninervis*. Freshwater marshes tend to be dominated by bulkuru sedge (*Eleocharis dulcis*) and a range of other aquatic species (Spain and Blackman, 1992).

The distribution of native terrestrial vegetation consists of the remnant stands seen in Map 6. Hot spots for ecologically valuable remnant vegetation include Alligator Creek, Mt Stuart, Paluma and Saunder’s Beach closed forest (Silke and Cumming, 1998). Endemicity in the region is mainly associated with highland areas and refuges, including Mt Elliot, Mt Stuart and Magnetic Island. Endemic species include the shrub *Babingontina papillosa*, which only occurs at Mt Elliot and Cape Cleveland in Bowling Green Bay National Park. *Eucalyptus paedoglauca*, also known as Mt Stuart Ironbark is an endemic eucalypt species found only on Mt Stuart. *Croton magneticus* is another endemic species to the Burdekin Dry Tropics coastal region, growing on both Magnetic Island and Mt Stuart and has been classified as vulnerable. *Grewia graniticola* is considered a near-endemic to the region as it is found on Magnetic Island, Cape Cleveland and in two areas near the region (Gloucester Bay and Mingela Bluff) (Townsville City Council, date unspecified).

Eucalypt woodlands to open forests dominate the coastal terrestrial landscape with some non-eucalypt coastal communities and heaths. Coastal dune communities, mangrove systems and saltmarshes dominate the coastal and island interface with the sea. Further inland vegetation classes are primarily non-remnant in the Burdekin Haughton Water Supply Scheme area with eucalypt woodlands and open forests dominating in the southern areas. The northern areas have a greater range of vegetation types with *Melaleuca* sp. low open woodlands and rainforest and scrubs. Remnant riparian/floodplain eucalypt open forest and woodlands areas are far more abundant inland than near the coast (see Map 7).

Condition and trend

Within the region, 20 species of terrestrial plant are considered rare, six are considered vulnerable, and one, the flowering shrub *Babingtonia papillosa*, is considered endangered. Some terrestrial species that are conservationally significant, such as the woodland tree *Albizia canescens*, were once very common in the region but due to clearing for timber, agriculture or development, have since become rare (Townsville City Council, date unspecified). A list of the conservationally significant plants for Burdekin Dry Tropics coastal region is given in Appendix E. Two plant species occurring in the region are classified as globally threatened: *Bonamia dietrichiana* and *Livistona drudei* (Blackman and Spain, 1992).

State-wide surveys of remnant vegetation have concluded that between 61-100% remnant vegetation remains in the majority of the coastal Burdekin Dry Tropics catchments as of 2001, except for the area of Cape Bowling Green, which contains only 51-60% remnant vegetation (Accad *et al*., 2003). This area also exhibited one of the highest land clearing rates in the State from 1997 to 1999. The clearing rate of this area has since dropped, only to be replaced by a sharp increase in the clearing rate of the Bohle River catchment area in 1999-2000 (Accad *et al*., 2003). Although there are many remnant vegetation patches that experience some level of protection, up to 90% of native vegetation communities are not represented in conservation areas, with less than 2% of regional ecosystems in the Bowen-Broken represented in conservation areas (Greening Australia, 2003).

There is a considerable area of remnant vegetation in the Burdekin Dry Tropics coastal region that is classified as 'of concern' under the *Vegetation Management Act 1999.* Sections of vegetation on Cape Cleveland, the Burdekin floodplain, Cape Pallerenda, Upstart Bay, Cape Upstart, Gloucester Island, and most vegetation on Magnetic Island and in Paluma National Park are classified as 'of concern' (see Map 6). Some remnant riparian vegetation in the Burdekin Dry Tropics coastal region is classified as endangered, this is further detailed in the Section 5.1.15.

Saltmarsh condition varies greatly within the region with catchments such as Ross River exhibiting a generally poor condition of saltmarsh and extensive loss in most sections, whereas the adjacent Haughton River catchment contains less disturbed saltmarsh (Bruinsma, 2001).

Surveys conducted as part of the GBRMPA State of GBR World Heritage Area Reporting suggest that no major declines of mangrove area have occurred in the region over the last 40 years (GBRMPA, 1998). However, localised loss and damage has occurred from extensive reclamation activities, undertaken in the construction of ports, marinas and the like.

Seagrass meadows in the region are described as healthy but vulnerable to threats such as tropical cyclones and water quality declines (Mellors, 2004).

The plants of the Burdekin Dry Tropics coastal region are primarily threatened by weed invasion, hot fires and/or land clearing. One of the most notorious weed species is paragrass, which has become a major threat to native grasses in coastal wetlands (Capp, 2004). Concern has been raised especially for the fate of the rare water plant *Aponogeton queenslandicus* as it is being smothered by paragrass and another weed, hymenachne, in several wetlands (Vidler, 2003). Replacement of native plants by weeds can also have a detrimental effect on animals that depend on their growth for habitat and nutrition, for example, wader birds can experience local population declines due to changes in coastal wetland vegetation (Vidler, 2003).

Land clearing is also a major threat to Burdekin Dry Tropics coastal plant species, both directly through the removal of vegetation and indirectly through fragmentation. Evidence of severe habitat fragmentation can be found in the lower Burdekin River sub-catchment and the coastal areas of Townsville (Greening Australia, 2003).

The condition and trend of most aquatic plants, particularly at the species level, is poorly known and an important knowledge gap for the region.

Summary of major issues and knowledge gaps

The condition and trend of most aquatic plants, particularly at the species level, is poorly known and an important knowledge gap for the region.

Weed invasion and clearing are important issues occurring in the region which impact on plant survival.

5.3 Water Flow and Quality

5.3.1 <u>Water Flow Regime</u>

Description

Dominated by wet summers and dry winters, peak flows occur from December to April with low, or negligible, flows from May to November. Smaller tributaries may cease flowing altogether during the dry season. In general, waterway flow in the Burdekin Dry Tropics region is dominated by large cyclone- or monsoon-driven events, followed by extended dry periods. In addition to this pronounced annual fluctuation, there is a marked variability from year-to-year – series of wet years are followed by series of low flow (dry) years.

A flood history for the Burdekin River reconstructed by Isdale *et al*. (1998) using coral cores extends back more than 300 years, and suggests that stream flow over the last 100 years was generally lower and less variable than in the preceding two centuries.

The major surface water use in the coastal area is for irrigation, which occurs principally on the lower Burdekin River floodplain. Water supplies are also provided for power generation, industry and mining in the central and south-eastern sections of the area, and for urban use/development in the region. Major water resource infrastructure in the area includes dams, weirs, channels and pipelines, sand dams,

Pumping station between Alva and Ayr
(David Scheltinga)

pumps and pumping stations for extracting water, and stream channels. Water supplies to irrigation areas and other supply locations along the river system are reticulated between storages and diversion/extraction points via supplemented river reaches and artificial channels and pipelines.

Change in flow can occur due to changes to run-off brought about by land-use and is usually assessed by comparing the ratio of flood flow to low flow, as well as flow amount and duration. Changes in flow patterns also occur due to water extraction for irrigation.

A river's flow affects all aspects of its condition and character. The characteristics of the flow determine sediment movement, channel width, channel depth and bank morphology. Flow affects water quality and the type and variety of aquatic and riparian habitats, as well as fish breeding patterns and reproductive success. Flow characteristics include not just the volume of water, but also the pattern of its delivery, such as flooding or low flows in the dry season.

Hydrologists usually distinguish between flood flow and low flow ('base flow'). Flood flow is mainly affected by run-off generated during major storms and cyclones and is responsible for flooding, bedload and washload transport. Base flow is the flow generated by groundwater discharge. In major rivers, base flow generally persists throughout the entire year, while smaller rivers and streams usually cease flowing during the dry season.

The use of land and water resources significantly affects flow regimes. Changes in flow regime may:

- affect the reproduction/productivity of marine, estuarine and freshwater species;
- reduce seasonality and flooding;
- change riparian and flood plain vegetation;
- cause channel erosion with increasing water velocities or accretion when water velocities decrease;
- reduce base flow, leading to poorer ambient water quality; and
- cut off or reduce access to habitats.

Condition and trend

River flow in the region is affected by several dams (Burdekin Falls Dam (Lake Dalrymple), Eungella Dam and Paluma Dam, Ross River Dam (Lake Ross)), many weirs (six in the Belyando/Suttor, two in the upper Burdekin and five in the lower Burdekin, three weirs in the Ross River, two weirs in the Haughton River) and numerous extraction pumps (about 26 in the Belyando/Suttor).

Val Bird Weir on the Haughton River (CSIRO)

The Department of Natural Resources and Mines maintains a stream-gauging network to determine river flow, and data is now easily accessible at http://www.nrm.qld.gov.au/watershed. Consequently, good hydrographic and hydrologic data is available for the Burdekin Dry Tropics region with most of the major sub-catchments being well gauged. Fairly robust regionalisation techniques have also been developed recently that allow a reasonable extrapolation of hydrologic characteristics to ungauged streams (Post and Croke, 2003; Post, 2004). However, this said, extrapolated data is no match for real data and more gauging stations in the right places would benefit our knowledge of river flow in the region.

The construction of dams and weirs greatly modifies the duration and pattern of a river's flow. Flow conditions in the lower Burdekin River have changed dramatically following the completion of the Burdekin Falls Dam in 1987. Before construction of the dam, the Burdekin River at Clare Weir flowed for around 95% of the time; however, it now flows all year round. In addition to flowing all year round, low flows below the dam have been elevated, while medium to high flows have been reduced. For example, before the dam was constructed, for 20% of the time, flows were 2 cumecs (cubic metre of water per second) or less. However, after construction of the dam, for 20% of the time, flows are now 10 cumecs or less, an increase of around 8 cumecs during low flow periods (Post, 2004). Consequently, the river has changed from an intermittently flowing river into a perennial system with elevated dry season base flows and a reduced magnitude of flood flows.

The Ross River is a significant natural feature of North Queensland's most densely populated urban centre, Townsville-Thuringowa. There are a number of pressures impacting the river, which require management intervention to ensure the waterway environs are not detrimentally affected. Flow of the Ross River is heavily regulated due to the Ross River Dam and three weirs (Black, Gleesons and Aplins) to maintain water levels along the river course. Up until the 1970s the weirs were the main water supply for Townsville and Thuringowa. After Ross Dam was constructed it became the main source of raw water with treatment carried out at the Douglas Water Treatment Plant. Black Weir has been retained by NQ Water as an emergency water supply with Aplins Weir and Gleesons Weir transferred to Townsville City Council in 2001.

Although it is clear that the change to flow regimes (at least below the Burdekin Falls Dam) has altered in-stream habitats and impacted upon freshwater, estuarine and marine organisms, we have very little data to quantify the extent of these impacts. There is also little information on how much the changed pattern and frequency of freshwater pulses into the GBR lagoon may have affected the nearshore zone.

Extraction of water for irrigation reduces the overall amount of water available for flow. Depending on the timing and quantities of extraction, this can significantly affect the flow regime. Excess irrigation water taken from the lower Burdekin River is put onto farms and then drains into smaller coastal creeks and wetlands, changing their flow regime. This tail water elevates the water level in these creeks and wetlands as well as altering their water quality (most tail water is very turbid and may have elevated nutrients and contain pesticides (Müller *et al*., 2000)).

Another flow-related issue is the reputed loss of groundwater springs. The Burdekin Dry Tropics region has many springs that flow year-round, creating valuable aquatic habitat in an otherwise dry catchment. Anecdotal evidence suggests that there has been a reduction in spring flow and some springs have dried up. Verification of this change and identification of its causes is flagged as a key knowledge gap.

Ongoing concerns over increasing groundwater extractions also led to the construction of the Giru Weir (1,020 ML) in 1977 and the Val Bird Weir (615 ML) in 1983, on the Haughton River, to improve groundwater recharge in the Giru area. Both of these weirs are now owned and operated by SunWater. In addition to enhancing groundwater recharge, both Val Bird and Giru weirs provide impoundment areas that are directly accessed by surface water users.

5.3.2 In-stream Water Quality

Water quality is a central issue for the Burdekin Dry Tropics region. When assessing impacts of water quality on freshwater, estuarine and marine ecosystems, it is necessary to differentiate between different types of flow events (i.e. flood (high flow) versus low (base flow)), because this can affect the movement of sediment, nutrients and other contaminants like pesticides. Floods determine the total loads of sediments and nutrients that enter the marine environment (Roth *et al*., 2002). Good ambient water quality during low flow is critical for freshwater habitats. Both the marine and freshwater environments are strongly affected by changes to flow as a result of current land management practices and the use of water resources (e.g. irrigation).

There are reasonable estimates of sediment and nutrient delivery to the nearshore environment of the region for the Burdekin River. Through catchment modelling there is also a reasonable understanding of the spatial distribution of sources of the materials, as well as patterns of deposition. However, there are very few data on actual sediment, nutrient or other contaminant concentrations/loads in the rivers, making validation of discharge models difficult. More importantly, this indicates that we can anticipate serious difficulties in determining reliable water quality benchmarks from which to develop future water quality targets. The absence of such data is compounded by our current inability to quantify the impact of poor ambient water quality on aquatic processes (Roth *et al*., 2002).

Water quality covers a broad range of issues (such as flood flows versus low (ambient) flows), and different people and institutions mean different things when using the term ‘water quality’. Therefore, it is important to clearly define which aspect of water quality is being assessed.

Flood Flow In-stream Water Quality

Bedload Events

Description

Bedload events refer to the off-site impact of coarse sediments moved along the riverbed during flooding. Bedload events have little impact on terrestrial systems, except in the case of over-bank floods, where floodplain deposition might affect nearby terrestrial systems. Bedload sediment is deposited in streams, estuaries or very close to the shoreline and does not penetrate very far into the GBR lagoon.

Sedimentation occurs naturally in streams, wetlands and along coastlines and changes in the quantity and composition of the sediments have potentially adverse consequences for the ecosystem. The Burdekin Dry Tropics region is largely an event-driven system (i.e. dominated by major cyclones) and most of the bedload leaves the catchment during brief, major flood events occurring every five to twenty years (Roth *et al*., 2002).

Coarse sediments determine the shape of the coastal environment. They are rapidly deposited close to the coastline, and then reshaped by the currents and winds to form beaches and dune systems. Cape Bowling Green was formed, and is replenished, by coarse sediments from the Burdekin River.

Within streams, increased delivery and deposition of sediments has the potential to fill waterholes and deeper sections of streams, resulting in reduced aquatic productivity and loss of aquatic habitats. The flow regime may change, causing flooding and breakouts due to the river channel's reduced capacity to carry floodwaters. Dams and weirs trap bedload sediment and reduce their storage capacity. Bedload sediment is unlikely to pass through Lake Dalrymple, reducing sediment delivery to stream reaches below the dam and potentially resulting in reduced bedload reaching the coast. This may contribute to coastline erosion. Reduced sediment delivery alters stream morphology by increasing bank erosion and deepening the river channel. Thus, some sections of the catchment may experience increased sedimentation whilst those below the dam receive less bedload sediment (Roth *et al*., 2002).

Condition and trend

Measuring bedload, particularly in episodic, flood-dominated systems like the Burdekin River, is technically difficult and expensive. Consequently, very little bedload transport data exists for rivers in the Burdekin Dry Tropics region. Most of our understanding of bedload in the region is derived from general scientific and engineering principles and data from similar river systems elsewhere.

Given that bedload transport principles are reasonably well understood, it is possible to model bedload transport and deposition processes in a river network, provided we have data on river flows (discharge) and the amount of coarse sediments delivered to individual river reaches by soil erosion processes. As some of this data is available for the Burdekin, various modelling exercises have been undertaken for the whole basin as well as for individual sub-catchments (Prosser *et al*., 2001, 2002).

River reaches in the upper catchments generally show low rates of bedload deposition due to their higher flow energy, indicating that coarse sediments will be readily transported downstream. In flatter landscapes associated with the coast, rates of bedload deposition are predicted to be significantly higher, potentially affecting in-stream aquatic ecosystems by processes such as the burial of previously permanent waterholes. Critical data and further understanding of the processes are still required for coastal waterways.

<u>Washload Events</u>

Description

Washload includes the fine sediments suspended within the water column, and the associated turbidity, particulate and dissolved nutrients and contaminants (e.g.

pesticides), mobilised during cyclones or heavy monsoonal rainfall. The effects of washload events are mainly restricted to marine and freshwater aquatic ecosystems.

Clay particles and colloids (particles smaller than clay) are usually the main fraction of suspended solids contained within washload. Clays and colloids adsorb soil nutrients and bind organic matter. Consequently, washload is the main way in which particulate nutrients from the land reach aquatic environments. Washload further contributes to nutrient delivery because it also includes all forms of dissolved nutrients (e.g. nitrate and ammonia originating from inorganic fertilisers). Other particulate matter suspended in washload consists of fine organic particles (detritus). This is a major source of energy and food for many aquatic organisms.

Due to the high settling times associated with suspended particles contained in washload, it can be transported over large distances and delivered far out into the Great Barrier Reef lagoon during floods. Major flood plumes from the region, while predominantly remaining in the nearshore zone (i.e. within 20 km of the coast) have been shown to move as far north as Cairns under certain circumstances, and are known to persist for many days. Smaller, more frequent plumes will extend as far as the Palm Island Group. However, there is also evidence that much of the suspended sediment load flocculates and settles when salinity levels reach around one-third the strength of seawater. This usually happens within a few kilometres from the river mouth. Thus flood plumes only carry a fraction of the total washload beyond this point. Most fine sediments that settle out before this are redistributed by coastal hydrodynamics along the shoreline and trapped in estuaries and northerly facing embayments (Roth *et al*., 2002).

There are several estimates of the quantity of sediments being discharged into the GBR lagoon from the Burdekin Dry Tropics region. Extrapolations of estimates by Miles Furnas from the Australian Institute of Marine Science indicate that maximum annual sediment discharge ranges from 0.2 to 20 million tonnes, with 1974 and 1991 being the only years on record where sediment discharge was greater than 10 million tonnes (Miles Furnas, pers. comm.). The long-term average annual sediment discharge is about 3.8 million tonnes. This represents about 20-40% of the total sediment being delivered to the GBR lagoon. As a result, washload, and its associated nutrients and other contaminants (e.g. pesticides), is the main impact of terrestrial run-off on nearshore zones of the Great Barrier Reef lagoon. However, it is important to realise that the majority of the load is delivered in a few, infrequent major flood events, interspersed by many years of low sediment discharge and reworking of these sediments.

The most recent reviews of current scientific understanding are almost unanimous in their assessment, that if left unchecked, further increases in the rate of sediment, nutrient and other contaminant delivery to the GBR lagoon will be detrimental for nearshore reefs and seagrass meadows (McCullock *et al*., 2003). This is borne out by evidence from Hawaii and Florida, where a decline in reef systems has been clearly associated with nutrients originating from terrestrial run-off. Increased levels of sediments and nutrients are not likely to have direct impacts, but there is evidence that increased levels of nutrients (in particular dissolved nitrogen) in combination with a change in the composition of suspended sediments will reduce the ability of corals to recover from damage caused by natural events such as bleaching and cyclones (Roth *et al*., 2002).

Lake Dalrymple probably traps only a small proportion of the washload transported down the Burdekin River system during large flood events (Faithful and Griffiths, 2000). The washload trapped in Lake Dalrymple by the Burdekin Falls Dam stays suspended in the water column throughout most years, giving the dam its brown, turbid appearance. As this water is released downstream for irrigation throughout the year, the river below the dam is also essentially turbid when it would otherwise have greater clarity. This turbid water is also redistributed into normally clear coastal creeks and wetlands on the floodplain. The delivery of turbid water is increasingly an issue for the two Water Boards operating in the Burdekin delta, because the turbidity reduces the efficiency of artificial recharge pits designed to replenish the delta aquifers from which irrigation water is being extracted (Arunakumaren *et al*., 2000; Narayan, 2003).

Condition and trend

Recent findings from the analysis of coral cores, using innovative tracing techniques, indicate increased washload as far back as the 1870s, when livestock were introduced into the region. This suggests that grazing has been, and continues to be, the major source of sediments delivered by washload events. There is some evidence that sediment discharge has increased post-European settlement (McCulloch *et al*., 2003). Studies of sediments in the nearshore zone of the Burdekin estuary (Cape Bowling Green Bay) demonstrated a two-fold increase in mud accumulation and associated heavy metals dating from the goldmining activities in the 1890s until recent times. Several other studies, including the National Land and Water Resource Audit (NLWRA) work, confirm that sediment export through washload delivery has increased about four-fold since European settlement. While the Burdekin River catchment also exports great quantities of nutrients annually, nutrient export is relatively low, on a per hectare basis, when compared to other Australian streams. However, the degree of impact of event-driven washload on marine and freshwater environments is still uncertain and requires further study. In the meantime, it is advisable to adhere to the precautionary principle and reduce the level of washload transport during flood. This requires knowledge of where the main sources of washload are located in the catchment, in order to allow for targeted management intervention (Roth *et al*., 2002; Roth, 2004).

Information available about the composition of washload during major flow events is sparse and episodic. Different types and sources of sediment require different strategies for management. Sand, silt, clays and colloids have entirely different chemical composition, are transported at different times and are strikingly different in their impact on the receiving environments. Therefore, in addition to determining total sediment loads, future work must include a closer examination of the sediment itself.

Low Flow (Ambient) In-stream Water Quality

Description

Ambient water quality refers to the quality of the water during normal, low flow (i.e. non-flood) conditions (base flow). Ambient water quality is determined by parameters such as turbidity, pH, temperature, salinity, nutrient and contaminant (e.g. pesticide) concentrations, and dissolved oxygen levels. Given that these ‘base flow’ conditions represent the typical or average state of a waterway, the ambient water quality may have a far greater bearing on aquatic species than the episodic flooding events.

In contrast to major floods, ambient water quality is determined mainly by local effects and the accession of nutrients through groundwater discharge into rivers. Ambient water quality determines the health of freshwater and estuarine ecosystems. A steady supply of nutrients and surface water contaminants in moderate concentrations (chronic impact) may have greater impact than a single, large, infrequent pulse. This is because returns of excess irrigation water (‘tail water’), and smaller rain events, wash sediment and nutrients into local streams where they persist. The chronic impact of poor ambient water quality is greatest as base flow ceases and rivers contract to a series of permanent waterholes during the dry season. In addition to these effects, there is evidence that the deterioration of water quality as a result of cattle and pig loitering in waterholes may be important in determining the health of aquatic ecosystems.

During periods of elevated water flow, water quality is the same, or very similar, along the river. It alters where new rivers enter the stream. When the floods pass, and flows return to normal or even cease, sites begin to exhibit individual characteristics. Some may remain turbid all year while others may become clear. Ambient conditions will be different each year depending on rainfall patterns. Because of this, substantial variation between waterholes and between different years, ambient water quality is very variable. Some waterholes naturally have poor water quality and are vulnerable to disturbance, whilst others are more tolerant of disturbance.

Major impacts of ambient water quality include: increased turbidity blocking sunlight and affecting ecological processes; increased nutrient levels contributing to eutrophication, and decreased oxygen levels that can be lethal to fish and other organisms (‘fish kills’).

Condition and trend

Accessible data about water quality in the Burdekin Dry Tropics coastal region is limited, particularly data required to establish a statistically sound baseline. The AUSRIVAS program, which monitors river health parameters across Australia, has carried out episodic monitoring of river health at a few sites in the Burdekin River catchment. A State of the River Condition report, produced for other catchments across Queensland, has not yet been published for the Burdekin catchment.

Data collected by the State of the Rivers (SOR) team during their survey of 57 sites in the Burdekin catchment was used to supplement the Technical Advisory Panel’s (TAP) site investigations. The data collected during site inspections by the TAP and the SOR team was one of the key data sources for the TAP's condition assessments for the following ecosystem components: geomorphology, hydraulic habitat, riparian vegetation and aquatic vegetation. Key data sources for the condition assessment of water quality in the plan area were existing NR&M and Australian Centre for Tropical Freshwater Research (ACTFR) water quality data sets, catchment condition information, ACTFR water quality and ecological processes research, and a review of ecotoxicology literature and water quality guidelines (Melissa Browne, pers. comm.; NR&M, 2005).

More continuous records are available for sub-catchments in the Townsville Field Training Area (ACTFR monitoring) and Barratta Creek. Data about nutrients is reported in the National Land and Water Resources Atlas (NLWRA, 2001). Available information demonstrates the very poor oxygen conditions of wetlands on the floodplain and the likely causative agents and processes (Roth *et al*., 2002). Although the Burdekin Dam is the source of elevated turbidity in the lower Burdekin and the floodplain areas, the effect of this elevated turbidity on the 159 km of river reach below the dam, as well as the associated floodplain distributary channels and wetlands has yet to be evaluated.

Yearly Sediment and Nutrient Exports from the Burdekin Basin

Description

The Burdekin basin is dominated by the Burdekin River, one of the largest rivers in the GBR catchment area. The smaller drainage basins in this region are the Haughton and Don Rivers with several coastal streams also present, such as Barratta Creek, Rocky Ponds Creek, Elliot Creek and Euri Creek.

Condition and trend

There have been focused studies on aspects of water quality in the Burdekin catchment such as limnology of Lake Dalrymple, groundwater in the delta area, run-off from beef pasture, but no comprehensive study of the whole catchment has been carried out. Sediment delivery from the catchment to the river and coast has been modelled by Prosser *et al*. (2002) and a comprehensive report on the sources of sediment and nutrient exports to the GBR world heritage area has been published by Brodie *et al*. (2003). A short term modelling project run by NR&M is currently underway using improved baselayer datasets to further the water quality understanding in the Burdekin catchment. This project is working with NRM bodies along the Great Barrier Reef coast so that useful water quality targets can be developed (Lex Cogle, pers. comm.).

Table 11 lists the modelled (Brodie *et al*., 2003) and previous results of suspended sediments (SS), total nitrogen (TN) and total phosphorous (TP) loads from the Haughton, Burdekin and Don rivers to the coast.

Table 11. Suspended sediment and nutrient loads from the Burdekin basin to the coast.

Author	Haughton River			Burdekin River			Don River		
	SS (kt/y)	TN (t/y)	TP (t/y)	SS (kt/y)	TN (t/y)	TP (t/y)	SS (kt/y)	TN (t/y)	TP (t/y)
Brodie *et al*. (2003)	286	887	154	2808	9622	1922	408	976	205
Furnas (2003)	270	621	122	3770	8633	1695	270	629	124
Belperio (1983)	300	-	-	3600	-	-	250	-	-
Moss *et al*. (1992)	-	-	-	-	-	-	175	-	-
Neil *et al*. (2002)	-	-	-	-	-	-	225	-	-
Horn *et al*. (1998)	-	-	-	-	-	-	134	-	-
NLWRA (2001)	170	-	-	2440	-	-	510	-	-

Source: Brodie *et al*. (2003).

Yearly Sediment and Nutrient Exports from the Black and Ross River Basins

Description

These basins consist of a number of streams and small rivers between Ingham and Townsville. The major streams are Crystal Creek, Ollera Creek, Rollingstone Creek, Bluewater Creek, Black River, Bohle River, Ross River and Alligator Creek.

Condition and trend

Land-use on these catchments varies widely with the upper reaches of most streams in rainforests of the Wet Tropics World Heritage Area or Mt Elliott. The lower reaches are dominated by sugarcane and agriculture/horticulture cultivation in the north and urban and industrial development in the south (Townsville and Thuringowa). Beef grazing is also an important land-use in the Ross catchment. The Ross River is heavily regulated with one major dam (Lake Ross) and three weirs. There is little published work on water quality for these streams (see Horn *et al*., 1998 for Black River). Brodie *et al*. (2003) has summarised suspended sediment and nutrient loads for the Black and Ross Rivers (see Table 12).

Table 12. Suspended sediment and nutrient loads from the Burdekin basin to the coast.

Author	**Black River**			**Ross River**		
	SS (kt/y)	**TN (t/y)**	**TP (t/y)**	**SS (kt/y)**	**TN (t/y)**	**TP (t/y)**
Brodie *et al*. (2003)	161	571	99	80	307	44
Furnas (2003)	140	319	62	180	411	81
Belperio (1983)	250	-	-	250	-	-
Horn *et al*. (1998)	67	-	-	-	-	-
NLWRA (2001)	80	-	-	60	-	-

Source: Brodie *et al*. (2003).

5.3.3 Groundwater Quality

Description

Groundwater is the water that occurs beneath the earth's surface in permeable rock formations including unconsolidated sediments and fractured bedrock. The groundwater resources in the Burdekin basin fall into two main categories (1) groundwater extraction which results in a reduction in water table levels, and (2) groundwater recharge which results in maintenance of the water table level or even a rising water table as has occurred in the Burdekin Haughton Water Supply Scheme area (Map 26).

Groundwater results from rainfall that infiltrates and moves through the soil before it discharges into springs, seeps, wetlands, river channels or the ocean. It can play a key role in the maintenance of river base flows during the dry season. Contamination of groundwater by nutrients or other contaminants (such as pesticides and heavy metals) may have an on-site impact on the quality of the groundwater itself, as well as potential off-site impacts via the discharge of groundwater into rivers or use of groundwater for irrigation.

In order for agricultural nutrients and contaminants to be leached into groundwater, they have to be present in soluble form and there has to be some drainage of soil water below the root zone during some part of the year (usually the wet season or when excess irrigation is applied). The key nutrient at risk of being leached is nitrogen in the form of nitrate. In very sandy soils, with low clay and organic matter content, other nutrients (mainly cations such as ammonium, potassium and calcium) are at risk of being leached. Phosphorous is usually not leached. Soluble pesticides at risk of being leached include herbicides like atrazine, and to a lesser degree, diuron.

Conditions promoting the entry of nutrients and contaminants to groundwater are commonly encountered in intensive agricultural systems such as irrigated sugarcane and horticultural crops. Industry (and urban areas) can also be sources of pollutants to groundwaters.

Condition and trend

The unconsolidated sediments associated with the Burdekin delta represent a major alluvial aquifer system. Almost 2,000 large production bores extract around 330,000-550,000 ML/year of groundwater from this aquifer for sugarcane production. The aquifer is very dynamic and natural recharge and discharge occurs in response to seasonal conditions and aquifer hydraulic properties. It is also supplemented by artificial recharge with water from the Burdekin River. Preliminary modelling work suggests that groundwater discharge to the sea (base flow) from the delta area ranges between 4,000-13,000 ML/year (Arunakumaren *et al*., 2000; Narayan, 2003).

Nitrate levels have been monitored in groundwater wells in the lower Burdekin River sub-catchment for close to twenty years. In the period 1997-2000, high nitrate concentrations (above 50 mg/L) were measured in 5% of the 397 sampled bores, medium nitrate concentrations (25-50 mg/L) were measured in approximately 7% of the bores sampled (Weier, 1999). Investigations indicate that the most likely source of the nitrates was inorganic fertiliser. A comparison of the 1997-2000 data collected by Keith Weier from CSIRO with the data compiled by Jon Brodie and others (Australian Centre for Tropical Freshwater Research) in 1984 seems to show that high nitrate concentrations associated with fertiliser use have been present since as early as the 1970s, but that the proportion of incidences where bores had high nitrate concentrations is now higher than in the 1970s. These findings indicate that the entry of nitrate into groundwater should be addressed in the irrigation areas (Roth *et al*., 2002).

From an ecological perspective, it is useful to distinguish between natural background levels of nitrate and increases brought about by human activity. Levels below 1 mg/L of nitrate are low and probably close to natural levels, whereas concentrations above this indicate some level of human-induced nitrate contamination.

Data collected by CSIRO in collaboration with other agencies indicate that there are regions in the delta where the combination of high groundwater pumping rates and pump density is affecting the quality of groundwater. High nitrate levels (greater than the ANZECC trigger value for long-term environmental risk) have been found in the irrigation water at several trial sites. At least 50% of nitrate found can be traced back to inorganic sources such as fertiliser. The amount of nitrogen leaching beneath the cane root zone varied widely from 12 to 200 kg/ha. One of the reasons for the high loads is the background nitrate content in the irrigation water, which varied from 2-15 mg/L NO3-N (nitrate-nitrogen). Apart from exceeding the ANZECC environmental threshold of 5 mg/L on occasions, this represents an under-utilised resource and an opportunity to help bioremediate the aquifer (Charlesworth and Bristow, 2004). This means that many crops could potentially obtain their total nitrogen requirement from the irrigation water.

Outside of the irrigation areas there is little information available on groundwater contamination. However, it is unlikely that there is significant contamination occurring in grazing lands or other extensively used land.

Salinisation of groundwater due to seawater intrusion refers to the replacement through mixing of freshwater in aquifers by seawater. Groundwater bodies below the coastline form an interface between freshwater and seawater (also called the saltwater wedge). This interface is quite dynamic; in wet seasons with increased freshwater recharge, the freshwater aquifers have the potential to push the saltwater wedge towards the sea. Conversely, when groundwater is extracted for irrigation and other human uses, the pressure of the freshwater aquifer on the saltwater wedge lessens and the wedge has the potential to move landwards. The more groundwater extracted over extended periods, the greater the potential for the seawater wedge to move inwards towards the extraction bores, until these may eventually start pumping salty water. It is very difficult to push the salt water wedge back out once it has penetrated inland.

Water quality degradation (or even loss of groundwater resources) due to seawater intrusion is a major issue affecting the use of the Burdekin delta aquifer for irrigation purposes. The areas most under threat of seawater intrusion are those closest to the shoreline, or adjacent to tidal estuaries. Current data suggests that the seawater interface extends kilometres inland, placing some inland pumping bores under threat of seawater intrusion. The regions most susceptible to this are the coastal areas of the North Burdekin Water Board. The South Burdekin Water Board region is less prone to the problem because it has a smaller coastline, shallower basement and stronger hydraulic gradient.

As the Burdekin Haughton Water Supply Scheme (BHWSS) area borders the Ramsar wetlands of Bowling Green Bay, it is possible that groundwater extraction and irrigation may affect the hydrological integrity of the wetlands – currently a knowledge gap. Similarly increasing water tables from excessive recharge after irrigation has the potential to change the hydrological regime of wetlands.

Saltwater intrusion is confined to the delta area of the Burdekin River and only limited studies have been undertaken. Although a monitoring network is in place, it is currently under review and being supplemented with additional bores. A groundwater model has also been developed for the Burdekin delta and is currently being tested and refined (Narayan, 2003; Roth *et al*., 2002).

Understanding the processes of seawater intrusion into coastal aquifers is a complex task. The degree to which the process is reversible varies from region to region and is not always well understood. This is compounded by our current lack of understanding of the broader geohydrology of the lower Burdekin River floodplain. We know little about the hydrological interconnectedness of various aquifers, how they interact with the surface waters, and how irrigation activity in the BHWSS affects regional groundwater hydrology, both of the delta and the adjacent Bowling Green Bay wetlands.

Given the dependence of a large part of the irrigation area in the Burdekin delta on the integrity of the groundwater resource, an improved understanding of seawater intrusion within the BHWSS and the Burdekin delta is critical.

The water quality problems now being experienced in parts of the Burdekin delta may be due to the combined effects of the artificial recharge scheme bringing salts to the delta for nearly 40 years, combined with a 200% increase in the number of pumps removing water from the aquifer. The effect of salts on the Burdekin aquifer may well be moderated by the climate, which provides the potential for large flushing events, although this needs further investigation. While flushing events may be a positive for salinity mitigation, they may increase the risk of moving more nutrients and agrochemicals from the root zone into the aquifer and from the aquifer into marine and freshwater environments.

In most areas, rainfall across the catchment is far less than the amount of water used by plants for transpiration, so that in general terms there is not much water that passes through the soil to recharge groundwater aquifers. However, heavy monsoonal rainfall during the wet season will usually give some recharge. Only limited water balance information is available for a few sites in the Burdekin catchment. Other than for the irrigation areas, there is not much information available on groundwater resources (e.g. the depth and quality of aquifers). This represents a major knowledge gap (Roth *et al*., 2002).

6 LAND-USE AND WATER RESOURCES

6.1 Coastal Development

Approximately 31% of the Burdekin Dry Tropics coastal region is under freehold tenure (Map 11). This has implications for the protection of natural resources as the potential for coastal development is increasing on freehold land. However, coastal development can be an asset to the region if done in an ecologically sustainable manner. However, when poorly planned and managed, coastal development is a major pressure on natural resources with subsequent impacts on the socio-economic assets of the region.

Townsville's coastal development (David Scheltinga)

Negative interactions between coastal development and the natural environment have occurred in the region and are likely to be exacerbated by future development. For example, coastal development has been linked to increased turbidity in Upstart Bay, which has affected seagrass survival (Rasheed and Thomas, 1999). When habitat is disturbed or destroyed, animal and plant species can be lost and biodiversity decreased.

The Great Barrier Reef Marine Park Authority also acknowledges the interaction between coastal development, especially the clearing of important wetlands, mangroves and other vegetation, and a decline in water quality (GBRMPA, 2004i). Changes in water quality (a physical parameter) are known to impact other biological parameters, not just seagrass survival as mentioned above, but also coral survival (GBRMPA, 2004), fish growth (Clarke, 1998), marine turtle health (Limpus *et al*., 2002), algae distribution (GBRMPA, 1998b) and crown-of-thorns seastar populations (GBRMPA, 2004).

Introduction of weed and pest species into remnant natural areas is another potential impact of coastal development. Saltmarsh communities often bear the greatest impact of coastal development compared to other saline wetland communities as they grow on relatively high, waterfront land and are therefore very desirable for coastal development. Coastal developments restrict the landward recruitment of saltmarsh, disrupting the natural balance between mangroves and saltmarsh.

Earthworks in coastal floodplains can potentially reveal Acid Sulphate Soil (ASS). Exposure of these soils to oxygen in the air creates a chemical reaction that produces sulphuric acid (same as battery acid, with a pH of less than 1), which can acidify soils, groundwater and run-off. Not only can this acid be harmful to animals and plants directly, it can also reduce the oxygen of waterways and release heavy metals like aluminium from the soil in toxic quantities (Ahern *et al*., 2002). Fish exposed to acidified waters are more susceptible to 'red spot' infection that causes large red lesions to appear on the fish's body and often results in mortality (Ahern *et* *al*., 2002). Although no comprehensive mapping of potential and actual acid sulphate producing soils has been conducted, the coastal floodplains of the Burdekin Dry Tropics region are thought to be at high risk of developing ASS upon disturbance because their topography is relatively low lying with many drainage paths below 5 AHD (Sadler, date unspecified).

Clearing and disturbance for coastal development is a major cause of mangrove decline in the Burdekin Dry Tropics region and elsewhere.

Privately owned wetlands in the region are subject to increasing pressure from coastal development. Serpentine Lagoon is a privately owned, 200 ha *Melaleuca* sp. swamp located 45 km south of Townsville and provides habitat to a diverse animal population, including the rare cotton pygmy goose (Townsville City Council, 1999a). Serpentine Lagoon has been identified as being an important and unique wetland habitat and has subsequently been registered as a private property Nature Refuge under a Voluntary Conservation Agreement (see Section 4.10) and is listed on both the Wetlands of National Significance list and Register of the National Estate. A rehabilitation and protection project has been established at the site to assist in the recovery of the site from a cyclone that damaged it in 1998 (Townsville City Council, 1999a).

6.1.1 Urban Land

The predicted population targets for the Townsville and Thuringowa regions are given in Table 13 below. It is predicted that the population of the Townsville region will increase by 7.8% from 2001 to 2006 and then by 8.7% from 2006 to 2011 (King, 2003). Bowen, the other major population centre in the Burdekin Dry Tropics region is expected to experience a population decline, as shown by Table 14 where all population projections in the series (even the 'high' series) show a population decline from current levels.

Coastal urban development in Townsville (David Scheltinga)

Table 13. Townsville and Thuringowa population trends.

Year	Estimated Population
2005	154,390
2006	157,188
2007	159,949
2008	162,697
2009	165,418
2010	168,128
2011	170,839

Source: Queensland Department of Local Government and Planning, July 2002.

Table 14. Bowen population trends.

Prediction Type	1991	1996	2001	2006	2011	2016	2021
High	13,492	13,142	13,690	12,262	12,047	11,928	11,919
Medium	13,492	13,142	13,500	12,143	11,812	11,584	11,471
Low	13,492	13,142	13,390	11,966	11,483	11,112	10,863

Source: MWREDC, 2003a

Population growth is also occurring in Thuringowa, especially at Mt Low-Bushland Beach, Deeragun, Condon and Kirwan (King, 2003). Planning areas for urban development also include riparian zones with a 39-unit complex being recently constructed along the river in South Townsville (Townsville Enterprise Limited, 2003).

Urban area is an important land-use within the region, providing work and accommodation for a large percentage of the region's population as well as sites for industry and retail/wholesale trade. Within the Burdekin Dry Tropics region, trade (retail and wholesale), health and community services, manufacturing and education are the four main employers (see Table 22, Section 6.6.5). However, employment in sectors varies between local government areas (LGAs) and the majority (80%) of employment is localised in the coastal 'urban' LGAs of Townsville and Thuringowa (Table 15).

Table 15. Summary of major sector employment within the Burdekin Dry Tropics (BDT) region compared to coastal LGAs.

Sector	Number people - 2001 (% of BDT region)				
	BDT region	Thuringowa LGA	Townsville LGA	Burdekin LGA	Bowen LGA
Trade (retail and wholesale)	16,174	5,198 (32%)	8,048 (50%)	1,470 (9%)	1,019 (6%)
Health and community services	8,134	2,247 (28%)	4,648 (57%)	558 (7%)	377 (4%)
Manufacturing	7,114	2,165 (30%)	3,323 (47%)	1,235 (17%)	253 (4%)
Education	6,738	1,751 (26%)	3,678 (55%)	540 (8%)	331 (5%)
Agriculture	4,607	313 (7%)	567 (12%)	2,250 (49%)	1,609 (35%)
Total employed (all sectors)	83,318	23,016 (28%)	43,018 (52%)	8,366 (10%)	5,555 (7%)

Source: QRBIS (2003); ABS (2001).

Trade (retail and wholesale) ($787 m)[1], manufacturing ($778 m)[1], dwelling investment ($466 m)[1] and construction ($441 m)[1] are four of the five highest industries for gross regional product, most of which occurs in urbanised areas (Greiner *et al*., 2003). Thus, urban areas are important in terms of employment and earnings both locally and regionally.

However, the development of the coastal strip for urban expansion is placing increasing pressure on coastal habitats in Queensland (EPA, 2003a). The Queensland State of the Environment 2003 report identified the Townsville coast as one of four key areas of rising population within Queensland (EPA, 2003a). It is therefore not surprising that the location of coastal urban expansion in the Burdekin Dry Tropics region tends to occur in the north, around Townsville. This 'urban development' often occurs in strips adjoining the coast or rivers (estuaries).

[1] values for the Northern Statistical division from 2001-2003.

The beaches north of Townsville are currently experiencing significant urban development, as is Magnetic Island and the coastal settlements at Phantom Springs and Cungulla south of Townsville (GBRMPA, 1998c). Issues such as service provision, urban stormwater management and sewage treatment plant outfall have been associated with these particular developments (GBRMPA, 1998c). Smaller coastal communities throughout the region tend to be experiencing urban expansion (GBRMPA, 1998c).

Urban development planning areas in Townsville are aimed at reducing urban sprawl and the associated cost of infrastructure development and are thus focused on the redevelopment of Townsville's CBD. A growth rate of 27% has been recorded and has been associated with the increase in inner city apartment complexes and other high-density urban developments. Recently completed/currently being constructed developments in the inner city region include the Highpoint Unit Development, Melton Crest Apartments and No. 1 The Strand (Townsville Enterprise Limited, 2003).

Extensive areas of rural residential development occur in Thuringowa City along the coast north of Townsville (GBRMPA, 1998c).

6.1.2 Agricultural Land

Cropping between Ayr and Alva (David Scheltinga)

In terms of the area of land used, employment and gross production value, agriculture is an important industry in the Burdekin Dry Tropics region as a whole, and locally within some LGAs, particularly the coastal LGAs of Burdekin and Bowen. Approximately 80% of the coastal catchments region is used for agriculture (with most of this land used for grazing (~70% of the region) (Map 25). The agriculture industry is the major employer in the Burdekin and Bowen LGAs, making up 49% and 35% of employment, respectively (Table 15, see also Section 6.6). Agriculture ($503 m)[2] is the second highest earner in the Burdekin Dry Tropics region in terms of gross regional product (Greiner *et al*., 2003).

However, as discussed previously with regard to employment, the value of production varies between local government areas (LGAs) with much (58%) of agricultural production value for the Burdekin Dry Tropics region being localised in the coastal 'agricultural' LGAs of Burdekin and Bowen (Table 16).

Livestock (mainly cattle grazing) production value from the coastal LGAs is relatively less important in terms of production value (and probably employment) compared to cropping in these areas. Approximately 83% of the Burdekin Dry Tropics region's cropping value comes from the coastal LGAs, whereas only 30% of the livestock production value comes from the coastal area.

[2] value for the Northern Statistical division from 2001-2003.

Table 16. Summary of agricultural production value within the Burdekin Dry Tropics (BDT) region compared to coastal LGAs.

Sector	Production Value in $millions for 2001 (% of BDT region)				
	BDT region	Thuringowa LGA	Townsville LGA	Burdekin LGA	Bowen LGA
Total crops	409	11.1 (2.7%)	7.4 (1.8%)	180 (44%)	140 (34%)
Total livestock	271	2.6 (1.0%)	3.2 (1.2%)	12 (4.4%)	64 (24%)
Total agriculture	681	13.6 (2.0%)	10.6 (1.6%)	192 (28%)	204 (30%)

Source: ABS Agriculture Census (2001).

The major crop in terms of area and production value in the coastal region is sugarcane. Other crops include a range of fruit and vegetable horticultural crops (Burdekin Dry Tropics Board, 2004a).

Widespread clearing, loss of streamside vegetation, overgrazing and poor cropping practices have degraded land, causing problems within catchments. These include erosion of fertile topsoil and dryland salinity, effects that threaten the livelihoods of farmers. At the same time, many land management practices, such as tillage, and fertiliser and pesticide use, have downstream impacts on rivers and estuaries. Sedimentation, eutrophication, pesticide residues and algal blooms threaten the livelihoods of commercial fishers and other estuary users (Turner *et al*., 2004).

Pasture grasses introduced to replace native vegetation are less effective in reducing run-off (Turner *et al*., 2004). Exotic grasses like Hymenachne threaten important wetland values in the Burdekin Dry Tropics coastal region (Commonwealth Department of Transport and Regional Services, 2000). Rubber vine, which grows particularly vigorously in riparian zones and is capable of displacing native vegetation, is widespread in the region and is expanding its range. Feral animals, especially pigs, are damaging some environments and are likely to be affecting the conservation status of some fauna. The cane toad is well established in the region and the long-term impacts of its presence on native fauna remain unclear.

Herbicides are often used to control weeds such as Chinese apple and parkinsonia on agricultural properties in the region. Rain washes traces of these toxic chemicals down creeks and rivers and into the sea, bays and inlets, where they can be harmful to fish, shellfish and other animals higher up the food chain, including humans. These poisons may cause mangroves and saltmarshes protecting the shore from coastal erosion to dieback (Turner *et al*., 2004).

The major storage within the catchment is the SunWater owned and operated Burdekin Falls Dam, which provides a secure water supply to irrigated farms in the lower Burdekin and strategic backup for the twin cities of Townsville and Thuringowa. The Burdekin Falls Dam dominates flow regulation, with an ability to store 1,860,000 ML of water, which represents about 88% of the total storage capacity in the catchment. The dam was completed in 1987 and provides water for irrigation to whole of the lower Burdekin as surface water for the Burdekin Haughton Water Supply Scheme (BHWSS) (total area ~ 83,000 ha with about 43,000 ha irrigated) and recharge water for the North and South Burdekin Water Board (total area ~ 85,000 ha with about 40,000 ha irrigated). It also provides some flood mitigation for the lower Burdekin floodplain and delta area around Ayr and Home Hill as a secondary benefit. A number of weirs and pump stations on the Burdekin and Haughton Rivers distribute water throughout the BHWSS and to Lake Ross (storage capacity – 219,000 ML) at Townsville, as part of the BHWSS.

The BHWSS has recently expanded, resulting in further loss of natural flood plain habitats and significant modifications to their hydrological patterns (Danaher, 1995).

Dryland salinity refers to the salinisation of soil and water resources triggered by changes to vegetation (particularly tree-clearing) and the subsequent effects on water balance. Dryland salinity has rendered soils unproductive and water unfit for consumption or irrigation and in many instances the salinisation of soil and water resources is an irreversible process, and even where reversible, reclamation of saline land is extremely costly.

Development of dryland salinity is still at a relatively minor level in the Burdekin Dry Tropics coastal region, though the extent of the problem is generally underestimated. It can take a long time after the cause (e.g. land-clearing) before salinisation occurs. Outbreaks are possible at any time due to past land management practices.

Several dryland salinity outbreaks have occurred in the catchment. These, and data from other previous work, have been included as criteria in the preparation of the State-wide maps of salinity hazard (Map 12). The study indicates a high salinity hazard for parts of the Burdekin Dry Tropics region. It is important to realise that this is only a hazard map, and whether the salinity hazard actually eventuates depends on future land management. Also, at this stage there is very little data on actual salinity levels in soils and there are very few groundwater bores with salinity data for the Burdekin Dry Tropics region. Consequently, there is still a high degree of uncertainty in relation to the salinity hazard. However if no action is taken, salinity is likely to become a serious issue in the Burdekin Dry Tropics region (Roth *et al*., 2002).

Salinisation of groundwater and soils may also occur due to irrigation. As irrigation water always contains some level of salts, irrigation invariably leads to the accumulation of salts in the soil profile. Salt accumulation is usually managed by ensuring sufficient water drains below the root zone to flush salts beneath the roots. If the drainage measures are inadequate or insufficient, flushing is constrained. Continued application of water will then invariably lead to a rise in groundwater tables. If the groundwater itself is saline, this will compound and accelerate irrigation-induced salinisation. If unmanaged, the combined process of salt accumulation and rising water tables will jeopardise the long-term viability of the land.

Results of groundwater monitoring in the irrigation area of Burdekin Haughton Water Supply Scheme (BHWSS) indicate that extensive areas in the BHWSS are under threat of irrigation salinity. In some areas, saline groundwater is less than 2 m from the soil surface and is now starting to express itself in loss of production. These areas include Mona Park, Giru and Leichhardt Plains.

Irrigation salinity within individual settings in this area is well understood as a result of several studies, including an extended pumping trial on Leichhardt Plains. Not as well understood, and less well documented, are the regional aspects of irrigation salinity, i.e. the nature of the interactions between surface waters, shallow, irrigation-affected water tables, and the regional hydrology, in particular how this interaction is affecting adjacent wetlands.

6.1.3 *Industrial Land*

Industry is an important employer and money-maker for the region. However, the development of major industries is identified as placing high pressures on coastal natural resource assets in the Burdekin Dry Tropics region, with port and industrial area expansion in the Townsville area recognised as being an issue of particular concern (GBRMPA, 1998c).

Townsville Port and industrial area (David Scheltinga)

The recent development of a zinc refinery south of Townsville and the possible construction of a base load power station and a major industrial site (3,000 ha) at Woodstock, south-west of Townsville are some of the industrial developments in the region. Industrial developments that are currently under investigation include the QNI Yabulu Expansion Project, Sun Metals Plant Stage 2, Balcooma Base Metals mine, and the Detroit diesel Base construction. The expansion of maritime industries with new port access, reclamation for port extension and port-related future industrial development is also expected to occur, or is currently occurring, in Townsville (GBRMPA, 1998c). All proposed industrial and port development in Townsville occur within of immediately adjacent to tidal waters or lands and therefore are likely to have significant impacts on local coastal wetlands (Rob Coles and Jane Mellors, pers. comm.).

6.2 Coastal Aquaculture

There are 237 aquaculture licences/permits in the Burdekin Dry Tropics region however aquaculture operations frequently hold more than one permit so it is unlikely that there are 237 separate aquaculture farms in the region. The majority of aquaculture licences/permits are for exotic fish (62), prawns (63), and native fish (58) (EPA, 2003a). Research species, crayfish and anemones are also cultured.

Aquaculture facilities present throughout the coastal region, with sites located on Fantome Island in the Palm Islands Group, Magnetic Island, Ross River, near the Haughton River, south of Cape Bowling Green, Lynch's Beach, Upstart Bay, Bowen and the Don River (Map 27).

The aquaculture industry is seen as having growth potential in the Burdekin Dry Tropics coastal region and is predicted by Bowen's Mayor to be important in the future development of the shire (King, 2003). This growth is being encouraged by the Burdekin and Bowen Shire Councils in the form of aquaculture forums (Austasia Aquaculture, 2000). The southern coastal margin of the Burdekin Dry Tropics coastal region in particular, is predicted to be the site of significant aquaculture development in the future due to its high site suitability (Burdekin Dry Topics Board, 2004b). In 2000, there were two aquaculture farms being constructed in Bowen with two more in the development process (Austasia Aquaculture, 2000).

Mapping of land suitability for aquaculture, conducted by the Queensland State Government shows that many areas in the Burdekin Dry Tropics coastal region have only minor or moderate limitations to aquaculture development and are therefore potentially suitable sites for this industry. Areas inland of Toolakea, parts of Great Palm Island, the northern most part of the region (i.e. Black River sub-region, parts of the Bowling Green Bay wetlands, the wetland area south of Cape Bowling Green, southern Abbot Bay and eastern Abbot Point are all deemed to have only minor limitations to aquaculture (Map 28) (Department of State Development and Innovation, 2004). Other areas, such as Upstart Bay, Cape Cleveland and Cape Pallarenda, have been classified as having moderate limitations to aquaculture development.

Marine prawn ponds are the current focus of most aquaculture operations and these are present north of Townsville and Bowen on coastal plains and in the Burdekin delta (Burdekin Dry Tropics Board, 2004b). Not all have been successful though, with three marine prawn aquaculture farms being permanently abandoned and at least two causing major concerns to neighbouring properties (Vern Vietch, pers. comm.). Pen-raising of barramundi and freshwater pond culture of red claw crayfish are also being conducted in the region (Burdekin Dry Tropics Board, 2004b).

The southern Burdekin Dry Tropics region, around Abbot Point, currently has two established aquaculture projects; a fish breeding farm in Good Fortune Bay and a prawn farm in Longford Creek. A prawn farm in the Elliot River (about 20 km west of Abbot Point) is currently being constructed with focus for future development also being placed on this area (Ports of Queensland Corporation, 2005) in the form of two projects under investigation; the 300 ha Guthalungra Prawn Farm and the Bowen Aquaculture Centre, which is expected to produce 1.3 million crabs and 560 tonnes of barramundi a year and 40 direct jobs once established (MWRDC, 2004). The aquaculture development at Guthalungra, currently under consideration by the *EPBC Act* has caused concerns to be raised that it will threaten the Elliot River Wetlands system and contribute to nutrient enrichment of northern Abbot Bay (Vern Veitch, pers. comm.).

Though statistics specifically applicable for the Burdekin Dry Tropics coastal region are not available, it is clear that aquaculture provides a substantial economic input into the region. Farm gate value for aquaculture produce of the northern Queensland region was estimated to be worth $19.71 million for the 2002/03 financial year. The industry also created 157 full time equivalent jobs in the northern Queensland region (Lobegeiger and Wingfield, 2004).

Large-scale aquaculture of Australian marine fauna may bring ecological benefits as well as economic and social advantages, for example, it may alleviate fisheries pressure on wild populations. However, aquaculture also brings environmental liabilities that could prove challenging. In order to establish aquaculture operations, local coastal ecosystems are often destroyed or severely modified. Hydrodynamics of neighbouring areas are frequently altered, for example there are investigations being conducted into the role of Pacific Reef Fisheries site at Alva Beach and the saltwater intrusion that is occurring in the area. Similar concerns have been raised about a smaller farm at Cape Cleveland (Vern Veitch, pers. comm.).

Aquaculture ponds and open cages may discharge nutrient-rich wastes, including uneaten feed, faecal waste and chemicals, which can degrade downstream water quality, and can potentially increase the frequency of algal blooms (Ports of Queensland Corporation, 2005). Caged finfish farming can cause localised organic loading of sediments below the cages, leading to oxygen depletion. Aquaculture can lead to increased incidence of disease in wild populations and to the introduction of exotic species through escapes. If not managed properly, saline seepage below the aquaculture ponds can degrade groundwater systems. Finally, where aquaculture relies on wild-caught stock, there is a risk of depleting wild populations (Turner *et al*., 2004).

6.3 Maritime Industries

Major marine industry infrastructure exists in the region in the form of the Townsville Port and marina consisting of a small craft facility and a full range of marine service industries (GBRMPA, 1998c) and the Port of Abbot Point, Australia's most northerly coal port, 25 km north of Bowen (MWREDC, 2001).

Townsville Port facilities (David Scheltinga)

Townsville is one of Queensland's major ports and regularly handles sugar, minerals (particularly zinc and copper) (AMSA, date unspecified), petroleum products and general cargo (GBRMPA, 1998c). Abbot Port is also substantial with a total port throughput in 2003/04 of 12,094,893 tonnes (Ports Corporation of Queensland, 2004). Bowen Harbour, in the south of the region, is a smaller port with marina facilities. Other marine industry infrastructure are the Townsville Marina, Breakwater Marina and Ross River Marina.

Major areas of maritime industry development include the Townsville Ocean terminal where there is a proposal to construct dedicated berthing facilities and a terminal for cruise and military ships. Thirty-five hectares of land is likely to be reclaimed for the establishment of associated recreation and residential developments. The construction of a ferry terminal, pontoon and accommodation at Nelly Bay was recently completed.

Boat Ramps in the area include Balgal Boat Ramp, the Townsville Sailing Club paved boat ramp, Townsville National Park Boat Ramp, Magnetic Island Boat Ramp in Horseshoe Bay, Pallarenda Park Boat Ramp, Bohle River Boat Ramp, Nelly Bay Boat Ramp, Cungulla Boat Ramp, Cocoa Creek Boat Ramp, Cromarty Creek Boat Ramp near Giru, Hell Hole Creek Boat Ramp, Doughboy Creek Boat Ramp at Cungulla, the Ocean Creek double ramp about 13 kilometres from Ayr, Groper Creek ramps about 27 kilometres from Ayr, Phillips' Creek gravel boat ramp, Molongle Creek double boat ramp 56 kilometres south of Home Hill, Kierle's Landing on Rita Island Road and Sandhills Road, Plantation Creek double cement ramp and Bowen Boat Ramp.

A harbour, ferry landing pontoon, boat ramp, barge ramp, and residential and commercial properties adjacent to the Great Barrier Reef Marine Park were recently constructed in Nelly Bay on Magnetic Island (GBRMPA, 2004g). Another island in the region that is popular with tourists is Orpheus Island, which has recently constructed public moorings in its coastal waters (GBRMPA, 2002). An important marine infrastructure component of the region is the REEFREP station on Pelorus Island which tracks the progress of large ships traversing the Palm Passage through the Palm Island Group, which is one of the three major shipping route bisecting the GBR.

Shipping activity, and the associated service infrastructure, is increasing in Queensland with the growth rate at a level that will increase pressure on coastal resources (EPA, 2003a). Port management and operations are undertaken by government-owned port authorities and Queensland Transport operating under the *Transport Infrastructure Act 1994*, *Transport Operations* (*Marine Safety*) *Act 1994* and the *Transport Operations* (*Marine Pollution*) *Act 1995*. Under these acts the ports have planning powers for current and future port land-use and the power to maintain or improve navigation channels (i.e. dredge).

Townsville marina (David Scheltinga)

The expansion of maritime industries with new port access, reclamation for port extension and port-related future industrial development are currently being proposed/occurring in Townsville (GBRMPA, 1998c). Areas of maritime industry development include the Townsville Ocean terminal where there is a proposal to construct dedicated berthing facilities and a terminal for cruise and military ships. Thirty-five hectares of land is likely to be reclaimed for the establishment of associated recreation and residential developments (Townsville Enterprise Limited, 2003). Magnetic Island is another major area of maritime industry construction due to the Nelly Bay Harbour development that will incorporate ferry terminal, pontoon, residential and tourist accommodation (Townsville Enterprise Limited, 2003). Plans are also underway to expand Bowen Harbour with the addition of a small boat harbour and marina (MWREDC, 2001).

“Marine works such as extractive industries, dredging, reclamation and boating infrastructure (marinas, boat harbours, jetties and pontoons) generally accompany building and subdivision on the coast. These coastal-dependent land uses provide economic and social benefits to the community but also have cumulative impacts on coastal resources and their values” (EPA, 2003a, pg 6.14).

The Port of Townsville handled over 77% ($2,049.8 million) of the total overseas commodity exports originating from North Queensland, making it one of Queensland’s largest cargo ports (AMSA, date unspecified). The economic benefits of the port to the regional economy are considerable. During the 1998/99 period port activities, manufacturing industry and port clients generated a direct economic output of $699.6 million, generating further additional output of $677.5 million through other industries. It has been estimated that 1,566 jobs were created directly by the industry with 6,349 jobs indirectly created (AMSA, date unspecified). Abbot Port also significantly contributes to the region’s economy and community and is coming under increasing pressure to expand (Ports Corporation of Queensland, 2004).

Shipping poses a potential threat to local ecosystems through the introduction of invasive pest species via ballast water and hull fouling. These exotic animals and plants frequently out-compete, or are voracious predators of, native species. Oil spills, waste disposal, contamination from toxic antifoulants like tributyltin (which affect non-target species and are recalcitrant in sediment), noise and boat strikes may also result from shipping/boating and can have a detrimental impact on coastal resources. The physical impacts of grounding and anchors can destroy corals, while groundings can also have a chemical impact in the form of antifoulants contamination. Other threats to the area include sediment impacts from navigational dredging in ports, which can affect corals hundreds of meters away (GBRMPA, 2003a).

See marine waters section (Section 5.1.12) for water quality parameters of the marine environments adjacent to ports, marinas, transport lands.

The Great Barrier Reef Marine Park is designated as a Particularly Sensitive Sea Area by the International Maritime Organisation so shipping in the area is subject to several environmental protection measures. Some areas in the marine park (though none in the Burdekin Dry Tropics region) require the presence of a pilot on board for certain vessels. There is a mandatory GBR Ship Reporting System (REEFREP) in the inner Palm Passage that requires ships of a certain size to notify REEFREP of their presence in order for their movements to be monitored, reducing the risk of a collision with other ships (and consequentially pollution) and enhancing human safety (AMSA, 2003). Penalties are in place for ships that damage the reef, contravene zoning, navigation, ship safety and other legislative provisions (GBRMPA, 2003a).

Four ships were detained for non-compliance in the Burdekin Dry Tropics region in 2004. They were the ‘Hellenic Sea’, which was detained at Abbot Point on 9 December 2004 because its MF/HF DSC controller unit was defective. ‘Western Zenith’ was detained at Townsville on the 12 November 2004 as its MF/HF DSC radio was inoperative. ‘Opal Naree’ was detained in Townsville on the 14 May 2004 because the Chief Officer and Third Mate did not have Flag State STCW endorsements and there were insufficient valid deck officers as per manning certificates. ‘Murshidabad’ was detained at Abbot Point on 7 February 2004 because its oil pollution prevention equipment was defective. The ‘Derwent’ was detained in Townsville on 27 February 2004 due to various loadline deficiencies (AMSA, 2004).

Maritime accidents and near misses most commonly occur between fishing vessels and trading ships. This is almost always the result of non-compliance with The International Regulations for Avoiding Collisions at Sea (Queensland Transport and GBRMPA, 2000). Three major incidents have occurred in the Burdekin Dry Tropics region between 1985 and 2000. The first of these was the collision between the fishing vessel ‘Dhikarr’ and the light tender ship ‘Cape Moreton’ in June 1986 at Cape Cleveland. The second occurred in December 1992 at Middle Reef where the bulk coal carrier ‘Fareast’ collided with ‘Ronda Lene’ a fishing vessel. The most recent incident occurred in December 1996 off Townsville where the fishing vessel ‘Moonshot’ collided with the Turkish ship ‘Gumbet’ (AMSA, 2001).

Ships are also required to comply with the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78), which effectively prohibits the discharge of all pollutants (except sewage) from ships within the Great Barrier Reef lagoon (GBRMPA, 1998). However, the Great Barrier Reef Marine Park Authority has acknowledged that despite the high level of regulation “there is still a significant rate of non-compliance with discharge standards” (GBRMPA, 1998).

The risk of pest invasion is increasing within the region as approximately 64,650,000 tonnes of ballast water enters Townsville waters every year (GBRMPA, 2001).

The Ports Corporation of Queensland's environmental program (Ecoports) undertook risk assessment studies for potential introduced marine pest species at Abbot Point Port (Simona Trimarchi, pers. comm.). The Abbot Point survey was conducted by The School of Marine Biology and Aquaculture at James Cook University and CRC Reef on behalf of Ecoports using the guidelines for sampling developed by the CSIRO Centre for Research on Introduced Marine Species (CRIMP) for baseline port surveys. CRIMP has also completed impact studies on designated pest species, population monitoring of pest species, development of a risk assessment framework for assessing likely new introductions (‘next pests’) (Hoedt *et al*., 2001). Information resulting from these surveys is collated into the National Introduced Marine Pest Information System (NIMPIS) web accessible database (EPA, 2003c; CSIRO, 2003).

Another monitoring project being conducted at Abbot Point Port involves the deployment of Asian green mussel traps on the wharf that are checked every three months for suspect organisms. There has been no detection of introduced marine pests by this monitoring regime after 4-5 years (Simona Trimarchi, pers. comm.).

The Townsville Port Authority conducts quarterly sediment metal concentration surveys at over 200 sample sites in the Shipping Channel, Ross Creek and Ross River (Anderson and Roche, 2000) and regularly monitors dredge spoil material (Townsville Port Authority, 2004). Water quality testing and the monitoring of biological indicators, fouling organisms and introduced pests are also conducted regularly as part of the Townsville Port Authority Environmental Management Authority (Townsville Port Authority, 2004).

6.4 Fisheries (Commercial, Recreational and Traditional Owner)

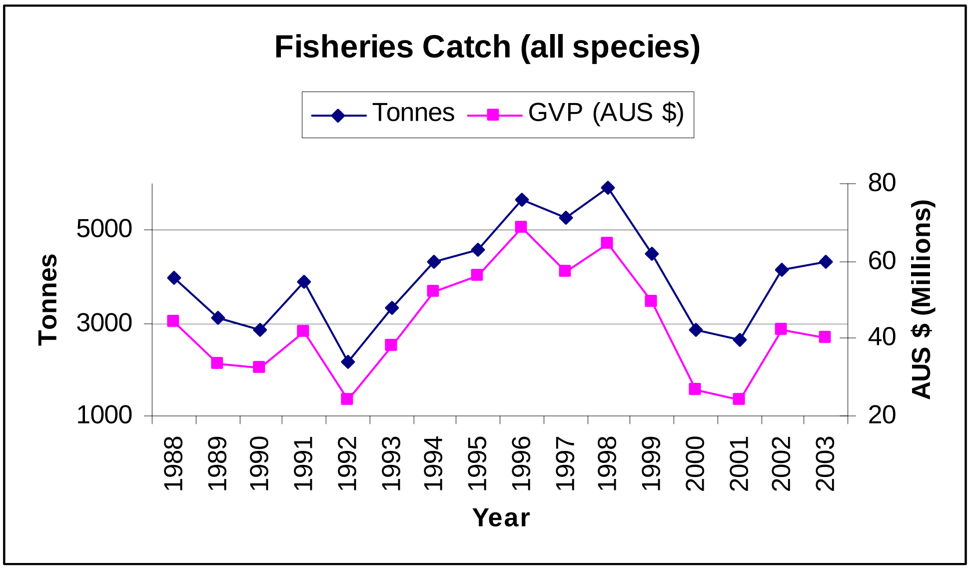
Overall, the fishery’s catch in the Burdekin Dry Tropics coastal region has varied considerably in the past but is showing signs of stabilising and, in terms of both tonnes and gross value of production (GVP) ($), appears to be currently equivalent to 1988 values (Fig. 5). (Note: although the fishing effort (number days fished per boat) has remained relatively constant since 1989 the actual number of boats in the fleet has decreased over recent years).

In 1999, 540 boats recorded 5,882 fishing days for the waters of Upstart Bay, representing less effort but larger catches than the previous five years (DPI&F, 2005b). The main target commercial fishery species for these waters in 1999 included shark (72 tonnes), Spanish mackerel (19 tonnes), barramundi (6.9 tonnes), mullet (3.2 tonnes) and blue-salmon (2.7 tonnes). Additional fish species included flathead, trevally, whiting, queenfish, cod, grunter, bream, king salmon, mackerel and mixed fish species (DPI&F, 2000). The main target commercial species for prawn fisheries in these waters were tiger prawns (*Penaeus* spp) (33 tonnes), banana prawns (*Penaeus* spp) (20 tonnes), king prawns (*Penaeus* spp) (15 tonnes), endeavour prawns (*Metapenaeus* spp) (4.1 tonnes) and coral prawns (*Metapenaeopsis* spp) (1.4 tonnes). Scallops (mud: 313 tonnes; saucer: 11 tonnes), mud crabs (55 tonnes), bugs (14 tonnes), squid (0.24 tonnes) and blue swimmer crabs (0.12 tonnes) were also important fishery components of these waters (DPI&F, 2000). Over the last few years there have been major changes in the management of fisheries in the region, making this data essentially only useful for the purposes of discussion against more recent data.

In 2003, the total nearshore (within approximately one 30 minute grid off the coast) commercial catch of all fisheries from the Burdekin Dry Tropics coastal region was 4,198 tonnes (worth $39.66 million) (DPI&F, 2004a). The major commercial fisheries in the region in 2003 were based on prawns (1,795 tonnes) (especially tiger (833 tonnes) and king (704 tonnes) prawns) with a gross value of $22,414,300, unspecified shark (733 tonnes; $4,397,500), bugs (341 tonnes; $4,096,200) and mud crab (173 tonnes; $1,820,500). Next to shark, the most important finfish in the region for 2003 were mackerel (388 tonnes; $2,450,500 – mostly grey and Spanish varieties), barramundi (164 tonnes; $1,147,000), blue threadfin (110 tonnes; $439,200) and coral trout (35 tonnes; $345,200) (DPI&F, 2004a). For more detailed information see Appendix F. Maintenance of the fishing fleet supports many ancillary industries in the region.

To limit the impact of the new GBR marine park zoning on the crabbing industry of the region, two 500 m wide strips along the coast of Cleveland Bay and Bowling Green Bay have been designated ‘commercial crab fisheries areas’ within the otherwise conservation park zone (EPA, 2004n).

Figure 5. Commercial fisheries catch for the Burdekin Dry Tropics region.



Source: DPI&F (2004) – grids used: I20, J20, I21, J21, K21, L21, L22 and M22.

The Burdekin Dry Tropics coastal region supports a range of commercial and recreational fisheries. Recreational fishing occurs throughout the region from freshwater to inshore and offshore areas. In 1997, the total estimated recreational catch (including fish released) for Rollingstone Creek, Leichhardt Creek, Althaus Creek, Black River, Sleeper Log Creek, Bluewater Creek, Bohle River, Haughton

River, Barramundi Creek, Burdekin River, Plantation Creek, Burdekin River Anabranch, Mud Creek and the Don River combined was 1,176,776 fish (2.1% of Qld total) from 157,874 trips (1.5% of Qld total). The main species caught by recreational fishers were spotted mackerel, trevally, barramundi, whiting, bream, grunter and mud crab (see Appendix B). There are suggestions that the catch rate of recreational fishing is decreasing (GBRMPA, 1998).

A survey of Traditional Owner fisheries in North Queensland, Northern Territory and North Western Australia has been conducted. However, it reports on regions that are much larger than the scope of this report. In the absence of more specific information concerning the Burdekin Dry Tropics coastal region's Traditional Owner fishery, the information from the North Queensland survey has been used here to provide a basic outline of the fishery. North Queensland Traditional Owner fishing has proportionally higher offshore and coastal fishing effort and proportionally lower river and dam fishing effort than other States. Not surprisingly, north Queensland also has proportionally more Traditional Owner fishing activity from boats than other States, however, the majority of fishing is shore-based (Henry and Lyle, 2003).

In terms of fishing technique by recreational fishers and Traditional Owner populations, line fishing with bait is by far the most popular, followed by hand collection, while spears and nets also feature prominently. Mullet, catfish, perch/snapper, bream and barramundi are the most caught finfish by Traditional Owner populations. Some species are traditionally harvested by Traditional Owner groups that cannot be legally harvested by other groups, these include dugongs, crocodiles, turtles and turtle eggs (Henry and Lyle, 2003). It is generally thought that Traditional Owner fishery occurs close to communities and is a low-intensity fishery (GBRMPA, date unspecified). However, little more is known of Traditional Owner fishing methods, targeted species or catch rates.

"Fishing, hunting and collecting have direct impacts on the species/taxa in the estuarine and marine environment. Harvesting of finfish, crabs, prawns, squid, scallops and bugs throughout Queensland is undertaken mainly by the commercial and recreational sectors. The commercial sector is licensed by the government to harvest seafood either for consumption by the Australian community or for sale overseas to generate export income for Australia. Traditional Owner communities harvest these and other species such as dugong and turtle for customary and subsistence purposes" (EPA, 2003a, pg 6.22).

"In addition to harvest pressures, climatic effects, declines in habitat health and area, predation by other animals and natural mortality have impacts on fish stocks. Increase in the human population in coastal areas also results in coastal development, habitat destruction, run-off and pollution. These effects place both direct and indirect pressure on fish stocks" (EPA, 2003a, pg 6.22).

Queensland's Department of Primary Industries and Fisheries (DPI&F) monitors both recreational and commercial fisheries in the Burdekin Dry Tropics region. The Recreational Fishing Information System (RFISH) was developed in 1995 and conducts surveys of participation and catch trends about every two years (see http://chrisweb.dpi.qld.gov.au/chris/ – 'recreational catch'). This system includes telephone surveys, angler diary surveys, boat ramp surveys and analysis of historical collections of fishing club competition records (DPI&F, 2004c). Commercial fisheries undergo stock monitoring and assessment by DPI&F. Logbook monitoring of daily catch and effort is also conducted, with the resulting information entered into the Commercial Fisheries Information System (CFISH) database (DPI&F, 2005b). Annual status reports for each fishery are being developed by DPI&F and will be publicly available by the end of 2005 (see http://dpi.qld.gov.au/fishweb/11253.html) (Anthony Roelofs, pers. comm.). Long-term monitoring of important fish species is also conducted in the Burdekin Dry Tropics region by DPI&F. The species monitored in this region are barramundi in the Burdekin River, mud crab at Cape Bowling Green and offshore reef fisheries. CRC Reef is contributing seasonal data for barramundi and information on shark species composition and abundance through their Coastal Fisheries Monitoring Project (DPI&F, 2004d).

Under the Commonwealth Government's *EPBC Act Amendment* (*Wildlife Protection Act*) *2001* management agencies must show that fisheries operate in accordance with the objectives of ecologically sustainable development (as defined by DEH in their *Guidelines for the Ecologically Sustainable Management of Fisheries*). Presently, submissions (including ecological assessments) are available for the following Queensland fisheries important to the region:

- east coast otter trawl fishery;
- east coast spanish mackerel fishery;
- east coast beche-de-mer fishery;
- east coast trochus fishery;
- east coast pearl fishery;
- east coast tropical rock lobster fishery;
- marine specimen shell fishery;
- rocky reef finfish fishery;
- river and inshore beam trawl fishery;
- coral reef fin fish fishery; and
- blue swimmer crab pot fishery. (see http://www.deh.gov.au/coasts/fisheries/qld/index.html)

Although these documents are unprecedented reviews of the status and management arrangements for each fishery, they report on the fishery as a whole (with some spatial analysis). They do provide a realistic whole-of-fishery assessment of ecological impacts, i.e. environmental impacts of fishing operations, bycatch and monitoring regimes. The fisheries that have been assessed have also been accredited as being sustainably managed in the mid to long term.

6.5 Tourism

Tourism is recognised as a key industry in Queensland, attracting both domestic and international visitors to regional areas and thus providing economic benefits to these communities. The Burdekin Dry Tropics coastal region is no exception; in fact, Townsville is one of the top four tourist destinations in the State (EPA, 2003a). This is primarily due to its proximity to the Great Barrier Reef, the World Heritage listed Wet Tropics Rainforest and Magnetic Island and its warm, tropical climate. Festivals such as the Bowen Birthday Bash, Coral Coast Festival, Wet Weekend Fishing Classic, Burdekin International Food Festival, Moongunya Festival, Capsicum Festival, Bowen River Catfish Classic, Palmer St Jazz Festival, Burdekin Water Festival and Mardi Gras, attract a wide range of visitors (MWRDC, 2003; King, 2003).

Coastal areas are the most popular tourist and recreation destination. As well as generating economic benefits and employment, the tourism industry can impact on the coastal, marine and estuarine ecosystems of the region unless properly managed.

Popular tourist spot ‘The Strand’ in Townsville (David Scheltinga)

The Burdekin Dry Tropics coastal region is accessible by plane, rail, coach, boat and major highways. In 2000, travellers to North Queensland arrived in the largest proportion by road (67%), air travel accounted for 15% of travellers, rail and bus amounted to 2%, while water transport and ferry accounted for 1% of visitors (King, 2003). Surveys have found that though the region is popular with international visitors the majority of visitors come from other areas in Queensland (King, 2003). In the 1999/2000 financial year, 21% of the international tourists to the north Queensland region were from the United Kingdom, 14% from Germany, 11% from the United States of America, 6% from New Zealand and 5% from Canada (King, 2003).

Recent reports suggest a slight decline in the international tourist industry for the region in 2002-2003, which has been attributed to the United States war on terrorism and SARS. The Townsville domestic tourism market, however, has remained strong, partially due to the introduction of discounted airfares by Virgin Blue (King, 2003).

The domestic visitor market for Bowen has also remained strong as it primarily consists of the self-drive caravan market and the backpacker market (due to the abundance of seasonal work available in the horticulture industry) (MWRDC, 2003). It is predicted that the international market may take some time to recover and is dependent on international advertising presenting Australia as a safe destination (King, 2003).

Further tourism developments such as the Cromarty Wetlands make-over and the construction of a new resort on Magnetic Island, as well as an expansion of eco-tourism opportunities will also encourage growth of the industry. The tourism industry in the Bowen Shire which currently contains 11 hotel/motels, ten caravan parks, eight holiday units/cottages and three resorts, is also undergoing significant growth and development (MWRDC, 2003).

Local businesses within the region offer and promote boat hire, waterfront cafes and seafood restaurants, estuary cruises, fishing and dive charters, cultural tours, bushwalking, joy flights and various other tours. Other tourism operations available in the Burdekin Dry Tropics coastal region and on Magnetic Island specifically include:

- day tours;
- overnight and extended tours;
- diving and fishing charters;
- long range roving tours;
- aircraft or helicopter tours;

- bareboats (self-sail);
- cruise ships;
- beach hire;
- water sports; and
- passenger ferries (GBRMPA, 2004).

Some of the recreational activities offered in the area include:

- fishing;
- diving, snorkelling and swimming;
- reef walking;
- yachting and boating;
- motorised water sports;
- sea kayaking and windsurfing;
- photography;
- shell collecting;
- bushwalking;
- fossicking; and
- bird watching (MWRDC, 2003; GBRMPA, 2004).

Tourism invigorates the local economy both directly and indirectly. Total overnight visitor expenditure in Townsville was estimated in 1999 to be $621 million and during this period tourism employed 7,091 people and accounted for 5% (or $290 million) of Gross Regional Product in the Townsville region (Tourism Queensland, 2004).

Tourism and recreation can have wide-ranging effects on coastal resources including beach and dune systems, wetlands, forests and heathlands, rocky foreshores, reef systems, estuarine waters and Traditional Owner cultural sites (EPA, 2003a). The effects of relatively low-impact activities, such as camping, swimming, boating and fishing, accumulate and can be quite significant over a number of years. Litter is a problem in many areas – it is unsightly and can entangle or choke native animals. The rapid growth of small towns, particularly when populations boom during holiday season, can overload the capacity of septics and other local wastewater disposal systems with waterway pollution a result. Foreshore development often replaces ecologically valuable streamside vegetation with concrete or stone walls, roads and fertilised lawns (Turner *et al*., 2004).

The sheer size of the tourism industry in the region (especially in Townsville) (EPA, 2003a) often leads to coastal wetlands being bulldozed for new resorts, golf courses and marinas. At the heart of this problem lie conflicting social values relating to people's priorities for recreation. People visit coastal areas for different reasons and the different ways in which we use them for recreation are not always compatible (e.g. high-speed water craft such as speedboats and jet skis may be hazardous to swimmers). Another problem is that of too many people wanting the same thing, with overcrowding affecting both users and the environment (Turner *et al*., 2004).

High-density boating activity and marinas can cause water and sediment pollution (nutrients, toxicants, pathogens) from spills, exhausts, untreated sewage and antifouling chemicals. In addition, construction of marinas can lead to the physical destruction of foreshore and bottom-dwelling aquatic communities. Wash from boats can erode shorelines, while anchors and propellers can damage sensitive sea-floor habitats. Speedboats can cause disturbances to wildlife such as nesting birds and injury or death to turtles, dugongs and other large animals (Turner *et al*., 2004). Repetitive, physical damage by reef walking, snorkelling and SCUBA diving can cause significant degradation at popular sites.

High levels of access, particularly during holiday seasons, can place a strain on public amenities, leading to foreshore erosion, four-wheel-drive damage to vegetation, high levels of litter, septic overflows, weed introductions and a range of boating impacts (Turner *et al*., 2004).

Tourism is a growing industry within the Burdekin Dry Tropics coastal region with new coastal developments occurring at Bowen and Magnetic Island in particular (GBRMPA, 1998c). Developments planned or underway for Magnetic Island include the Dunoon Resort Redevelopment in Picnic Bay, which will consist of a 36 unit tourist accommodation complex and a new five star resort, the Sea Temple Resort and Spa is also being constructed at Radical Bay consisting of 12 luxury beach houses and 98 apartments (Townsville Enterprise Limited, 2003).

The development of tourism facilities is also proposed at Cromarty Wetlands south of Townsville near Giru (Townsville Enterprise Limited, 2003). Plans for the catchments and coastal land adjacent to Upstart Bay include subdivision, construction of tourist resorts and the development of aquaculture facilities (Environment Australia, 2001). Tourism development is also occurring at Thuringowa in the form of the Thuringowa Riverway Project, which will develop tourism at key nodes along the Ross River (Townsville Enterprise Limited, 2003).

Although these issues are complex there is evidence that integrated management, education and adequate zoning and enforcement can alleviate many of the potential damaging impacts.

6.6 Socio-economic Viability/Resource Sustainability

Much of the information supplied in this section is extracted from: Mackenzie *et al*. (2004).

6.6.1 Land-use within the Burdekin Dry Tropics region

The dominant land classification across the region, shown in Table 17, is agriculture, accounting for 90% of land-use. Grazing accounts for the majority (97%) of the agricultural land-use and 87% of all land-use in the region.

Table 17. Land classification across the Burdekin Dry Tropics region – 1997.

Land use	Area (ha)	%
Dryland cropping/pasture	*364,777*	*2.6*
Irrigated cropping/pasture	*45,205*	*0.3*
Total cropping/pasture	409,981	3.0
Dryland horticulture	*702*	*0.00*
Irrigated horticulture	*6,406*	*0.05*
Total horticulture	7,107	0.05
Grazing	12,433,997	87.4
Total agriculture	**12,851,085**	**90.4**
Forestry	**155,401**	**1.1**
Intensive use	**106,907**	**0.8**
Managed resource protection	**19,194**	**0.1**
Minimal use	**758,796**	**5.3**
Nature conservation	**224,789**	**1.6**
Waters	**103,503**	**0.7**
No data	**0**	**0.0**
Total area (ha)	**14,219,676**	**100.0**

Source: Land-use area sourced from National Land and Water Resource Audit, Land-use of Australia April 1996 – March 1997 which was derived and compiled by the Bureau of Rural Sciences. The data were constructed by automated analyses of a one-year sequence of normalised difference vegetation index images with a 0.01 degree cell size. Classification assigns the dominant land-use of one cell the area of the entire cell, thus the results will both over- and under-estimate the areal extent of individual land-use classes. Estimates of error propagation within the dataset do not accompany the dataset. Therefore, we can only caution that the results will be more accurate in more homogenous landscapes and less accurate at the edges of homogenous landscapes and in heterogenous landscapes. Notes: Forestry; includes production and plantation. Water; includes estuary/coastal waters, lakes, marshes/wetlands, reservoirs and rivers. Managed resource protection; includes Traditional Owner use. Nature conservation; includes managed habitat, national parks, protected areas and conservation areas. Minimal use; includes defence areas and remnant native cover. Intensive use; includes transport and communication, and urban areas.

6.6.2 Sectoral Contribution to Gross Output in the Region

Table 18 shows industry contribution to gross output from the economy of Burdekin Dry Tropics region. At farm gate prices, beef cattle is the single largest contributor to agricultural output by value in the region with 38.2%, followed by sugarcane and vegetables contributing 24.9% and 23.1% respectively. In terms of value produced per hectare under management, cropping is by far the most profitable sector.

Table 18. Gross output, Burdekin Dry Tropics region 2001.

Sector	Value ($)	% of agriculture total
Crops		
Cereals for grain	42,773,836	6.3
Cotton	2,047,937	0.3
Nurseries, flowers and turf	6,664,369	1.0
Sugarcane	169,660,572	24.9
Fruit	21,823,188	3.2
Vegetables	157,435,531	23.1
Pastures and grasses	1,200,567	0.2
Other Horticulture	8,375,805	1.2
Total value of crops	**409,981,805**	**60.2**
Livestock		
Beef cattle	260,563,510	38.2
Milk	2,187,009	0.3
Pigs	4,221,942	0.6
Poultry and eggs	3,532,619	0.5
Sheep and wool	797,175	0.1
Other livestock	240,011	0.0
Total value of livestock	**271,542,267**	**39.8**
Total value of agriculture	**681,524,072**	**100.0**

Source: ABS Agriculture Census (2001).

6.6.3 Farm Performance Measures

During 2001-02 data from a total of nine farms in the Burdekin Dry Tropics region were collated for this report. Given the relatively small size of the sample the sampling errors are likely to be high.

Table 19 shows the farm performance measures reported in the farm survey of resource management performed by ABARE during 2001-02.

The Burdekin Dry Tropics region has the highest level of total capital on average per farm of the six NRM regions of the Great Barrier Reef (GBR) catchment and well in excess of the average total capital for the whole GBR region ($2,566,073). Not surprisingly then, debt levels are also the highest when compared to the other regions. However, farmers in the Burdekin Dry Tropics are earning much higher profits at full equity in comparison to farmers in other regions of the GBR catchment and of those landholders surveyed only 4% of Burdekin Dry Tropics respondents agreed that profit was falling. There may well be a high level of optimism about future returns in the Burdekin Dry Tropics, hence a greater willingness to incur debt despite relatively low returns (3%).

Table 19. Farm performance measures[3] in the Burdekin Dry Tropics compared to the whole GBR catchment.

Farm performance measure	Burdekin – Value (average per farm)	Whole GBR catchment – Value (average per farm)
Farm cash income	$39,154	$69,627
Farm business profit	$116,134	$21,710
Total capital	$6,785,794	$2,566,073
Farm equity ratio	86%	85%
Profit full equity	$193,980	$48,167
Rate of return	3%	2%
Farm business debt	$945,553	$289,144
Total off-farm income	$2,035	$12,960

Source: ABARE (2004) – unpublished data.

The Burdekin Dry Tropics region has a comparable average debt to equity ratio (86%) to the GBR region as a whole (85%). As stated above, farms in the Burdekin Dry Tropics region have the highest level of profit at full equity and second highest rate of return of the regions examined suggesting perhaps that farmers in the Burdekin Dry Tropics region may be better placed to invest in sustainable land practice than other regions in the GBR catchment.

6.6.4 Agricultural Land Management

The total area of holdings for the Burdekin Dry Tropics region reported in the 2001 Agricultural Census was 13,504,784 ha. 24% of this land was reported to be leased from the crown, while 71% was owned and operated, 4% was leased or rented and 0.4% was listed as other.

Irrigation

Of the total land holdings in the region approximately 0.7% (98,705 ha) of land is irrigated. Irrigated land in the region is primarily located in the Burdekin and Bowen LGAs which have the highest value of agricultural output in the region.

Cultivation Techniques

68% of land cultivated in the Burdekin Dry Tropics region was prepared using zero or minimal till. The different cultivation techniques across the region are listed in Table 20.

Table 20. Cultivation techniques used in the Burdekin Dry Tropics region.

Land Preparation Technique	% of land prepared
No cultivation or zero till (apart from actual sowing operation)	33
Minimal till, One or two cultivations only (immediately prior to sowing)	35
Conventional cultivation, land prepared with other cultivation	32

Source: ABS Agricultural Census (2001).

[3] These values are for 2001-2002. However, conditions have changed considerably due to the recent drought. For example, it is estimated that farm cash income for broadacre industries in Queensland will fall from $112,800 to $41,000 in 2002-2003. In Queensland, farm business profit is expected to fall from $43,800 to $38,000 (ABARE, 2002, p 566).

Tree Planting
In the 2001 ABS Agricultural Census it was reported that 62 ha of land (0.0005% of total holdings) was planted with seedlings for nature conservation or to protect land and water across the Burdekin Dry Tropics region.

Protective Fencing
With reference to Table 21, in 2001, 71,309 ha of agricultural land in the region was fenced off from grazing. 38.6% of the protective fencing in the region is used to protect creeks and rivers.

Table 21. Land fenced off from grazing in the Burdekin Dry Tropics region.

Land Protected	% of total land fenced off
Saline Areas	2.0
Other degraded areas	7.9
Planted trees and shrubs	0.1
Creeks and rivers	38.6
Remnant native vegetation	5.5
All other areas	46.0
Total area protected (ha)	**71,309**

Source: ABS Agricultural Census (2001).

Salinity Management
Of the agricultural establishments in the region approximately 9% indicated that they had land affected by salinity. In addition, approximately 25% of all establishments reported that they were using salinity management practices.

6.6.5 Industry Sectoral Contribution to Employment in the Burdekin Dry Tropics region

Table 22 details the employment by industry in the region and shows changes in employment in these industries since 1996. It also shows that the industries contributing the most to employment in the region are the service sectors. In 2001 the major employer in the region was the trade sector which contributed 19.4% to the total employment. Health and community services (9.8%), manufacturing (8.5%), and education (8.1%) were the next major sectors employing people within the region.

The Census data shows an increase in employment since 1996 in the trade, construction, health and community services and government administration sectors. Employment declined in the cultural, sport and recreation services sector while remaining steady in other sectors of the regional economy.

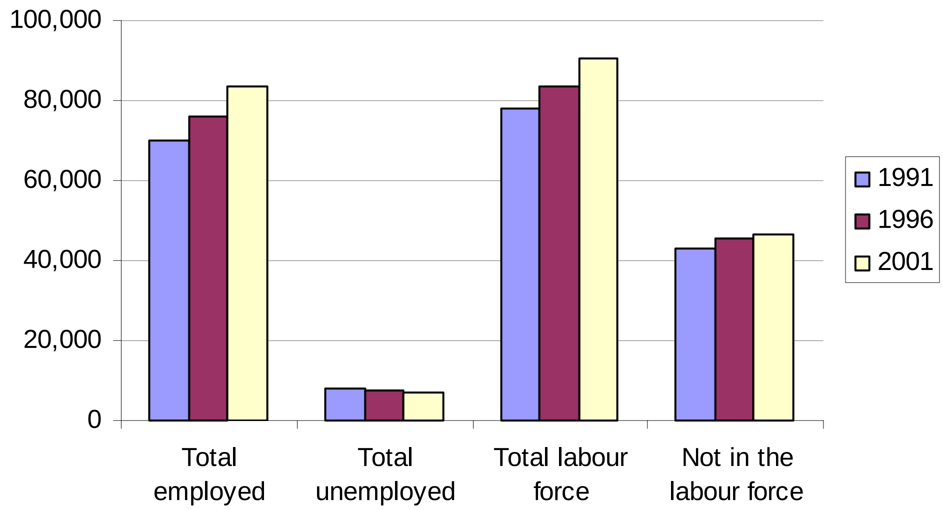
The number of people employed and the total number of people in the labour workforce in the Burdekin Dry Tropics region has increased over the last three Census periods (Fig. 6). Over the same period, the unemployment rate has decreased from 10% in 1991 to 8% in 2001. Of those individuals employed in 2001, 31.7% were in part-time employment, an increase from 29.1% in 1996 (QRBIS, 2003). The Burdekin Dry Tropics region workforce participation rate at the 2001 Census was 66.2% (QRBIS, 2003), which is higher than the Queensland rate of 63.1% (ABS, 2001).

Table 22. Sector employment in the Burdekin Dry Tropics region.

Sector	Number of people – Census 1996	%	Number of people – Census 2001	%
Trade (retail and wholesale)	14,495	19.1	16,174	19.4
Health and community services	6,950	9.1	8,134	9.8
Manufacturing	6,657	8.8	7,114	8.5
Education	6,063	8.0	6,738	8.1
Property and business services	5,551	7.3	6,129	7.4
Construction	4,905	6.5	5,830	7.0
Defence	4,179	5.5	4,655	5.6
Agriculture	4,395	5.8	4,607	5.5
Transport and storage	3,652	4.8	4,218	5.1
Accommodation and restaurants	3,586	4.7	4,061	4.9
Government administration	2,799	3.7	3,475	4.2
Personal and other services	2,596	3.4	2,975	3.6
Mining	1,931	2.5	2,004	2.4
Cultural, sport and recreation services	2,182	2.9	1,860	2.2
Other	2,451	3.2	1,750	2.1
Finance and insurance	1,524	2.0	1,480	1.8
Communication services	1,144	1.5	1,108	1.3
Electricity, water and gas	726	1.0	795	1.0
Commercial fishing	173	0.2	180	0.2
Forestry and logging	32	0.0	31	0.0
Total	**75,991**	**100.0**	**83,318**	**100.0**

Source: QRBIS (2003).

Figure 6. Employment in the Burdekin Dry Tropics NRM region at the Census years 1991, 1996 and 2001.



Source: QRBIS (2003).

6.6.6 *Income*

The median weekly individual income for the region at the 2001 Census was $300-$399 which is the same as that for the State. 13.4% of individuals earned between $200-299 per week (Table 23). The median weekly family income was $800-$999 in 2001, which was the same as the State.

Table 23. Individual weekly income in 2001.

Individual weekly income	Number of people - Census Year 2001	%
Neg/Nil	8,550	5.9
$1 - $39	2,201	1.5
$40 - $79	3,675	2.5
$80 - $119	4,037	2.8
$120 - $159	6,964	4.8
$160 - $199	11,720	8.1
$200 - $299	17,711	12.2
$300 - $399	12,835	8.8
$400 - $499	12,352	8.5
$500 - $599	11,641	8.0
$600 - $699	9,110	6.3
$700 - $799	8,306	5.7
$800 - $999	9,966	6.9
$1,000 - $1,499	9,179	6.3
$1,500 or more	3,587	2.5
Not Stated	10,770	7.4
Overseas Visitors	2,492	1.7
Total	**145,096**	**100.0**

Source: QRBIS (2003).

6.6.7 *Community Vitality*

Population and Age Structure

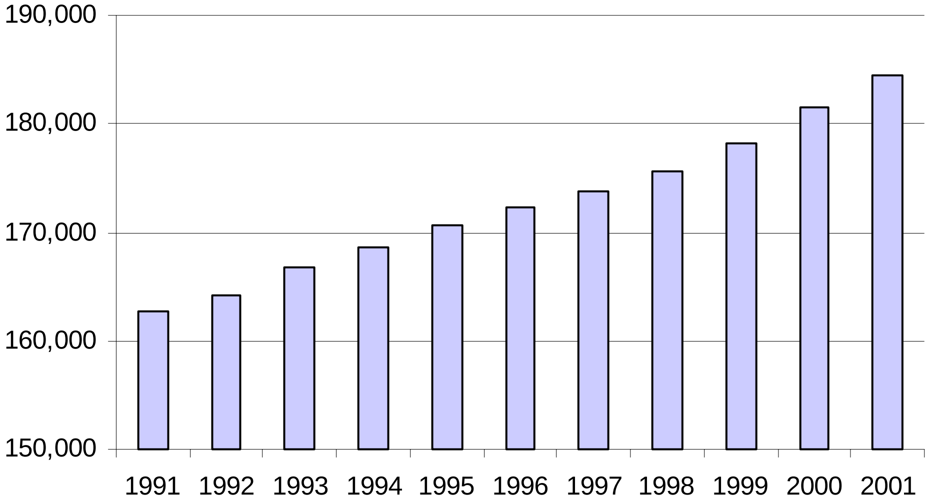
The population in the region has increased between 1991 and 2001 (Fig. 7). In 2001, the population of the region was 184,541 people accounting for 5% of the population of Queensland (ABS, 2001). This is an increase of 12,165 people between 1996 and 2001. This represents a relatively low 7.1% increase from the 1996 Census compared to the State increase of 8.5%.

The bulk of the population lives in the coastal centres of Townsville, Thuringowa and Burdekin.

The population of the region is ageing (Fig. 8). The median age of people in the region in the 2001 Census was 32 years, compared with 30 years in the 1996 Census and 25-29 years in the 1991 Census (QRBIS, 2003; ABS, 2001).

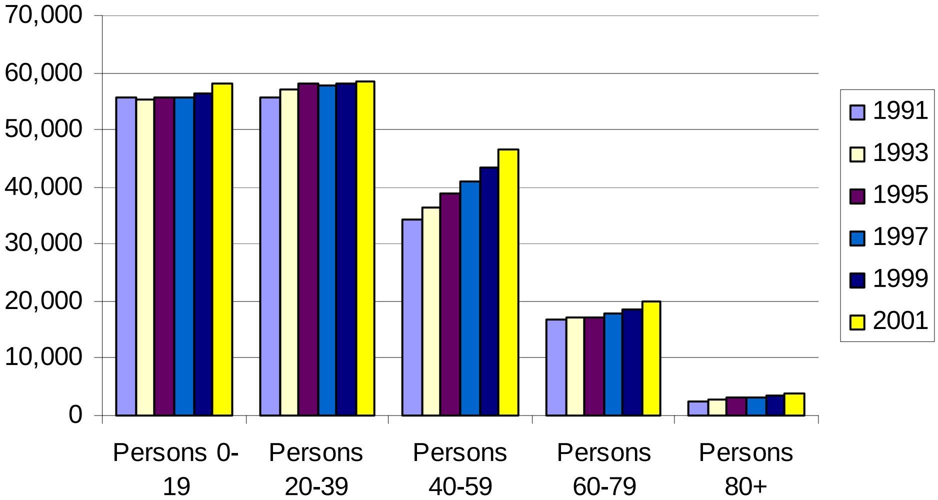
It is projected that the population will continue to increase to 216,000 by the end of 2019, at an average rate of 1% per annum, though the population is ageing (Fig. 9). This annual average population growth rate is lower than that projected for the State (1.43% per annum).

Figure 7. Change in total population living in the Burdekin Dry Tropics NRM region between 1991 and 2001.



Source: QRBIS (2003).

Figure 8. Age profile for the Burdekin Dry Tropics NRM region.



Source: QRBIS (2003).

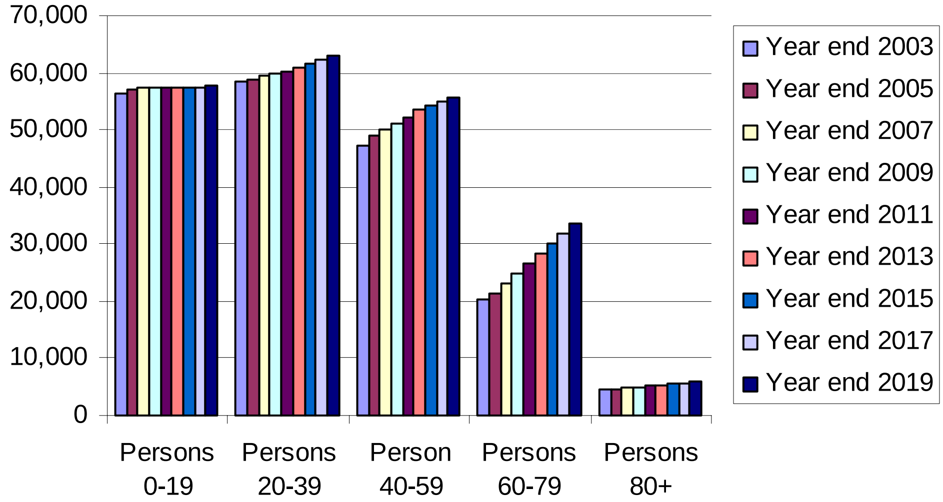
Migration

At the 2001 Census, 24% of the population within the region reported that they had moved location within the last year, with 53% moving within the last 5 years (QRBIS, 2003).

The Index of Relative Disadvantage

According to the index of relative socio-economic disadvantage calculated in 1996, the Northern statistical division which covers most of the Burdekin Dry Tropics region received a score of 981, slightly lower than Queensland as a whole, which scored 988. The index of relative socio-economic disadvantage is a measure of the relative disadvantage between geographic locations. Scores above 1,000 are considered relatively advantaged. The index scores are derived from attributes including low-income levels, level of educational attainment, high unemployment and jobs in relatively unskilled occupations (McLennan, 1998).

Figure 9. Age projections for the Burdekin Dry Tropics NRM region.



Source: QRBIS (2003).

Education

Of people aged 15 years and over, 0.5% did not attend school, 11.1% completed grade 8 or less, 31.4% left after completing grade 10 and 38.3% completed grade 12. 34.6% of people in region are, or have, received some form of tertiary (post high school) education. This is up from 29.9% in 1996 and 26.7% in 1991 (QRBIS, 2003).

Communication

<u>Access to Computers</u>

41% of residents in the region reported that they used a computer at home in the week prior to Census night, 2001. The internet was used by 36% of people (with 26% of people accessing the internet from home) in the week prior to Census night, 2001.

<u>Language</u>

Approximately 4.8% of people in the region speak a language either in addition too, or instead of, English. This has decreased from the last two Census periods (5.2% in 1991 and 5.1% in 1996) (QRBIS, 2003). In 2001 the percentage of people living in the region that were born in a non-English speaking country was 5.6% (QRBIS, 2003). Of all the people born overseas but now living in the region 3.6% speak English poorly or not at all (ABS, 2001).

7 CONCLUSION

The Burdekin Dry Tropics Board is currently in the process of developing an integrated regional NRM plan to maintain and improve the ecological and environmental health of its natural resources. While this process is well advanced for the terrestrial and freshwater environments of the region, until now, relatively little has been done on the estuarine, coastal and marine environments. This report is the first stage in the process of addressing this disparity.

The Burdekin Dry Tropics coastal region is a unique area with considerable diversity of marine and terrestrial species and habitats. The important estuarine, coastal and marine ecosystems present in the region include: coastal plains, saltmarsh, seagrass meadows, mangroves, macroalgal beds, estuaries, wetlands, rocky shores, sandy shores, marine waters, inter-tidal mudflats, beaches, sandy shoals and dunes, sub-tidal sand/mud substrates, reefs, islands and riparian vegetation. Within these ecosystems live a wide range of animal and plant species, some of which are of national and/or international significance.

The coastal region encompasses internationally significant wetlands, commercially and ecologically valuable animals and plants, and part of the Great Barrier Reef World Heritage Area. The exceptionally high conservation value of this coastline, and the human related pressures it is experiencing, has prompted the development of a variety of estuarine, coastal and marine management and protection measures. Sections of the region have been classified as State and/or Commonwealth marine parks, Ramsar sites, Fish Habitat Areas, Important Wetlands and Dugong Protection Areas.

Approximately 1,900 terrestrial plant and 800 animal species have been recorded within the region. Of these, 27 plant and 58 animal species are of conservational significance. The area is important for migratory shorebird/wader species, marine mammals and reptiles, with extensive areas of seagrass incorporated in the dugong sanctuaries. The vast areas of sheltered shoreline, creeks and inter-tidal wetlands provide significant spawning, nursery and juvenile habitats for many key commercial and recreational fisheries species.

Eucalypt forests dominate the coastal terrestrial landscape with some non-eucalypt coastal communities and heaths. Coastal dune/beach communities, mangrove systems and saltmarshes dominate the coastal and island interface with the sea.

The Burdekin Dry Tropics coastal region is home to more saltmarsh area than surrounding regions, though there has been extensive loss, especially in the Ross River catchment. There is high seagrass species richness in the region, which supports commercially important prawn species, dugongs and turtles. Extensive seagrass meadows occur in Cleveland Bay, Upstart Bay and Bowling Green Bay.

The region supports high mangrove diversity (approximately 17 species) which in turn provides habitat for a diverse range of species listed as vulnerable or rare, such as the coastal sheath tailed bat, saltwater crocodile and the rusty monitor, as well as providing habitat for commercially important fish, crab and prawn species at critical life stages.

There are many notable and unique reefs in the region, some with high (>60%) soft coral cover. The Great Barrier Reef's only population of the rare soft coral *Nephthyigorgia* sp. and one of the largest colonies of the stony coral *Montipora digitata* occur in the region with outcrops of the rare brain star coral (*Goniastrea* sp.) also present.

Of the 26 estuaries in the region examined, seven are listed as 'near pristine', 11 as 'largely unmodified' and eight as 'modified'. None were found to be in the poorest condition category of 'extensively modified'. Water quality monitoring of Cleveland Bay and Bowling Green Bay show relatively high levels of nutrients and suspended solids. Surveys conducted in 2000 show chlorophyll *a* levels (an indicator of nutrient enrichment) have doubled in Cleveland Bay since 1988.

The marine waters off the Burdekin Dry Tropics coast are home to a huge diversity of invertebrate organisms. There is very little precise data available concerning species lists, distribution, conditions and threats for most marine and terrestrial invertebrate species with only the pest species receiving significant attention.

Within the region, 20 species of plant are considered rare, six are considered vulnerable, and one, the endemic flowering shrub *Babingtonia papillosa*, is considered endangered. Other endemic species include *Eucalyptus paedoglauca*, also known as Mt Stuart Ironbark and *Croton magneticus* which has been classified as vulnerable.

Information on the condition and trend of several ecosystems (e.g. inter-tidal flats, sub-tidal substrates, rocky shores) in the region is scarce or nonexistent even though it is well documented that they are essential natural resources which are at risk from human actions.

Major threats to estuarine, coastal and marine habitats and species in the area are coastal development, inappropriate agricultural activities, changes to hydrology, removal/disturbance of habitat and species, pests (particularly weeds and marine pests), changes to the freshwater flow regime, salinisation of groundwater, vegetation removal, polluted stormwater run-off, inappropriate recreational activities (such as quad bikes on dunes) and water quality declines (particularly in nutrient enrichment or increased turbidity). Seagrass and reef ecosystems are particularly sensitive to water quality declines.

Natural events, such as cyclones and droughts, can also severely impact on ecosystems and water quality in the region.

Generally, the overall condition of aquatic ecosystems and ambient water quality within the coastal catchments has more to do with the accumulation of many localised effects than it does with catchment-scale processes. The main factor influencing ambient water quality, other than changes in flow, is local land-use. In grazing areas, livestock and/or feral animals loiter in streams and their riparian zones, affecting water quality. In cropping areas, localised run-off to streams and entry to groundwater may be the main impact. In fact, any alteration that affects water depth, flow, light exposure, temperature etc. can have a large impact on ambient water quality. Alterations to physical stream characteristics also play a major role in the condition of aquatic ecosystems and water quality (e.g. riparian vegetation, aquatic weeds, construction of weirs, bund walls and tidal barriers).

Although the degree of localised impact varies between waterbodies, the additive effect of many localised impacts on ambient water quality can be significant for the whole catchment. Management of local water quality problems has a high chance of success because the problem is localised and landholders can see the improvements.

Suggestions of general targets, actions and outcomes for the coastal region:

- The stability of dunes and other coastal landforms are maintained. For example, inappropriate activities (e.g. grazing, quad bike riding, vehicle access) on dune systems are avoided with public access to the coast improved (e.g. better signage, fencing and access points managed and locations coordinated).
- Riparian vegetation areas along waterways are maintained and rehabilitated.
- Land susceptible to soil erosion because of slope, soil type or land-use practice are protected/managed to avoid or minimise sediments entering waterways.
- Disturbance to coastal wetlands, conservationally and commercially important species, and significant habitats (such as wildlife nesting and breeding areas (e.g. wading bird roost sites, turtle nesting beaches)) are minimised.
- Damage/disturbance to reefs and other estuarine/marine ecosystems or significant species from boating/shipping activities is minimised.
- Estuarine, coastal and marine sites of cultural significance are protected/managed in keeping with the values of the site.
- Surface and groundwater management practices are improved and accredited land and water management plans are developed for the region.
- Spatially relevant water table targets (both quantity and quality) are set.
- Groundwater monitoring systems are implemented and data used to fine tune future land and water management practices.
- Irrigation practices are improved to better match crop nutrient and water requirements thereby minimising surface run-off and deep drainage from the root zone.
- Water quality is improved for targeted water quality parameters and at least maintained for all others in line with guidelines appropriate for the protection of the values and uses of waterways in the region (progressively set and refine locally relevant guideline values based on the best available information for appropriate water quality parameters, including nutrients (nitrogen and phosphorous), toxicants (e.g. metals, pesticides, herbicides, hydrocarbons, etc.) and turbidity/suspended particulate matter).
- Water flows are managed such that any detrimental impacts on estuarine, coastal and marine ecosystems as a result of changed (increased or decreased) flow or impeded animal access due to barriers, such as dams, weirs, levees, bund walls, is minimised.
- The awareness of local community, Traditional Owner groups and landholders to estuarine, coastal and marine issues is increased and opportunities for them to participate in the monitoring, rehabilitation and protection of habitat and species is provided, encouraged and supported.

- The quality and quantity of stormwater run-off is managed to ensure that environmental values of the estuaries and marine waters are protected.
- Areas of State significance are protected from activities that adversely impact on their environmental values unless those activities can demonstrate a net benefit to the State as a whole and their impacts are minimised.
- Coastal wetlands are protected from further loss or degradation, with any human impacts prevented or at least minimised.
- Pest plant or animal species that are currently present are removed where possible or managed to minimise any adverse impacts they may have. The risk of pest introduction is minimised. The management of aquatic weeds in waterways, particularly those which now flow all year round due to irrigation water and tailwaters, is a high priority in the Burdekin Haughton Water Supply Scheme area.
- Commercial and recreational fisheries species are managed sustainably, through the protection of critical inshore habitats and uninhibited fish access to freshwater, estuarine and marine habitats.
- Research is undertaken on ecosystems/habitats that are deemed to be poorly understood in order to help their future management.
- Biodiversity is safeguarded through the conservation and appropriate management of the diverse range of habitats occurring in the region.
- Areas with acid sulphate soil or high salinity potential are managed to minimise the risk of impacts occurring and those areas currently impacted by acid sulphate soils or salinity undergo remediation activities.
- Areas of high natural conservation value currently outside existing conservation areas are adequately protected.
- The adoption rate of ‘best practice farming methods’ is maximised.
- Research is encouraged and supported to fill important gaps in our knowledge of natural resources, pressures and processes occurring in the region.
- The capacity of people to participate in natural resource management is enhanced.

8 REFERENCES

ABARE. 2002. *Australian commodities: forecasts and issues*, Vol. 9. Australian Bureau of Agricultural and Resource Economics, Canberra.

ABARE. 2004. *Unpublished data*. Australian Bureau of Agricultural and Resource Economics, Canberra.

ABS Agricultural Census. 2001. *Agriculture census*. Australian Bureau of Statistics, Canberra.

ABS. 1991. *Community profile census*. Australian Bureau of Statistics, Canberra.

ABS. 1996. *Community profile census*. Australian Bureau of Statistics, Canberra. http://www.abs.gov.au/ausstats/abs@.nsf/w2.5?OpenView

ABS. 2001. *Community profile census*. Australian Bureau of Statistics, Canberra. http://www.abs.gov.au/ausstats/abs@census.nsf/Census_BCP_LGA_ViewTemplate?ReadForm&Expand=1

ACTFR. Date unspecified. Overview of water quality processes and management strategies in waterways of the Burdekin region. In: Volume 2, Appendices. *A proposed typological basis for providing new situation-specific water quality advice to resource managers in Queensland's dry and wet-dry tropics*. Pp. 127-143 pp. Australian Centre for Tropical Freshwater Research report no. 04/04.

Accad, A., Neldner, V.J., Wilson, B. A. and Niehus, R.E. 2003. *Remnant vegetation in Queensland*. *Analysis of remnant vegetation 1997-1999-2000-2001*, *including regional ecosystem information*. Queensland Herbarium, Environmental Protection Agency, Brisbane.

Ahern, C., Johnston. P. and Watling, K. 2002. *Acid sulfate soils: an important coastal water quality issue*. Coast to Coast 2002.

AIMS. 2001a. *Stanley Reef back*. http://adc.aims.gov.au:9555/waAesthetics/servaesthetics?fullReefID=19045S&zone=1

AIMS. 2001b. *Stanley Reef first flank*. http://adc.aims.gov.au:9555/waAesthetics/servaesthetics?fullReefID=19045S&zone=2

AIMS. 2001c. *Stanley Reef front*. http://adc.aims.gov.au:9555/waAesthetics/servaesthetics?fullReefID=19045S&zone=3

AIMS. 2001d. *Stanley Reef second flank*. http://adc.aims.gov.au:9555/waAesthetics/servaesthetics?fullReefID=19045S&zone=4

AIMS. 2002a. *Fantome Island Reef back*. http://adc.aims.gov.au:9555/waAesthetics/servaesthetics?fullReefID=18053S&zone=1

AIMS. 2002b. *Fantome Island first flank*. http://adc.aims.gov.au:9555/waAesthetics/servaesthetics?fullReefID=18053S&zone=2

AIMS. 2002c. *Fantome Island Reef front*. http://adc.aims.gov.au:9555/waAesthetics/servaesthetics?fullReefID=18053S&zone=3

AIMS. 2002d. *Fantome Island second flank*. http://adc.aims.gov.au:9555/waAesthetics/servaesthetics?fullReefID=18053S&zone=4

AIMS. 2003a. *Havannah Island Reef first flank*. http://www.aims.gov.au/monmap/aesthetics/aes18065Sf1.html

AIMS. 2004a. *Pandora Reef trends in cover of benthic organisms*. http://adc.aims.gov.au:9555/waReefPage/servrpdetail;jsessionid=A2FE4BD351C35620B86CA457CEC3CCD8?reefID=18051&reefSubID=S&method=vpoint

AIMS. 2004b. *Pandora Reef trends in fish abundance*. http://adc.aims.gov.au:9555/waReefPage/servrpdetail;jsessionid=A2FE4BD351C35620B86CA457CEC3CCD8?reefID=18051&reefSubID=S&method=fish

AIMS. 2004c. *Middle Reef trends in cover of benthic organisms*. http://adc.aims.gov.au:9555/waReefPage/servrpdetail?reefID=19011&reefSubID=S&method=vpoint

AIMS. 2004d. *Pandora Reef*. http://adc.aims.gov.au:9555/waReefPage/servreefpagenew?fullReefID=18051S

Alongi, D.M. 1990. Effects of mangrove detrital outwelling on nutrient regeneration and oxygen fluxes in coastal sediments of the central Great Barrier Reef. *Estuarine Coastal and Shelf Science* **31**: 581-598.

Alongi, D.M. and McKinnon, A.D. 2004. The cycling and fate of terrestrially-derived sediments and nutrients in the coastal zone of the Great Barrier Reef shelf. *Marine Pollution Bulletin* **51**: 239-252.

AMSA. 2001. *Review of ship safety and pollution prevention measures in the Great Barrier Reef*. http://www.amsa.gov.au/Shipping_Safety/Great_Barrier_Reef_and_Torres_Strait/GBR_Review_Report/Documents/shipimp.pdf

AMSA. 2003. *REEFREP - mandatory ship reporting system*. http://www.amsa.gov.au/shipping_safety/AUSREP_and_REEFREP/REEFREP/

AMSA. Date unspecified. *The Great Barrier Reef and Torres Strait shipping impact study*. http://www.amsa.gov.au/Shipping_Safety/Great_Barrier_Reef_and_Torres_Strait/GBR_Review_Report/Documents/shipimp.pdf

Andersen, F.Ø. and Kristensen, E. 1988. Oxygen microgradients in the rhizosphere of the mangrove *Avicennia marina*. *Marine Ecology Progress Series* **44**: 201-204.

Andersen, A.N. and Spain, A.V. 1996. The ant fauna of the Bowen Basin, in the semi-arid tropics of central Queensland (Hymenoptera: Formicidae). *Australian Journal of Entomology* **35**: 213-221.

Anderson, C. and Roche M. 2002. *Cleveland Bay Status Report*, *Cleveland Bay Consortium*. http://www.clevelandbayconsortium.com/index.cfm?Menu=StatusReport&PageID=318

ANZECC. 2000. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. *Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand*. http://www.deh.gov.au/water/quality/nwqms/introduction/

Arunakumaren, N.J., McMahon, G.A. and Bajracharya, K. 2000. *Water management in the lower Burdekin: phase 2*, *groundwater model conceptualisation*. 79 pp. Department of Natural Resources, Brisbane.

Ash, A. 2001. *Burdekin*. http://www.marine.csiro.au/iawg/Public/inventory/Burdekin.html

AuseMade. 2004. *Orpheus Island*. http://www.ausemade.com.au/qld/destination/o/orpheusis.htm

Austasia Aquaculture. 2000. *Austasia Aquaculture home page*. http://www.austasiaaquaculture.com.au/book.php?newsID=4144

Australian Government. 1995a. *Australian treaty series 1981 No. 6*. http://www.austlii.edu.au/au/other/dfat/treaties/1981/6.html

Australian Government. 1995b. *Australian treaty series 1988 No. 22*. http://www.austlii.edu.au/au/other/dfat/treaties/1988/22.html

Australian Government and Queensland Government. 2003. *Reef Water Quality Protection Plan*. http://www.gbrmpa.gov.au/corp_site/key_issues/water_quality/rwqpp

Australian Government. 2004. *Burdekin report card*. http://www.nrm.gov.au/state/qld/burdekin/publications/report-card/#problems

Australian Museum. 2002. *Overview for the conservation of marine invertebrates*. Report for Environment Australia. http://www.amonline.net.au/invertebrates/marine_overview/chapt6m.html

Baldwin, C.L. 1986. Fringing reef: science industry and management. *Proceedings of a Workshop held at Magnetic Island Australia*, *23-25 October 1986*. http://www.gbrmpa.gov.au/corp_site/info_services/publications/workshop_series/ws009/ws009_full.pdf

Baird, A. 1999. *Microbial menace*, *CRC Reef*. http://www.reef.crc.org.au/publications/explore/feat51.html

Baran, E. 1999. A review of quantified relationships between mangroves and coastal resources. *Research Bulletin of the Phuket Marine Biological Center* **62**: 57–64.

Bavins, M., Couchman, D. and Beumer, J. 2000. *Fisheries guidelines for fish habitat buffer zones*. DPI&F, Brisbane. http://www.dpi.qld.gov.au/extra/pdf/fishweb/fhg003.pdf

Belperio, A.P. 1983. Terrigenous sedimentation in the central Great Barrier Reef lagoon: a model from the Burdekin Dry Tropics region. *Journal of Australian Geology and Geophysics* **8**: 179-190.

Blaber, S.J.M. Brewer, D.T. and Salini, J. P. 1989. Species composition and biomasses of fishes in different habitats of a tropical northern Australian estuary: their occurrence in the adjoining sea and estuarine dependence. *Estuarine, Coastal and Shelf Science* **29**: 509-531.

Blackman, J.G. 2001. *Queensland*, *a directory of important wetlands in Australia*. Third edition. Queensland Environmental Protection Agency. http://www.deh.gov.au/water/wetlands/database/directory/qld.html

Blackman, J.G. and Spain, A.V. 1999. *Bowling Green Bay*. *Information sheet on Ramsar wetlands*. Ramsar Sites Database Service. http://www.wetlands.org/RSDB/default.htm

BoM. 2003. *Flood warning system for the Don River*. http://www.bom.gov.au/hydro/flood/qld/brochures/don/don.pdf

BoM. 2004a. *Climate of Townsville*. http://www.bom.gov.au/weather/qld/townsville/climate.shtml

BoM. 2004b. *Climate information for Townsville*. http://www.bom.gov.au/cgi-bin/climate/cgi_bin_scripts/map_script_new.cgi?32040

BoM. 2004c. *Burdekin River*. http://www.bom.gov.au/hydro/wr/unesco/friend/burdekin/burdekin.shtml

Bosel, J. 2004. Project Rita report. *BDT Marine and Coastal News*. http://www.burdekindrytropics.org.au/Images/PDFs/COAST%20CARE/newsletterMay.pdf

Brodie, J., McKergow, L.A., Prosser, I.P., Furnas, M., Hughes, A.O. and Hunter, H. 2003. *Sources of sediment and nutrient exports to the Great Barrier Reef world heritage area*. 190 pp. ACTFR Report No. 03/11, Townsville.

Bruinsma, C., Danaher, K., Treloar, P. and Sheppard, R. 1999. *Coastal wetland resources of the Bowen region: Cape Upstart to Gloucester Island*. Department of Primary Industries, Queensland, Brisbane. http://www.dpi.qld.gov.au/fishweb/13549.html

Bruinsma, C. 2001. *Queensland coastal wetland resources: Cape Tribulation to Bowling Green Bay*. Information Series QI01064. Department of Primary Industries, Queensland, Brisbane. http://www.dpi.qld.gov.au/fishweb/7867.html

Burdekin Dry Tropics Board. 2004a. Draft Burdekin Dry Tropics natural resource management plan (2004-2009). 196 pp. Burdekin Dry Tropics Board, Townsville.

Burdekin Dry Topics Board. 2004b. *Community Information Paper*. http://www.burdekindrytropics.org.au/Images/PDFs/Regional%20Plan/Community%20Information%20Paper.pdf

Capp, G. 2004. *Fire and grazing to address town common para grass invasion*. CSIRO media release. Ref PR04_196 – 28 October 2004. http://www.csiro.au/index.asp?type=mediaRelease&id=paragrass&style=mediaRelease

Charlesworth, P.B. and Bristow, K.L. 2004. *Sustainable management of the Burdekin delta groundwater systems*. 24 pp. NPSI Project CLW32 – final report, CSIRO Land and Water, Canberra.

Clarke, A. 1998. *Drainage waterway management in North Queensland: a fisheries perspective*. Protection of wetlands adjacent to the Great Barrier Reef Workshop. http://www.gbrmpa.gov.au/corp_site/info_services/publications/workshop_series/ws024/

Cogger, *H.G.*, *Cameron*, *E.E.*, *Sadlier R.A. and Eggler*, *P. 1993*. *The action plan for Australian reptiles*. *The Endangered Species Unit*. http://www.deh.gov.au/biodiversity/threatened/action/reptiles/2.html

Coles, R.G., Lee Long, W.J., Helmke, S.A., Bennett, R.E., Miller, K.J. and Derbyshire, K.J. 1992. *Seagrass beds and juvenile prawn and fish nursery grounds Cairns to Bowen*. DPI&F Queensland Information Series, QI92012.

Coles, Rob and Mellors, Jane. Personal communication. 2005. Feedback from draft report, DPI&F Queensland.

Commonwealth Department of Transport and Regional Services. 2000. *Commonwealth Department of Transport and Regional Services*. http://www.dotars.gov.au/

Connell Wagner. 2004. *Ross River waterway management strategy: summary for public comments*. Prepared for NQ Water, Townsville and Thuringowa City Councils, 7 pp.

CSIRO. 2003. *CSIRO research – introduced marine pests*. http://www.marine.csiro.au/crimp/

Curran, M., Cole, M. and Allaway, W.G. 1986. Root aeration and respiration in young mangrove plants (*Avicennia marina* (Forsk. Vierth). *Journal of Experimental Botany* **37**: 1225-1233.

Danaher, K. 1995. *Coastal wetlands resources investigation of the Burdekin delta for declaration as fisheries reserves: report to ocean rescue 2000*. Department of

Primary Industries, Queensland, Brisbane. http://www.dpi.qld.gov.au/extra/pdf/fishweb/burdekin_report.pdf

DEH. 2003. *Annual state of the environment report*, *2002-03*. http://www.deh.gov.au/about/annual-report/02-03/reports-epbc-reporting.html

DEH. 2004a. *Australian marine protected areas*. http://www.deh.gov.au/coasts/mpa/about/australian.html#2

DEH. 2004. *Frogs species profile and threats database*. http://www.deh.gov.au/cgi-bin/sprat/public/spratprofileindex.pl?group=Frogs

DEH. 2005. *Terrestrial protected areas of Queensland*. http://www.deh.gov.au/parks/nrs/capad/2002/qld/qld-list102.html

Department of State Development and Innovation (2004) Coastal Aquaculture Land Suitability Assessment: Supporting Information, Brisbane.

Directory of Wetlands of International Importance. *Bowling Green Bay*. http://www.wetlands.org/RSDB/default.htm

Dobbs, K. 2001. *Marine turtles in the Great Barrier Reef World Heritage Area*. Great Barrier Reef Marine Park Authority. http://www.gbrmpa.gov.au/corp_site/info_services/publications/misc_pub/marine_turtles/marine_turtles.pdf

DPI&F. 1998. *Queensland's fisheries habitats: current condition and recent trends*. http://www.dpi.qld.gov.au/fishweb/1260.html#1

DPI&F, 2000, *Commercial Fisheries Information System (CFISH*), Fisheries Business Group in DPI&F log book data http://www.dpi.qld.gov.au/fishweb/2984.html

DPI&F. 2001. *Mangroves*. http://www.dpi.qld.gov.au/fishweb/2618.html#2

DPI&F. 2004a. *CHRIS web*. Grids used: I20, J20, I21, J21, K21, L21, L22 and M22. Department of Primary Industries and Fisheries, Queensland Government. http://chrisweb.dpi.qld.gov.au/chris/

DPI&F. 2004b. *Fish web*, *fish habitat areas*. http://www.dpi.qld.gov.au/fishweb/13401.html

DPI&F. 2004c. *Recreational fishing in Queensland*. http://www.dpi.qld.gov.au/fishweb/14519.html

DPI&F. 2004d. *Fisheries long term monitoring program*. http://www.dpi.qld.gov.au/fisheriesmonitoringprogram/

DPI&F, 2005a, *Noxious Fish- Species Information*, http://www.dpi.qld.gov.au/fishweb/14477.html#2

DPI&F. 2005b. *Commercial fisheries in Queensland*. http://www.dpi.qld.gov.au/fishweb/14526.html

Duke, N.C. and Burns, K.A. 1999. *Fate and effects of oil and dispersed oil on mangrove ecosystems in Australia*. Main Report, 212 pp; Executive Summary, 23 pp. Report to the Australian Petroleum Production Exploration Association. Australian Institute of Marine Science and CRC Reef Research Centre, James Cook University.

Duke, N.C. and Bell, A.M. 2005. Herbicides implicated as the cause of severe mangrove dieback in the Mackay region, NE Australia – serious implications for marine plant habitats of the GBR World Heritage Area. *Marine Pollution Bulletin* (in press).

Environment Australia. 2001. *A Directory of Important Wetlands in Australia*. Third edition. http://www.deh.gov.au/water/wetlands/database/directory/index.html

EPA. 1984. Thuringowa City, *Bowen Shire*, *Burdekin Shire and Townsville City Erosion Prone Areas Maps*. Coastal Erosion Unit formerly the Beach Protection Authority of the Department of Harbours and Marine QLD. http://www.epa.qld.gov.au/ecoaccess/coastal_development/search_agency_records/look_up_erosion_prone_areas/coastal_management_districts/

EPA. 2001. *State coastal management plan – Queensland's coastal policy*. 90 pp. EPA, Queensland Government, Brisbane.

EPA. 2002. *Biodiversity assessment and mapping methodology*. http://www.epa.qld.gov.au/publications/p00471aa.pdf/Biodiversity_assessment_and_mapping_methodology.pdf

EPA. 2003a. *State of the environment Queensland 2003*. EPA, Queensland Government, Brisbane.

EPA. 2003b. *Australian lace lid*, *endangered frogs*. http://www.epa.qld.gov.au/nature_conservation/wildlife/endangered_animals/endangered_frogs/australian_lacelid/

EPA. 2003c. *Marine species in Queensland ports*. http://www.epa.qld.gov.au/environmental_management/water/water_quality_monitoring/projects/introduced_marine_pests/marine_species_in_queensland_ports/

EPA. 2003d. *Bowling Green Bay*. http://www.epa.qld.gov.au/nature_conservation/habitats/mangroves_and_wetlands/bowling_green_bay/

EPA, 2003e. *Fish Kill Incidents for 2003*. *http://www.epa.qld.gov.au/environmental_management/water/water_quality_monitoring/fish_kill_reporting/recently_reported_fish_kills/fish_kill_incident_reports_for_2003/*

EPA. 2004a. *World heritage areas*. http://www.epa.qld.gov.au/parks_and_forests/world_heritage_areas/

EPA. 2004b. *Great Barrier Reef*. http://www.epa.qld.gov.au/parks_and_forests/world_heritage_areas/great_barrier_reef/

EPA. 2004c. *Parks and forests*. http://www.epa.qld.gov.au/parks_and_forests/

EPA. 2004d. *Magnetic Island National Park*. http://www.epa.qld.gov.au/projects/park/index.cgi?parkid=181

EPA. 2004e. *Bowling Green Bay National Park*. http://www.epa.qld.gov.au/projects/park/index.cgi?parkid=143

EPA. 2004f. *Cape Upstart National Park*. http://www.epa.qld.gov.au/projects/park/index.cgi?parkid=46

EPA. 2004g. *Paluma Range National Park*. http://www.epa.qld.gov.au/projects/park/index.cgi?parkid=192

EPA. 2004h. *Cape Pallarenda Conservation Park*. http://www.epa.qld.gov.au/projects/park/index.cgi?parkid=218

EPA. 2004i. *Townsville Town Common Conservation Park*. http://www.epa.qld.gov.au/projects/park/index.cgi?parkid=138

EPA. 2004j. *Paluma State Forest*. http://www.epa.qld.gov.au/projects/park/index.cgi?parkid=150

EPA. 2004k. *Nature refuges*. http://www.epa.qld.gov.au/publications/p01316aa.pdf/Nature_refuges.pdf

EPA. 2004l. *Nature refuges*. http://www.epa.qld.gov.au/nature_conservation/nature_refuges/

EPA. 2004m. *Marine parks*. http://www.epa.qld.gov.au/parks_and_forests/marine_parks/

EPA. 2004n. *GBR Coast Marine Park*. http://www.epa.qld.gov.au/parks_and_forests/marine_parks/gbr_coast_marine_park/

EPA. 2004o. *WildNet*. (Database). Queensland Environmental Protection Agency, Brisbane. Accessed 22 November 2004.

EPA. 2005. *Management plans and strategies*. http://www.epa.qld.gov.au/parks_and_forests/management/management_plans_and_strategies/

Fabricius, D. and De'ath, G. 2002. *Soft coral atlas of the Great Barrier Reef*. Australian Institute of Marine Science. http://www.aims.gov.au/pages/research/soft-corals/soft-corals00.html

Fairfax. 2005. *Magnetic Island*. http://www.walkabout.com.au/locations/QLDMagneticIsland.shtml

Faithful, J.W. and Griffiths, D.J. 2000. Turbid flow through a tropical reservoir (Lake Dalrymple, Queensland, Australia): responses to a summer storm event. *Lakes and Reservoirs: Research and Management* **5**: 231-247.

Faithful, J.W. 2002. *Surface water quality and 2002 post-wet season sediment quality*. Water quality in the Townsville/Burdekin Dry Tropics regions. National Heritage Trust Project, No. 2002153. Report to Conservation Volunteers Australia, Townsville Branch.

Furnas, M. 2003. *Catchments and corals: terrestrial runoff to the Great Barrier Reef*. 334 pp. Australian Institute of Marine Science and CRC Reef Research Centre, Townsville.

GBRMPA. Date unspecified. *Indigenous fisheries*. http://www.gbrmpa.gov.au/corp_site/key_issues/fisheries/indigenous_fisheries.html

GBRMPA. 1996. *Marine invertebrates*. http://www.reefed.edu.au/explorer/animals/marine_invertebrates/index.html

GBRMPA. 1998a. *Marine Park Management*. http://www.gbrmpa.gov.au/corp_site/info_services/publications/sotr/1998/management_frame.html

GBRMPA. 1998b. *State of the Great Barrier Reef world heritage area*. http://www.gbrmpa.gov.au/corp_site/info_services/publications/sotr/1998/index.html

GBRMPA. 1998c. *Preliminary study of potential impacts on the Great Barrier Reef world heritage area from coastal urban development: a scoping study to identify projects suitable for future funding proposals*. http://www.gbrmpa.gov.au/corp_site/info_services/publications/misc_pub/misc_004/

GBRMPA. 2001. *Great Barrier Reef water quality: current issues*. http://www.gbrmpa.gov.au/corp_site/key_issues/water_quality/current_issues/wq_report98-aug01.pdf

GBRMPA. 2002. *Public moorings help boaties protect the reef*, *media release*. http://www.gbrmpa.gov.au/corp_site/info_services/media/2002/2002-08-02.html

GBRMPA. 2003a. *Shipping and ports*. http://www.gbrmpa.gov.au/corp_site/management/zoning/rap/rap/overview/intro/ships.html

GBRMPA. 2003b. *Great Barrier Reef Marine Park zoning plan 2003*. Great Barrier Reef Marine Park Authority. Australian Government.

GBRMPA. 2004a. *Dugong protection areas*. http://www.gbrmpa.gov.au/corp_site/info_services/publications/dugong/sanctuaries.html

GBRMPA. 2004b. *Holbourne Island*. http://www.gbrmpa.gov.au/corp_site/management/zoning/rap/rap/tw/mnp_19_96.html

GBRMPA. 2004c. *GBR Traditional Owners*. http://www.reefed.edu.au/explorer/traditional_owners/index.html

GBRMPA. 2004d. *Coral bleaching: current conditions report*. http://www.gbrmpa.gov.au/corp_site/info_services/science/bleaching/conditions_report.html

GBRMPA. 2004e. *Coral bleaching and mass bleaching events*. http://www.gbrmpa.gov.au/corp_site/info_services/science/bleaching/

GBRMPA. 2004f. *Reef bioregions of the Great Barrier Reef world heritage area*. http://www.gbrmpa.gov.au/corp_site/management/zoning/rap/rap/bioregions/

GBRMPA. 2004g. *Water quality*. http://www.gbrmpa.gov.au/corp_site/key_issues/water_quality/

GBRMPA. 2004h. *Nelly Bay*. http://www.gbrmpa.gov.au/corp_site/management/eim/eia/nelly_bay.html#Figure%202

GBRMPA. 2004i. *Principal water quality influences on Great Barrier Reef ecosystems*. http://www.gbrmpa.gov.au/corp_site/key_issues/water_quality/principal_influences.html

Gibbs, R.J. 1993. Metals of the bottom muds in Townsville Harbour, Australia. *Environmental Pollution* **82**: 1-4.

Greenland, J.A., Limpus, C.J. and Currie, K.J. 2002. *Marine wildlife stranding and mortality database annual report 2002*. *III*. *Marine turtles*. http://www.epa.qld.gov.au/publications/p01293aa.pdf/Queensland_marine_wildlife_stranding_and_mortality_database_annual_report_20012002_III_Marine_turtles.pdf

Greening Australia. 2003. *Native vegetation management: a needs analysis of regional service delivery in Queensland – Burdekin*. Bushcare Support. http://www.deh.gov.au/land/publications/nvm-qld/pubs/qld-burdekin.pdf

Greiner, R., Stoeckle, N., Stokes, C., Herr, A. and Bachmaier, J. 2003. *Natural resource management in the Burdekin Dry Tropics: social and economic issues*. Report for the Burdekin Dry Tropics NRM Board. 178 pp. CSIRO Sustainable Ecosystems, Townsville.

Grice, T. Date unspecified. *Weeds in the Burdekin rangelands: impacts*. http://savanna.ntu.edu.au/downloads/burd2.pdf

Hansen, A. 2004. *BDT Marine and Coastal Newsletter*. Issue 3. http://www.burdekindrytropics.org.au/Images/PDFs/COAST%20CARE/BDT%20marine%20and%20coastal%20news%20july.pdf

Haines, J.A. and Limpus, C.J. 2000. *Marine wildlife stranding and mortality database annual report*. http://www.epa.qld.gov.au/publications/p01147aa.pdf/Marine_wildlife_stranding_and_mortality_database_annual_report_2000_III_Marine_turtles.pdf

Harvey, T. 2004. Personal communication. Queensland Parks and Wildlife Service/CRC Reef.

Hatcher, B.G., Johannes, R.E. and Robertson, A.I. 1989. Review of research relevant to the conservation of shallow tropical marine ecosystems. *Oceanography and Marine Biology Annual Review* **27**: 337–414.

Hazel, J. 2003. *The Indo-Pacific sea turtle conservation group March 2003 newsletter*. http://www.aims.gov.au/ipstcg/pdf/ipstcg-newsletter-march03.pdf

Henry, G. and Lyle, J. 2003. *The national recreational and indigenous fishing survey*, Commonwealth Government. http://www.affa.gov.au/corporate_docs/publications/pdf/fisheries/final_recsurvey_report.pdf

Hoey, J. and Chin, A. 2004. Crown-of-thorns starfish. In: *The State of the Great Barrier Reef On-line*. A. Chin (ed.). Great Barrier Reef Marine Park Authority, Townsville. http://www.gbrmpa.gov.au/corp_site/info_services/publications/sotr/cots/index.html

Hopley, D., Van Woesik, R., Hoyal, D.C.J.D., Rasmussen, C.E. and Steven, A.D.L. 1990. *Sedimentation resulting from road development*, *Cape Tribulation area*. Technical Memorandum No. 24. http://www.gbrmpa.gov.au/corp_site/info_services/publications/tech_memorandums/tm024/

Hoedt, F.E., Choat, J.H., Cruz, J.J. and Collins, J.D. 2001. *Sample collection methods and practical considerations for introduced species' surveys at tropical ports*. Technical report No. 35. 41 pp. CRC Reef Research Centre Ltd, Townsville. http://www.reef.crc.org.au/publications/techreport/TechRep35.html

Horn, A., Joo, M. and Poplawski, W. 1998. *Queensland riverine sediment transport rates – a progress report*. Department of Natural Resources, Brisbane.

Isdale, P.J., Stewart B.J., Tickle, K.S. and Lough, J.M. 1998. Palaeohydrological variation in a tropical river catchment: a reconstruction using fluorescent bands in corals of the Great Barrier Reef, Australia. *The Holocene* **8**: 1-8.

Johnson, D.P. 1985. *Age structure of the Fantome Island fringing reef*. Technical Memorandum No. 6. http://www.gbrmpa.gov.au/corp_site/info_services/publications/tech_memorandums/tm006/

Johnson, A.K.L., Ebert, S.P. and Murray, A.E. 1998. Spatial and temporal distribution of wetland and riparian zones and opportunities for their management in catchments adjacent to the Great Barrier Reef marine park. *Protection of wetlands adjacent to the Great Barrier Reef*, *GBRMPA Workshop Series* 24. Proceedings of a workshop held in Babinda, Queensland, Australia, 25-26 September 1997. D. Haynes, D. Kellaway and K. Davis (eds). http://www.gbrmpa.gov.au/corp_site/info_services/publications/workshop_series/ws024/ws024_paper_19.pdf

King, G. 2003. *Social Atlas*. Fifth Edition, Community and Cultural Services Department Townsville City Council. http://www.townsville.qld.gov.au/about/atlas/contents.asp

Kettle, B., Dalla Pozza, R. and Collins, J. 2002. *New Directions: A review of the impacts of dredging in Cleveland Bay*, *and research priorities for the next decade*. Report prepared for Townsville Port Authority Dredge Spoil Disposal Technical Advisory and Consultative Committee. http://www.townsville-port.com.au/pdf/dredging/

Lee Long, W.J. and Coles, R. 1995. *Status of Seagrasses in the Great Barrier Reef Region*. GBRMPA Workshop 23, Proceedings of a technical workshop held in Townsville, Queensland, Australia, 27-29 November 1995. D. Wachenfeld, J. Oliver and K. Davis (eds).

http://www.gbrmpa.gov.au/corp_site/info_services/publications/workshop_series/ws023/

Lee Long, W.J., McKenzie, L.J., Roelofs, A.J., Makey, L.J., Coles R.G. and Roder C.A. 1996. *Baseline survey of Hinchinbrook region seagrasses October* (*Spring*) *1996*. Research publication No. 51. http://www.gbrmpa.gov.au/corp_site/info_services/publications/research_publications/rp51/

Lee Long, W.J. McKenzie, L.J., Roelofs, A.J., Makey, L.E., Coles, R.G. and Roder, C.A. 1998. *Baseline Survey of Hinchinbrook Region Seagrasses – October (Spring) 1996*. GBRMPA Research Publication No. 51. http://www.gbrmpa.gov.au/corp_site/info_services/publications/research_publications/rp51/rp51_results.pdf

Limpus, C.J., Currie, K.J. and Haines, J.A. 2002a. *Marine wildlife stranding and mortality database annual report 2002*. *I*. *Dugong*. http://www.epa.qld.gov.au/publications/p01143aa.pdf/Marine_wildlife_stranding_and_mortality_database_annual_report_2002_I_Dugong.pdf

Limpus, C.J., Currie, K.J. and Haines, J.A. 2002b. *Marine wildlife stranding and mortality database annual report 2002*. *II*. *Cetacean and Pinniped*. http://www.epa.qld.gov.au/publications/p01191aa.pdf/Marine_wildlife_stranding_and_mortality_database_annual_report_2002_II_Cetacean_and_pinniped.pdf

Lobegeiger, R. and Wingfield, M. 2004. *Aquaculture production survey Queensland 2002-2003*. Report to farmers. http://www.dpi.qld.gov.au/extra/pdf/fishweb/ReportToFarmers_May04.pdf

Mackenzie, R., Robinson, J., Dent, J. and Scheltinga, D.M. 2004. *Capacity of NRM regions and local governments in the reef catchment to support sustainable land management practices and conservation on private and leasehold land*. 145 pp. CRC for Coastal Zone, Estuary and Waterway Management, Indooroopilly.

Magnetic Island Community Development Association Inc. and Magnetic Island Nature Care Association Inc. 2004. *Magnetic Island's world heritage values; a preliminary assessment*.

Mancuso, R. 2003. Red tide chokes beaches. *Townsville Bulletin*, 25 September, 2003. http://www.aims.gov.au/arnat/arnat-010-02-20000043.htm

Manson, F.J., Loneragan, N.R., Harch, B.D., Skilleter, G.A. and Williams, L. 2005a. A broad-scale analysis of links between coastal fisheries production and mangrove extent: A case-study for northeastern Australia. *Fisheries Research* **74**: 69–85.

Manson, F.J., Loneragan, N.R., Skilleter, G.A. and Phinn, S.R. 2005b. An evaluation of the evidence for linkages between mangroves and fisheries: a synthesis of the literature and identification of research directions. O*ceanography and Marine Biology Annual Review* **43**: 485-515.

Marsh, H. 1996. *Dugong status reports and action plans for countries and territories*. UNEP, early warning and assessment report series.

McCulloch, M., Fallon, S., Wyndham, T., Hendy, E., Lough, J. and Barnes, D. 2003. Coral record of increased sediment flux to the inner Great Barrier Reef since European settlement. *Nature* **42**: 727-730.

McKee, K.L. 1993. Soil physicochemical patterns and mangrove species distribution - reciprocal effects. J*ournal of Ecology* **81**: 477-487.

McKee, K.L., Mendelssohn, I.A. and Hester, M.W. 1988. Reexamination of pore water sulfide concentrations and redox potentials near the aerial roots of *Rhizophora mangle* and *Avicennia germinans*. *American Journal of Botany* **75**: 1352-1359.

McKenzie, L. 2004. *Data summary for seagrass-watch datasets of Shelley Beach*. Seagrass-Watch, DPI&F.

McLennan, W. 1998. *Information paper: 1996 census of population and housing*, *socio-economic indexes for areas*. Catalogue No. 2039.0. ABS, Canberra.

McPhail, I. 1998. The importance of wetlands to the Great Barrier Reef world heritage area , *Protection of wetlands adjacent to the Great Barrier Reef*, *GBRMPA Workshop Series 24*. Proceedings of a workshop held in Babinda, Queensland, Australia, 25-26 September 1997. D. Haynes, D. Kellaway and K. Davis (eds). http://www.gbrmpa.gov.au/corp_site/info_services/publications/workshop_series/ws024/

Mellors, Jane. 2004. *Seagrass watch program*. Personal communication. Queensland DPI&F.

Mortimer, M.R. 2000. Pesticide and trace metal concentrations in Queensland estuarine crabs. *Marine Pollution Bulletin* **41**: 359-366.

Morton, R.M. 1990. Community structure, density and standing crop of fishes in a subtropical Australian mangrove area. *Marine Biology* **105**: 385-394.

Moss, A. and Costanzo, S. 1998. *Levels of heavy metals in the sediments of Queensland rivers*, *estuaries and coastal waters*. Environment technical report No. 20. 20 pp. Queensland Department of Environment, Brisbane.

Moss, A.J., Rayment, G.E., Reilly, N. and Best, E.K. 1992. *A preliminary assessment of sediment and nutrient exports from Queensland coastal catchments*. 33 pp. Technical report No. 4, Qld Department of Environment and Heritage, Brisbane.

Müller, J.F., Duquesne, S., Ng, J., Shaw, G.R., Krrishnamohan, K. and Manonmanii, K. 2000. Pesticides in sediments from Queensland irrigation channels and drains. *Marine Pollution Bulletin* **41**, 294-301.

Müller, J.F., Haynes, D., McLachlan, M., Bohme, F., Wil, S., Shaw, G., Mortimer, M., Sadler, R. and Connell, D.W. 1999. PCDDs, PCDFs, PCBs and HCB in marine and estuarine sediments from Queensland, Australia. *Chemosphere* **39**: 1707-1721.

MWREDC. 2001. *Bowen*. http://www.mwredc.org.au/bowen/bowen.html

MWREDC. 2003a. *Mackay Whitsunday regional statistical profile June 2003: demographics*. http://www.mwredc.org.au/demographics.pdf

MWREDC. 2003b. *Mackay Whitsunday regional statistical profile June 2003: labour and industry*. http://www.mwredc.org.au/demographics.pdf

MWREDC. 2003c. *Tourism*. http://www.mwredc.org.au/tourism.pdf

MWREDC. 2004. *Active development register*. http://www.mwredc.org.au/adr.pdf

Narayan, K.A. 2003. *Groundwater flow and seawater intrusion modelling in the lower Burdekin*. 35 pp. Project report to NR&M, CSIRO Land and Water, Townsville.

Natural Resource Sciences. 2003. *Land cover change in Queensland 1999-2001*. Queensland Government, NR&M. http://www.nrm.qld.gov.au/slats/pdf/slats9901.pdf

Neil, D.T., Orpin, A.R., Ridd, P.V. and Yu, B. 2002. Sediment yield and impacts from river catchments to the Great Barrier Reef lagoon. *Marine and Freshwater Research* **53**: 733-752.

NHT. 2004. *Burdekin Dry Tropics priority projects*. http://www.nht.gov.au/nht2/projects/priority/qld.html#bdt

Nicholas, H. Date unspecified. History of early Bowen. http://www.bowenss.qld.edu.au/bowen_history.htm

NLWRA. 2001. Water-borne erosion. In: *Australian Agricultural Assessment 2001*. Vol. 1, Chapter 5. Pp 155-190. National Land and Water Resources Audit, Canberra.

Northern Queensland Threatened Frogs Recovery Team. 2001. *Recovery plan for the stream-dwelling rainforest frogs of the Wet Tropics biogeographic region of north-east Queensland 2000-2004*. Report to Environment Australia, Canberra. Queensland Parks and Wildlife Service, Brisbane. http://www.deh.gov.au/biodiversity/threatened/publications/recovery/rainforest-frogs/#6

NR&M. 2004a. *Interim resource operations licence* (*issued to SunWater*) *for Bowen Broken Rivers water supply scheme*. 13 pp. Department of Natural Resources and Mines, Queensland Government, Brisbane.

NR&M. 2004b. *Salinity in Queensland*. http://www.nrm.qld.gov.au/salinity/index.html

NR&M. 2005. Burdekin basin water resource plan - environmental condition report. Queensland Department of Natural Resources and Mines, Brisbane. In press.

Osborne, K. Ninio, R. and Sweatman, H. 1995. *The current status of sessile benthic organisms on the Great Barrier Reef*. Proceedings of a technical workshop held in Townsville, Queensland, Australia, 27-29 November 1995. D. Wachenfeld, J. Oliver and K. Davis (eds). http://www.gbrmpa.gov.au/corp_site/info_services/publications/workshop_series/ws023/

OzEstuaries. 2001. *Query database*. http://www.ozestuaries.org/frame1.html

Parkes, J., Henzell, R. and Pickels, G. *Managing Vertebrate Pests: Feral Goats*. Bureau of Resource Sciences and Australian Nature Conservation Agency. M. Bomford (ed.). http://www.affa.gov.au/corporate_docs/publications/pdf/rural_science/lms/ferals/ggchap1_6.pdf

Page, A.J. 2002. *Conservation values and levels of protection of shorelines and estuaries in Queensland coastal bioregions*. Technical report to Environment Australia. Queensland Environmental Protection Agency.

Page, A.J. and Hoolihan, D.W. 2002. *Ecological values and levels of protection of Queensland Estuaries*. Report to Environment Australia. Version 2.2. Queensland Environmental Protection Agency.

Pell, A.S. and Tidemann, C.R. 1997. The impact of two exotic hollow-nesting birds on two native parrots in savannah and woodland in eastern Australia. *Biological Conservation* **79**: 145-153.

Perna, C., Cappo, M. and Burrows, D. 2004. Fish habitat decline and recovery in the Burdekin River. In: *Catchment to reef: water quality issues in the Great Barrier Reef region*. Conference abstracts. 77 pp. D. Haynes and B. Schaffelke (eds). 9-11 March 2004, Townsville.

Perna, C. and Burrows, D. 2005. Improved dissolved oxygen status following removal of exotic weed mats in important fish habitat lagoons of the tropical Burdekin River floodplain, Australia. *Marine Pollution Bulletin* **51**: 138-148.

Port of Townsville. 2004. *Port of Townsville annual report 2003-2004*. 72 pp. http://www.townsville-port.com.au

Ports Corporation of Queensland. 2004. *Ports, people and projects report 2003/04*. http://www.pcq.com.au/2004/downloads/2004pcq_portsreport1.pdf

Ports Corporation of Queensland. 2005. *Port of Abbot Point draft environmental management plan*. http://www.pcq.com.au/2004/downloads/AbbotPointPortEMPDraftJanuary20051.pdf

Post, D.A. 2004. A new method for estimating flow duration curves: an application to the Burdekin River catchment, North Queensland, Australia. *Transactions of the 2nd Biennial Meeting of the International Environmental Modelling and Software Society* (IEMSS), 14-17 June, 2004, University of Osnabruck, Germany. Pp. 1195-2000.

Post, D.A. and Croke, B.F.W. 2002. Predicting hydrologic response from physio-climatic attributes: an application to ungauged sub-catchments of the Burdekin River, North Queensland. *Transactions of the First Biennial Meeting of the International Environmental Modelling and Software Society* (IEMSS), 24-27 June, 2002, University of Lugano, Switzerland. Pp. 334-339.

Preen, T. 1996. *Dugongs, boats, dolphins and turtles in the Townsville-Cardwell region and recommendations for a boat traffic management plan for the Hinchinbrook dugong protection area*. Research publication No. 67. http://www.gbrmpa.gov.au/corp_site/info_services/publications/research_publications/rp67/index.html

Pringle, A.W. 1989. The history of dredging in Cleveland Bay, Queensland and its effect on sediment movement and on the growth of mangroves, corals and seagrass. GBRMPA, Research Publication No. 11. Townsville Queensland Australia. http://www.gbrmpa.gov.au/corp_site/info_services/publications/research_publications/rp11/index.html.

Prosser, I.P., Moran, C.J., Lu, H., Scott, A., Rustomji, P., Stevenson, J., Priestley, G., Roth, C.H. and Post, D. 2002. *Regional patterns of erosion and sediment transport in the Burdekin River catchment*. Technical report 05/02, CSIRO Land and Water, Canberra.

Prosser, I.P., Rustomji, P., Young, W.J., Moran, C.J. and Hughes, A. 2001. *Constructing river basin sediment budgets for the National Land and Water Resources Audit*. CSIRO Land and Water Technical Report 15/01, Canberra.

Pusey, B.J., Arthrington, A.H. and Read, M.G. 1998, Freshwater fishes of the Burdekin River Australia; Biogeography, history and spatial variation in assemblage structure, *Environmental Biology of Fishes*, 53, 303-318.

Qld Herbarium. 2004. *Burdekin coast species list*. HERBRECS Job No 0405_130, Brisbane Botanic Gardens Mt Coot-tha. Queensland Herbarium. www.epa.qld.gov.au

QPWS. 1999. *Queensland land for wildlife action plan*. http://www.epa.qld.gov.au/publications/p00547aa.pdf/Queensland_Land_for_Wildlife_action_plan.pdf

QPWS. 2001. *Queensland parks – overview, section 1 of master plan for Queensland's park system. Queensland Government*. http://www.epa.qld.gov.au/publications/p00576aa.pdf/Master_plan_for_Queenslands_parks_system.pdf

QRBIS. 2003. *Queensland regional bodies information system web site*. http://www.oesr.qld.gov.au/qrbis/

Queensland Farmer's Federation. 2003. *Crazy ants leave Townsville*, *QFF bulletin*. http://www.dairypage.com.au/QFF/qff110403.htm

Queensland Government. 2003. *Palm Island*. http://www.mcmc.qld.gov.au/community/palm_island.php

Queensland Transport and GBRMPA. 2000. *Oil spill risk assessment for the coastal waters of Queensland and the Great Barrier Reef Marine Park*. http://www.msq.qld.gov.au/qt/MSQ.nsf/ReferenceLookup/risk_assessment_report_2.pdf/$file/risk_assessment_report_2.pdf

Ramsar Convention Secretariat. 2004. *Ramsar Convention on Wetlands*. www.ramsar.org

Rasheed, M. and Thomas, R. 1999. Seagrass and marine resources of the Upstart Bay dugong protection area. In: *Seagrass and marine resources in the dugong protection areas of Upstart Bay*, *Newry region*, *Sand Bay*, *Llewellyn Bay*, *Ince Bay and the Clairview region*. R.G. Coles, W.J. Lee Long, L.J. McKenzie and C.A. Roder (eds). Pp. 25-54. Research Publication No. 72. http://www.gbrmpa.gov.au/corp_site/info_services/publications/research_publications/rp72/

Rasheed, M.A., Thomas, R. and McKenna, S.A. 2005. *Port of Abbot Point seagrass, algae and benthic macro-invertebrate community survey*. DPI&F Information Series Q105044. 27 pp. DPI&F, Cairns.

Raven, R. Date unspecified. *Spiders of Australia*. http://www.uq.edu.au/~xxrraven/allspids.html

Reef CRC. 2001. *Land use and the Great Barrier Reef World Heritage Area*. http://www.reeffutures.org/topics/publications/CRC_reef.pdf

ReefED. 2004. *Soft corals*. GBRMPA. http://www.reefed.edu.au/explorer/animals/marine_invertebrates/corals/soft_corals.html

Riechelt, A.J. and Jones, G.B. 1994. Trace metals as tracers of dredging activity in Cleveland Bay – field and laboratory studies. *Australia Journal of Marine and Freshwater Research* **45**: 1237-57.

RIVER Group. 1999. *The RIVER report '96-'99 initial findings of an environmental research volunteer group active in the Townsville/Thuringowa coastal plains*. http://69.61.24.191/data/rivers/index.html

Robertson, A.I. and Duke, N.C. 1987. Mangroves as nursery sites: comparisons of the abundance and species composition of fish and crustaceans in mangroves and other nearshore habitats in tropical Australia. *Marine Biology* **96**: 193-205.

Ronnback, P. 1999. The ecological basis for economic value of seafood production supported by mangrove ecosystems. *Ecological Economics* **29**: 235-252.

Roth, C.H. 2004. A framework relating soil surface condition to infiltration and sediment and nutrient mobilization in grazed rangelands of northeastern Queensland, Australia. *Earth Surf*. *Process*. *Landforms* **29**: 1093-1104.

Roth, C.H., Lawson, G.L. and Cavanagh, D. 2002. *Overview of key natural resource management issues in the Burdekin catchment*, *with particular reference to water quality and salinity: Burdekin catchment condition study phase 1*. 98 pp. Report, CSIRO Land and Water and Queensland Department of Natural Resources and Mines, Townsville.

Ryan, S., Cully, T., Robinson, J. and Barchiesi, D. 2003. *Regulatory controls for Queensland wetlands*. Coastal CRC report. http://www.coastal.crc.org.au/pdf/regulatory_controls_wetlands.pdf

Sadler, A. Date unspecified. Free our drains: regional permits. Citiworks Townsville, Townsville City Council. http://www.ipwea.org.au/papers/download/sadler_a.pdf

Semple, P. and Williams, R.L. 1998. *Metals in sediment data summary – Queensland*, *1970 to 1992*. Environment data report No. 10. 92 pp. Queensland Department of Environment and Heritage, Brisbane.

Shoo, L.P. and Williams, Y. 2004. Altitudinal distribution and abundance of microhylid frogs (*Cophixalus* and *Austrochaperina*) of north-eastern Australia: baseline data for detecting biological responses to future climate change. *Australian Journal of Zoology* **52**: 667-676. http://www.publish.csiro.au/?act=view_file&file_id=ZO04023.pdf

Silke, D. and Cumming, R. 1998. *Burdekin plant hot spots*. http://www.drytropics.org/HotSpots.htm

Slater, P. 2004. *The Slater field guide to Australian birds*. Rigby, Sydney.

Spain A.V. and Blackman, J.G. 1992. *Directory of important wetlands*. Revised by Tait, J.T.P., Craven, S.A. and Perry, T.W. 1995. http://www.deh.gov.au/cgi-bin/wetlands/report.pl

Statutory Covenants Working Group. 2004. *Statutory covenants; guidelines for their use in Queensland*. http://www.nrm.qld.gov.au/land/management/pdf/stat_covenants.pdf

Stokes, T. and Dobbs, K. 2001. *Flora and fauna of the Great Barrier Reef: a compendium of information and basis for the species conservation program in the Great Barrier Reef Marine Park Authority*. http://www.gbrmpa.gov.au/corp_site/info_services/publications/misc_pub/fauna_flora/fauna_flora.pdf

Tait, G. and Perna, C. 1999. *Fish Habitat Management Challenges on an Intensively Developed Tropical Floodplain: Burdekin River North Queensland*. http://www.rivers.gov.au/acrobat/burdekin_fish_habitat.pdf

Taylor, R. 1998. *Bugs beware: here comes the good fungus*. Ecos, CSIRO Publication. http://downloads.publish.csiro.au/ecos/ecos_download.cfm?article_id=EC95p6.pdf&issue_id=95&issue_year=1998

Tomlinson, P.B. 1994. *The Botany of Mangroves*. 419 pp. Cambridge University Press, Cambridge.

Tourism Queensland. 2004. *Townsville region regional summary*. http://www.tq.com.au/tq_com/dms/9354A878AE84FEA49A5994E719ECE402.pdf

Townsville City Council. Date unspecified. *Natural assets database*. http://www.townsville.qld.gov.au/nad/

Townsville City Council. 1999a. *State of environment*. *Case study*. http://www.soe-townsville.org/data/casestudy_serpentine.pdf

Townsville City Council. 1999b. *The Rivers Report '96-'99*. *Initial findings of an environmental research volunteer group active in the Townsville/Thuringowa coastal plains*. http://www.soe-townsville.org/data/rivers/index.html

Townsville City Council. 2002. *Environmental excellence awards*. http://www.soe-townsville.org/awards/TCC_enviromental/excel2.html

Townsville City Council. 2004a. *Ross River recreational fishing enhancement plan*. http://www.soetownsville.org/cleangreen/fishwatch/rossriverfishplan.html

Townsville City Council. 2004b. *Land for wildlife*, *state of the environment*. http://www.soe-townsville.org/regional_nrm/landforwildlife/index.html

Townsville City Council. 2004c. *Protecting Magnetic Island's Wildlife Reflector Program*. http://www.townsville.qld.gov.au/services/envmgmt/docs/WildlifeReflectorBrochure.pdf

Townsville City Council. 2004d. *Townsville local government area pest management plan 2004-2008*. http://www.townsville.qld.gov.au/wwwdocs/health/tpl_00%20pest%20management%20plan/09%20part%20b%20pest%20animals%20for%20containment.pdf

Townsville City Council. 2004e. *Mosquito management plan*. http://www.townsville.qld.gov.au/services/health/pp_mosquitoplan.asp

Townsville Enterprise Limited. 2003. Development status report. http://www.townsvilleonline.com.au/Pages/Development/DevelopmentStatusReport.pdf

Townsville Port Authority. 2004. *Our environment*. http://203.52.104.70/theport/default.htm

Turner, L., Tracey, D., Tilden, J. and Dennison, W.C. 2004. Where river meets sea: exploring Australia's estuaries. 278 pp. Cooperative Research Centre for Coastal Zone Estuary and Waterway Management, Brisbane.

Tyler, M.J. 1998. *The action plan for Australian frogs*. Threatened species and threatened ecological communities. Department of the Environment and Heritage, Canberra. http://www.deh.gov.au/biodiversity/threatened/action/frogs/index.html

Valentine, P. 1998. *Gardening for butterflies*....*some basic principles and a Townsville case study*. http://farrer.csu.edu.au/ASGAP/APOL14/jun99-1.html

Vance, D.J., Haywood, M.D.E., Heales, D.S., Kenyon, R.A., Loneragan, N.R. and Pendrey, R.C. 1996. How far do prawns and fish move into mangroves? Distribution of juvenile banana prawns *Penaeus merguiensis* and fish in a tropical mangrove forest in northern Australia. *Marine Ecology Progress Series* **131**: 115-24.

Vidler, S. 2003. *Australian flora and fauna threatened by invasive plants*. Weed CRC. http://www.weeds.crc.org.au/documents/threatened_species_table.pdf

Webb, A. 1999. *South Townsville stormwater drainage fish survey*. Report No. 99/30. http://www.soe-townsville.org/data/actfr_reports/ross_ck_fish_survey_actfr99.pdf

Weier, K. 1999. The quality of groundwater beneath Australian sugarcane fields. *Australian Sugarcane*, June-July 1999, pp. 26-27.

Wilkie, D. 2004. *The Strand redevelopment: managing coastal impact – a success story*. Townsville City Council. http://www.soe-townsville.org/data/from%20GUY/strand_dawson_wilkie.pdf

WTMA. 2002. *Managing a world heritage area*. http://www.wettropics.gov.au/mwha/mwha_index.html

Yeates, D.K. Bouchard, P., Montieth, G.B., 2002, Patterns and levels of endemism in the Australian Wet Tropics rainforest: evidence from flightless insects, Invertebrate Systematics, 16, 605-619.

Youssef, T. and Saenger, P. 1996. Anatomical adaptive strategies to flooding and rhizosphere oxidation in mangrove seedlings. *Australian Journal of Botany* **44**: 297-313.

Zann, L.P. 1995. *Our sea*, *our future*, *major findings of the state of the marine environment report for Australia*. http://www.deh.gov.au/coasts/publications/somer/#about

Zeller, B. 1998. *Queensland fisheries habitats, current condition and recent trends*. 211 pp. DPI&F, Brisbane.

9 GLOSSARY

Anoxic – no oxygen present.

Bedload – bedload events refer to the off-site impact of coarse sediments moved along the riverbed during flooding.

Benthic – on the bottom of a body of water or in the bottom sediments.

Biodiversity – the variety of life in all its forms, levels and combinations. Includes ecosystem diversity, species diversity, and genetic diversity

Biomass – the total weight of all living organisms in a biological community or of a particular species/group.

Burdekin Dry Tropics coastal region – the area addressed by this resource condition report encompasses the estuarine, coastal and marine areas of the Burdekin Dry Tropics NRM region from Crystal Creek in the north to the Don River in the south. In general, it covers the coastal area, from the freshwater/saltwater interface to offshore coastal waters to 3 nautical miles and includes islands within these State waters.

Coast – all areas within or neighbouring the foreshore (from *Coastal Protection and Management Act 1995*)

Coast resources – the natural and cultural resources of the coastal zone (from *Coastal Protection and Management Act 1995*)

Coastal waters – Queensland waters to the limit of the highest astronomical tide (from *Coastal Protection and Management Act 1995*)

Coastal wetlands – includes tidal wetlands, estuaries, saltmarshes, melaleuca swamps (and any other coastal swamps), mangrove areas, marshes, lakes or minor coastal streams regardless of whether they are of a saline, freshwater or brackish nature (from *Coastal Protection and Management Act 1995*)

Coastal zone – coastal waters and all areas to the landward side of coastal waters in which there are physical features, ecological or natural processes or human activities that affect, or potentially affect, the coast or coastal resources (from *Coastal Protection and Management Act 1995*)

Condition – as used in this report, condition is defined as the state or health of individual animals or plants, communities or ecosystems.

Cumec – a measurement of water discharge (one cubic metre of water per second).

Cyanobacteria – photosynthetic bacteria previously called blue-green algae.

Ecosystem – the interacting system of a biological community and its non-living environmental surroundings. These are inseparable and act upon each other.

Embayment – a large indentation of a shoreline, bigger than a cove but smaller than a gulf.

Endemic – 'native' species confined to a given region (e.g. a species endemic to the Great Barrier Reef is not found anywhere else). GBRMPA

Ephemeral – lasting only a short period of time. Ephemeral watercourses flow after rain, and dries up during fine weather.

Eutrophication – the process of enrichment of water with nutrients that increase plant growth and the succeeding depletion of dissolved oxygen. A natural process that can be caused/enhanced by an increase in nutrient loads or decreased flushing rates resulting from human activity.

Extent – as used in this report, extent is defined as the area/distribution (usually hectares or km^2) covered by a particular habitat type (e.g. seagrass).

Genera – a taxonomic group of organisms, one level higher than species.

Habitat – the environment where a plant or animal lives. It includes physical (such as temperature, moisture and light) and biological (such as the presence of food or predator organisms) factors. It can define surroundings on almost any scale from ‘marine waters’ habitat, which encompasses the oceans, to microhabitats, such as the space between sand grains of a sandy shoal.

Hydrology – the cycle of water movement on, over and through the earth's surface.

Hypersaline – above normal levels of salinity.

Hypoxic – condition of low oxygen concentration.

Impoundments – an accumulation of water into ponds/dams/lakes by human-engineered blocking of natural drainage.

Riparian – relating to the bank of a waterway such as a river or stream.

Sessile – plants or animals that are permanently attached to a surface.

Spatial – pertaining to space or distance.

Stratification – the layering of water due to differences in density.

Taxa – a taxonomic group of organisms (of any rank, e.g. species, genera, family) considered to be distinct from other such groups.

Temporal – pertaining to time.

Topography – detailed study of the surface features of a region.

Tributyltin (TBT) – a toxic chemical used to prevent the fouling of ship hulls.

Washload – washload includes the fine sediments suspended within the water column, and the associated turbidity, particulate and dissolved nutrients and contaminants, mobilised during rainfall.

Zooxanthellae – microscopic algae that live in a symbiotic relationship with certain corals, clams, and some sponges.

10 ACRONYMS

ABARE – Australian Bureau of Agricultural and Resource

ABS – Australian Bureau of Statistics

ACTFR – Australian Centre for Tropical Freshwater Research

AHD – Australian Height Datum

AIMS – Australian Institute of Marine Science

AMSA – Australian Maritime Safety Authority

ASS – Acid Sulphate Soil

BDT – Burdekin Dry Tropics

BDTB – Burdekin Dry Tropics Board

BHWSS – Burdekin Haughton Water Supply Scheme

BIFMAC – Burdekin-Bowen Integrated Floodplain Management Advisory Committee

BoM – Bureau of Meteorology

COTS – Crown-of-Thorns Seastar

CRIMP – CSIRO Research into Marine Pests

CSIRO – Commonwealth Scientific and Industrial Research Organisation

DEH – Department of the Environment and Heritage

DPA – Dugong Protected Areas

DPI&F – Department of Primary Industries and Fisheries

EPA – Environmental Protection Agency

EPBC Act 1999 – *Environment Protection and Biodiversity Conservation Act 1999*

FHA – Fish Habitat Areas

GBR- Great Barrier Reef

GBRMPA – Great Barrier Reef Marine Park Authority

IPSTCG – Indo-Pacific Sea Turtle Conservation Group

JCU – James Cook University

LGA – Local Government Area

MWREDC – Mackay Whitsunday Regional Economic Development Corporation

NC Act 1992 – *Nature Conservation Act 1992*

NHT – Natural Heritage Trust

NLWRA – National Land and Water Resource Audit

PQC – Ports of Queensland Corporation

QPWS – Queensland Parks and Wildlife Service

QRBIS – Queensland Regional Bodies Information System

TAP – Technical Advisory Panel

WONS – Weeds of National Significance

WTMA – Wet Tropics Management Authority

11 ACKNOWLEDGEMENTS

We would like to acknowledge the following people for their assistance in producing this report. David Post (CSIRO Land and Water) provided information and comments on Water Quality and Flow section, and Gary Jensen and Melissa Brown (NR&M) supplied information on the lower Burdekin irrigation areas and state of the river conditions report. Rod Nielson (BDTB) greatly assisted with the production of several of the maps and 'digitalised' the coastal sbub-regions. Vern Vietch, Jane Mellors, Rob Coles, Tony Grice, David Foster, Arwen Rickert, David Reid, John Bennett, Tania Ashworth, Adam West, George Lukacs, Paul Pinjuh, Rob Fearon and Sally Peut reviewed drafts and provided valueable feedback, reference material and/or data. Andrew Broadbent (Department of State Development and Innovation) supplied the Aquaculture Suitability Map. Ben Cotton and Stephen Victory (Coastal Unit at the Environmental Protection Agency) supplied Coastal Erosion Prone Area maps. Vwendla Baumann and David Savage (NPWS) helped with island tenure information. Norm Duke (Marine Botany Group, UQ) gave advice on mangroves. Simona Trimarchi (Abbot Point Port Corporation) assisted with the provision of port information. Tim Harvey (IPSTCG) provided turtle condition information.

12 APPENDICES

12.1 Appendix A. Key coastal management issues

The following is an excerpt from State coastal Management Plan (EPA, 2001).
Important coastal management issues include:

- future management of significant and extensive wetland systems, including the Bowling Green Bay Ramsar site;
- siting of industrial land for future growth and expansion;
- expansion of the Townsville Port and identifying sustainable and appropriately placed road and rail access to the port;
- industrialisation of the region while ensuring that the necessary environmental protection measures are in place to protect the region's natural values, including breeding/nursery grounds;
- management of aquaculture developments;
- effective salinity and water management in intensive agricultural industries in the Burdekin;
- urban development along the coast;
- protection and conservation of rare and threatened species (dugongs, migratory wader birds, waterfowl and various species of marine turtle);
- protection of regionally appropriate sport and outdoor recreation resources;
- ecologically and culturally sustainable tourism and outdoor recreation, including consideration of impacts and capacity to contribute to the economy and quality of life;
- impacts of acid sulphate soils;
- storm tide threat and cyclone impacts;
- development of other agricultural industries such as horticulture;
- ongoing resolution of native title (land and sea) issues;
- recognition of Aboriginal Council jurisdictions;
- recognition of community-based land and/or sea management organisations;
- ongoing involvement of Indigenous Traditional Owners in management, planning and development, particularly during processes affecting land tenure designation or redesignation, including coordination of mechanisms by relevant agencies for involving Indigenous Traditional Owners;
- ongoing recognition of Indigenous Traditional Owner traditions and continuing rights and interests in coastal management (e.g. management of fishing activities, coordination of and access to scientific and research information, repatriation of remains), including Indigenous Traditional Owner access to cultural resources (e.g. traditional food for ceremonial purposes);
- recognising the importance to Indigenous Traditional Owners of maintaining management connectivity with upper reaches of catchments;
- preservation of Indigenous Traditional Owner cultural resources from inappropriate access or use, including appropriate management of Indigenous Traditional Owner knowledge and information;
- maintenance of Indigenous Traditional Owner cultural resources (values, places and items);
- Aboriginal peoples and Torres Strait Islanders with historical associations within the region may have aspirations to be involved in the management of cultural resources;

- identification and maintenance of cultural heritage resources (values, places and items);
- coordination of management between relevant agencies, including Commonwealth, State, and local government agencies, and Aboriginal councils; and
- impacts (health, safety and environmental) of defence-related activities (e.g. bombing exercises).

12.2 Appendix B. Estuaries data

The following information comes from the OzEstuaries (2001) 'query database' website.

12.2.1 Crystal Creek

The Crystal Creek system is river dominated with a wave-dominated delta and is in a largely unmodified condition. Table B.1 shows habitat and physical/tidal parameters for Crystal Creek. The estuary has low sediment trapping efficiency, naturally low turbidity and salt wedge/partially-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation.

Impacting land-use: agriculture.

A maximum of five commercial boats fished Crystal Creek and Ollera Creek in 1999, for a total catch of 9.04 tonnes. The commercial fishing effort was 145 days fished.

Table B.1. Habitat and physical/tidal parameters for Crystal Creek.

Habitat	**Area/distance**
Mangrove (km^2)	0.11
Saltmarsh/Saltflat (km^2)	0.05
Water area (km^2)	0.31
Inter-tidal flats (km^2)	0.03
Channel (km^2)	0.10
Physical/tidal parameters	
Perimeter (km)	10.85
Flood/ebb delta (km^2)	0.08
Entrance width (km)	0.19
Maximum length (km)	5.00
Mean wave height (m)	0.85
Maximum wave height (m)	3.30
Mean wave period (s)	5.89
Maximum wave period (s)	13.20
Tidal range (m)	2.40
Tidal period	Diurnal

Source: OzEstuaries (2001).

12.2.2 Ollera Creek

The Ollera Creek system is river dominated with a wave-dominated delta and is in a largely unmodified condition. Table B.2 shows habitat and physical/tidal parameters for Ollera Creek. The estuary has low sediment trapping efficiency, naturally low turbidity and salt wedge/partially-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation. It was noted during the condition assessment that this creek could be upgraded to ‘near pristine’ as it has some agriculture and clearing in the catchment and a road. However, the coastal plains are unmodified.

Impacting land-use: agriculture.

A maximum of five commercial boats fished Crystal Creek and Ollera Creek in 1999, for a total catch of 9.04 tonnes. The commercial fishing effort was 145 days fished.

Table B.2. Habitat and physical/tidal parameters for Ollera Creek.

Habitat	**Area/distance**
Mangrove (km^2)	0.35
Saltmarsh/Saltflat (km^2)	0.11
Water area (km^2)	0.09
Inter-tidal flats (km^2)	0.05
Rocky reef (km^2)	0.13
Channel (km^2)	0.08
Physical/tidal parameters	
Perimeter (km)	3.03
Entrance width (km)	0.16
Maximum length (km)	1.26
Mean wave height (m)	0.85
Maximum wave height (m)	3.30
Mean wave period (s)	5.89
Maximum wave period (s)	13.20
Tidal range (m)	2.40
Tidal period	Diurnal

Source: OzEstuaries (2001).

12.2.3 Rollingstone Creek

The Rollingstone Creek system is river dominated with a wave-dominated delta and is in a largely unmodified condition. Table B.3 shows habitat and physical/tidal parameters for Rollingstone Creek. The estuary has low sediment trapping efficiency, naturally low turbidity and salt wedge/partially-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation.

Impacting land-use: aquaculture.

Total estimated recreational catch (harvest and released) for Rollingstone Creek in 1997 was 8,115 fish (0.01% of Qld total) from 541 trips (0.005% of Qld total). Estimated catch (number): Bream 3,246; Grunter 2,705; Fingermark 1,623; and Mangrove Jack 541. A maximum of less than five commercial boats fished Rollingstone Creek in 1999. The commercial fishing effort was 97 days fished.

Table B.3. Habitat and physical/tidal parameters for Rollingstone Creek.

Habitat	Area/distance
Mangrove (km^2)	0.15
Water area (km^2)	0.30
Inter-tidal flats (km^2)	0.12
Coral (km^2)	0.24
Channel (km^2)	0.09
Physical/tidal parameters	
Perimeter (km)	11.94
Entrance width (km)	0.03
Maximum length (km)	5.56
Mean wave height (m)	0.85
Maximum wave height (m)	3.50
Mean wave period (s)	5.76
Maximum wave period (s)	12.90
Tidal range (m)	2.40
Tidal period	Diurnal

Source: OzEstuaries (2001).

12.2.4 <u>Leichhardt Creek</u>

The Leichhardt Creek system is river dominated with a wave-dominated delta and is in a near pristine condition. Table B.4 shows habitat and physical/tidal parameters for Rollingstone Creek. The estuary has low sediment trapping efficiency, naturally low turbidity and salt wedge/partially-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation. A condition assessment has not been undertaken on this creek.

Table B.4. Habitat and physical/tidal parameters for Leichhardt Creek.

Habitat	Area/distance
Mangrove (km^2)	0.43
Saltmarsh/Saltflat (km^2)	0.41
Water area (km^2)	0.28
Inter-tidal flats (km^2)	0.13
Coral (km^2)	0.32
Channel (km^2)	0.12
Physical/tidal parameters	
Perimeter (km)	9.78
Bedrock perimeter (km)	0.72
Flood/ebb delta (km^2)	0.13
Entrance width (km)	0.22
Maximum length (km)	2.78
Mean wave height (m)	0.58
Maximum wave height (m)	2.80
Mean wave period (s)	5.51
Maximum wave period (s)	12.70
Tidal range (m)	2.50
Tidal period	Diurnal

Source: OzEstuaries (2001).

12.2.5 Sleeper Log Creek

The Sleeper Log Creek system is river dominated with a wave-dominated delta and is in a largely unmodified condition. Table B.5 shows habitat and physical/tidal parameters for Sleeper Log Creek. The estuary has low sediment trapping efficiency, naturally low turbidity and salt wedge/partially-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation.

Impacting land-use: urban.

Total estimated recreational catch (harvest and released) for Leichardt Creek, Althaus Creek, Black River, Sleeper Log Creek and Bluewater Creek in 1997 was 32,550 fish (0.06% of Qld total) from 2,697 trips (0.03% of Qld total). Estimated catch (top 5 species by number): Mullet 15,876; Whiting 6,357; Sardine 6,027; Herring (Bait) 1,470; and Mud Crab 735. A maximum of eight commercial boats fished Leichardt Creek, Althaus Creek, Black River, Sleeper Log Creek and Bluewater Creek in 1999, for a total catch of 17.56 tonnes. The commercial fishing effort was 252 days fished.

Table B.5. Habitat and physical/tidal parameters for Sleeper Log Creek.

Habitat	Area/distance
Mangrove (km^2)	0.50
Saltmarsh/Saltflat (km^2)	0.43
Water area (km^2)	0.33
Inter-tidal flats (km^2)	0.06
Coral (km^2)	1.15
Channel (km^2)	0.25
Physical/tidal parameters	
Perimeter (km)	11.92
Flood/ebb delta (km^2)	0.09
Entrance width (km)	0.09
Maximum length (km)	2.87
Mean wave height (m)	0.58
Maximum wave height (m)	2.80
Mean wave period (s)	5.51
Maximum wave period (s)	12.70
Tidal range (m)	2.50
Tidal period	Diurnal

Source: OzEstuaries (2001).

12.2.6 Bluewater Creek

The Bluewater Creek system is river dominated with a wave-dominated delta and is in a largely unmodified condition. Table B.6 shows habitat and physical/tidal parameters for Bluewater Creek. The estuary has low sediment trapping efficiency, naturally low turbidity and salt wedge/partially-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation.

Impacting land-use: urban.

For recreational and commercial fishing catch and effort see Sleeper Log Creek.

Table B.6. Habitat and physical/tidal parameters for Bluewater Creek.

Habitat	Area/distance
Mangrove (km^2)	0.21
Saltmarsh/Saltflat (km^2)	0.10
Water area (km^2)	0.14
Inter-tidal flats (km^2)	0.05
Channel (km^2)	0.11
Physical/tidal parameters	
Perimeter (km)	5.62
Flood/ebb delta (km^2)	0.67
Entrance width (km)	0.03
Maximum length (km)	2.46
Mean wave height (m)	0.58
Maximum wave height (m)	2.80
Mean wave period (s)	5.51
Maximum wave period (s)	12.70
Tidal range (m)	2.50
Tidal period	Diurnal

Source: OzEstuaries (2001).

12.2.7 Althaus Creek

The Althaus Creek system is river dominated with a wave-dominated delta and is in a largely unmodified condition. Table B.7 shows habitat and physical/tidal parameters for Althaus Creek. The estuary has low sediment trapping efficiency, naturally low turbidity and salt wedge/partially-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation.

For recreational and commercial fishing catch and effort see Sleeper Log Creek.

Table B.7. Habitat and physical/tidal parameters for Althaus Creek.

Habitat	Area/distance
Mangrove (km^2)	0.36
Saltmarsh/Saltflat (km^2)	0.61
Water area (km^2)	0.29
Inter-tidal flats (km^2)	0.06
Floodplain (km^2)	0.10
Channel (km^2)	0.14
Physical/tidal parameters	
Perimeter (km)	9.32
Flood/ebb delta (km^2)	0.30
Entrance width (km)	0.05
Maximum length (km)	2.73
Mean wave height (m)	0.58
Maximum wave height (m)	2.80
Mean wave period (s)	5.51
Maximum wave period (s)	12.70
Tidal range (m)	2.50

Tidal period	Diurnal

Source: OzEstuaries (2001).

12.2.8 Black River

The Black River system is river dominated with a wave-dominated delta and is in a modified condition. Table B.8 shows habitat and physical/tidal parameters for Black River. The estuary has low sediment trapping efficiency, naturally low turbidity and salt wedge/partially-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation.

Impacting land-use: urban.

For recreational and commercial fishing catch and effort see Sleeper Log Creek.

Table B.8. Habitat and physical/tidal parameters for Black River.

Habitat	Area/distance
Mangrove (km^2)	0.44
Saltmarsh/Saltflat (km^2)	0.13
Water area (km^2)	0.46
Inter-tidal flats (km^2)	0.67
Tidal sand banks (km^2)	0.01
Channel (km^2)	0.31
Physical/tidal parameters	
Perimeter (km)	13.20
Flood/ebb delta (km^2)	1.80
Entrance width (km)	0.30
Maximum length (km)	4.37
Mean wave height (m)	0.87
Maximum wave height (m)	3.90
Mean wave period (s)	5.71
Maximum wave period (s)	12.60
Tidal range (m)	2.40
Tidal period	Diurnal

Source: OzEstuaries (2001).

12.2.9 Bohle River

The Bohle River system is river dominated with a tide-dominated delta and is in a modified condition. Table B.9 shows habitat and physical/tidal parameters for Bohle River. The estuary has low sediment trapping efficiency, naturally high turbidity and well-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation.

Impacting land-use: urban.

Generally, turbidity, dissolved oxygen, ammonia and oxidised nitrogen levels in the Bohle River estuary are below default water quality guidelines for the protection of aquatic ecosystems (ANZECC, 2000). Chlorophyll *a* concentrations from the middle estuary (median = 5.7 µg/L, 80^{th} = 8.2) and phosphate (median = 89 µg/L, 80^{th} = 155) are above ANZECC default trigger values for the protection of aquatic ecosystems (ANZECC, 2000).

Total estimated recreational catch (harvest and released) for Bohle River in 1997 was 20,467 fish (0.04% of Qld total) from 2,095 trips (0.02% of Qld total). Estimated catch (top 5 species by number): Poppy Mullet 16,771; Whiting 1,416; Longtom 1,082; Bream 541; and Box Fish 287. A maximum of five commercial boats fished Bohle River in 1999, for a total catch of 4.29 tonnes. The commercial fishing effort was 131 days fished. A fish habitat area (033-004A) is present in the Bohle River.

Table B.9. Habitat and physical/tidal parameters for Bohle River.

Habitat	**Area/distance**
Mangrove (km^2)	3.80
Saltmarsh/Saltflat (km^2)	12.89
Water area (km^2)	0.79
Inter-tidal flats (km^2)	1.46
Tidal sand banks (km^2)	0.03
Floodplain (km^2)	3.15
Channel (km^2)	1.39
Physical/tidal parameters	
Perimeter (km)	20.91
Flood/ebb delta (km^2)	2.25
Entrance width (km)	0.61
Maximum length (km)	8.72
Mean wave height (m)	0.87
Maximum wave height (m)	3.90
Mean wave period (s)	5.71
Maximum wave period (s)	12.60
Tidal range (m)	2.40
Tidal period	Diurnal

Source: OzEstuaries (2001).

12.2.10 Ross River

The Ross River system is tide dominated and is sub-classified as a tidal flat/creek. It is in a modified condition. Table B.10 shows habitat and physical/tidal parameters for Ross River. The estuary has low sediment trapping efficiency, naturally high turbidity and well-mixed circulation. Therefore, there is low risk of sedimentation.

Impacting land-use: urban. Townsville port is located at the mouth of the Ross River.

Generally, turbidity, dissolved oxygen, phosphate, ammonia and oxidised nitrogen levels in the Ross River estuary are below default water quality guidelines for the protection of aquatic ecosystems (ANZECC, 2000). Chlorophyll *a* concentrations from the middle estuary (median = 4.1 µg/L, 80th = 8.2) are above ANZECC default trigger values for the protection of aquatic ecosystems.

Total estimated recreational catch (harvest and released) for Ross River and Sandfly Creek in 1997 was 494,831 fish (0.89% of Qld total) from 74,161 trips (0.69% of Qld total). Estimated catch (top 5 species by number): Grunter 79,997; Mud Crab 58,072;

Silver Bream 52,512; Barramundi 33,744; and Trevally 27,306. A maximum of six commercial boats fished Ross River and Sandfly Creek in 1999, for a total catch of 3.91 tonnes. The commercial fishing effort was 176 days fished.

Table B.10. Habitat and physical/tidal parameters for Ross River.

Habitat	**Area/distance**
Mangrove (km^2)	2.66
Saltmarsh/Saltflat (km^2)	0.71
Water area (km^2)	3.29
Inter-tidal flats (km^2)	1.02
Channel (km^2)	1.53
Physical/tidal parameters	
Perimeter (km)	54.73
Flood/ebb delta (km^2)	1.07
Entrance width (km)	0.38
Maximum length (km)	21.92
Mean wave height (m)	0.19
Maximum wave height (m)	1.50
Mean wave period (s)	5.53
Maximum wave period (s)	10.00
Tidal range (m)	2.30
Tidal period	Semi Diurnal

Source: OzEstuaries (2001).

12.2.11 Sandfly Creek

The Sandfly Creek system is tide dominated and is sub-classified as a tidal flat/creek. It is in a modified condition. Table B.11 shows habitat and physical/tidal parameters for Sandfly Creek. The estuary has low sediment trapping efficiency, naturally high turbidity and well-mixed circulation. Therefore, there is low risk of sedimentation.

Impacting land-use: urban. Changes to catchment hydrology and a Sewage Treatment Plant (STP) have influenced creek condition.

For recreational and commercial fishing catch and effort see Ross River.

Table B.11. Habitat and physical/tidal parameters for Sandfly Creek.

Habitat	**Area/distance**
Mangrove (km^2)	0.80
Saltmarsh/Saltflat (km^2)	4.30
Water area (km^2)	0.10
Inter-tidal flats (km^2)	0.12
Floodplain (km^2)	0.16
Channel (km^2)	0.17
Physical/tidal parameters	
Perimeter (km)	3.93
Bedrock perimeter (km)	0.05
Entrance width (km)	0.07
Maximum length (km)	1.86
Mean wave height (m)	0.19

Maximum wave height (m)	1.50
Mean wave period (s)	5.53
Maximum wave period (s)	10.00
Tidal range (m)	2.30
Tidal period	Semi Diurnal

Source: OzEstuaries (2001).

12.2.12 Alligator Creek

The Alligator Creek system is river dominated with a tide-dominated delta and is in a largely unmodified condition. Table B.12 shows habitat and physical/tidal parameters for Alligator Creek. The estuary has low sediment trapping efficiency, naturally high turbidity and well-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation.

Impacting land-use: agriculture. Rural residential areas lie adjacent to Alligator Creek. Industrial meat works and Port facilities were historically recorded along the creek.

The level of recreational fishing pressure on the creek is recorded as medium around fisherman's retreat. A gill net fishery occurs in Alligator and Crocodile creeks with a maximum of less than five commercial boats fishing the creeks in 1999. The commercial fishing effort was 54 days fished.

Alligator Creek occurs within the Cape Bowling Green Bay National Park.

Table B.12. Habitat and physical/tidal parameters for Alligator Creek.

Habitat	**Area/distance**
Mangrove (km^2)	4.90
Saltmarsh/Saltflat (km^2)	5.02
Inter-tidal flats (km^2)	0.38
Channel (km^2)	1.07
Physical/tidal parameters	
Bedrock perimeter (km)	1.29
Flood/ebb delta (km^2)	2.29
Mean wave height (m)	0.19
Maximum wave height (m)	1.50
Mean wave period (s)	5.53
Maximum wave period (s)	10.00
Tidal range (m)	2.30
Tidal period	Semi Diurnal

Source: OzEstuaries (2001).

12.2.13 Crocodile Creek

The Crocodile Creek system is river dominated with a tide-dominated delta and is in a near pristine condition. Table B.13 shows tidal parameters for Crocodile Creek. The estuary has low sediment trapping efficiency, naturally high turbidity and well-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation. A condition assessment has not been undertaken on this creek.

For commercial fishing effort see Alligator Creek.

Crocodile Creek occurs within the Cape Bowling Green Bay National Park.

Table B.13. Habitat and physical/tidal parameters for Crocodile Creek.

Physical/tidal parameters	
Mean wave height (m)	0.19
Maximum wave height (m)	1.50
Mean wave period (s)	5.53
Maximum wave period (s)	10.00
Tidal range (m)	2.30
Tidal period	Semi Diurnal

Source: OzEstuaries (2001).

12.2.14 Haughton River

The Haughton River system is river dominated with a tide-dominated delta and is in a modified condition. Table B.14 shows habitat and physical/tidal parameters for Haughton River. The estuary has low sediment trapping efficiency, naturally high turbidity and well-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation.

Impacting land-use: agriculture.

Total estimated recreational catch (harvest and released) for Haughton River and Barramundi Creek in 1997 was 134,264 fish (0.24% of Qld total) from 10,601 trips (0.1% of Qld total). Estimated catch (top 5 species by number): Mud Crab 43,609; Grunter 33,747; Catfish Unspecified 19,571; Silver Bream 9,139; and Bream 7,815. A maximum of eight commercial boats fished Haughton River and Barramundi Creek in 1999, for a total catch of 3.8 tonnes. The commercial fishing effort was 174 days fished. A fish habitat area (015-050A – Bowling Green Bay Fish Habitat Area) is present in the Haughton River.

Table B.14. Habitat and physical/tidal parameters for Haughton River.

Habitat	Area/distance
Mangrove (km^2)	25.62
Saltmarsh/Saltflat (km^2)	16.28
Inter-tidal flats (km^2)	1.22
Tidal sand banks (km^2)	1.17
Channel (km^2)	6.36
Physical/tidal parameters	
Bedrock perimeter (km)	8.66
Flood/ebb delta (km^2)	9.73
Mean wave height (m)	0.09
Maximum wave height (m)	1.00
Mean wave period (s)	5.53
Maximum wave period (s)	11.70
Tidal range (m)	2.40
Tidal period	Semi Diurnal

Source: OzEstuaries (2001).

12.2.15 Barramundi Creek (also known as Morrison Creek)

The Barramundi Creek system is river dominated with a tide-dominated delta and is in a largely unmodified condition. Table B.15 shows habitat and physical/tidal parameters for Barramundi Creek. The estuary has low sediment trapping efficiency, naturally high turbidity and well-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation.

Impacting land-use: agriculture. A lot of ponded pasture development is present. Supratidal bund walls (tidal exclusion dams) are also present.

Barramundi Creek is a very popular recreational fishing site with beach hut development. A gill net commercial fishery (Barramundi) is present. For recreational and commercial fishing catch and effort see Haughton River. A fish habitat area (015-050A – Bowling Green Bay Fish Habitat Area) is present in Barramundi Creek.

Table B.15. Habitat and physical/tidal parameters for Barramundi Creek.

Habitat	Area/distance
Mangrove (km^2)	16.68
Saltmarsh/Saltflat (km^2)	19.92
Inter-tidal flats (km^2)	0.72
Channel (km^2)	4.66
Physical/tidal parameters	
Bedrock perimeter (km)	11.44
Flood/ebb delta (km^2)	5.31
Mean wave height (m)	0.22
Maximum wave height (m)	1.60
Mean wave period (s)	4.91
Maximum wave period (s)	9.80
Tidal range (m)	2.40
Tidal period	Semi Diurnal

Source: OzEstuaries (2001).

12.2.16 Q195 (Unnamed estuary)

The Q195 estuary system is tide dominated and is sub-classified as a tidal flat/creek. It is located at Longitude 147.214 and Latitude -19.422 and is in a largely unmodified condition. Table B.16 shows habitat and physical/tidal parameters for Q195. The estuary has low sediment trapping efficiency, naturally high turbidity and well-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation.

Impacting land-use: agriculture.

A maximum of 10 commercial boats fished Q195 and Barratta Creek in 1999, for a total catch of 15.51 tonnes. The commercial fishing effort was 502 days fished. A fish habitat area (015-050A – Bowling Green Bay Fish Habitat Area) is present in Q195.

Table B.16. Habitat and physical/tidal parameters for Q195.

Habitat	Area/distance
Mangrove (km^2)	2.92
Saltmarsh/Saltflat (km^2)	6.11

Habitat	Area/distance
Inter-tidal flats (km^2)	0.76
Channel (km^2)	0.86
Physical/tidal parameters	
Bedrock perimeter (km)	4.39
Flood/ebb delta (km^2)	2.52
Mean wave height (m)	0.22
Maximum wave height (m)	1.60
Mean wave period (s)	4.91
Maximum wave period (s)	9.80
Tidal range (m)	2.40
Tidal period	Semi Diurnal

Source: OzEstuaries (2001).

12.2.17 Barratta Creek

The Barratta Creek system is river dominated with a tide-dominated delta and is in a modified condition. Table B.17 shows habitat and physical/tidal parameters for Barratta Creek. The estuary has low sediment trapping efficiency, naturally high turbidity and well-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation.

Impacting land-use: agriculture. Barratta Creek lies within the Burdekin Haughton Water Supply Scheme area and has a highly turbid estuary. Extensive new irrigated agriculture developments have occurred in the catchment since 1990. Saltwater intrusion dams are present and modify the flow of the creek.

Barratta Creek has a medium-high level of recreational fishing and a beach hut development/settlement. For commercial fishing catch and effort see Q195. A fish habitat area (015-050A – Bowling Green Bay Fish Habitat Area) is present in Barratta Creek.

Table B.17. Habitat and physical/tidal parameters for Barratta Creek.

Habitat	Area/distance
Mangrove (km^2)	17.82
Saltmarsh/Saltflat (km^2)	21.88
Tidal sand banks (km^2)	0.89
Channel (km^2)	2.89
Physical/tidal parameters	
Bedrock perimeter (km)	7.03
Flood/ebb delta (km^2)	10.93
Mean wave height (m)	0.23
Maximum wave height (m)	1.90
Mean wave period (s)	5.09
Maximum wave period (s)	9.70
Tidal range (m)	2.40
Tidal period	Semi Diurnal

Source: OzEstuaries (2001).

12.2.18 Mud Creek

The Mud Creek system is wave dominated and is sub-classified as a strandplain. It is in a largely unmodified condition. Table B.18 shows habitat and physical/tidal parameters for Mud Creek. The estuary has low sediment trapping efficiency, naturally low turbidity and negative/salt wedge/partially-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation.

Impacting land-use: agriculture.

Total estimated recreational catch (harvest and released) for Burdekin River, Plantation Creek, Burdekin River Anabranch and Mud Creek in 1997 was 308,336 fish (0.55% of Qld total) from 40,869 trips (0.38% of Qld total). Estimated catch (top 5 species by number): Whiting 89,510; Mud Crab 88,451; Grunter 17,739; Bream 16,014; and Cod 13,310. A maximum of 13 commercial boats fished Burdekin River, Plantation Creek, Burdekin River Anabranch and Mud Creek in 1999, for a total catch of 53.39 tonnes. The commercial fishing effort was 1,881 days fished. A fish habitat area (Burdekin Fish Habitat Area) is present in Mud Creek.

Table B.18. Habitat and physical/tidal parameters for Mud Creek.

Habitat	**Area/distance**
Mangrove (km^2)	5.98
Saltmarsh/Saltflat (km^2)	0.64
Water area (km^2)	1.08
Inter-tidal flats (km^2)	0.10
Tidal sand banks (km^2)	0.03
Barrier backbarrier (km^2)	0.36
Channel (km^2)	0.71
Physical/tidal parameters	
Perimeter (km)	12.62
Bedrock perimeter (km)	0.55
Flood/ebb delta (km^2)	0.36
Entrance width (km)	0.45
Maximum length (km)	4.48
Maximum width (km)	0.78
Mean wave height (m)	1.01
Maximum wave height (m)	4.00
Mean wave period (s)	5.41
Maximum wave period (s)	10.20
Tidal range (m)	2.40
Tidal period	Semi Diurnal

Source: OzEstuaries (2001).

12.2.19 Plantation Creek

The Plantation Creek system is wave dominated and is sub-classified as a strandplain. It is in a largely unmodified condition. Table B.19 shows habitat and physical/tidal parameters for Plantation Creek. The estuary has low sediment trapping efficiency, naturally low turbidity and negative/salt wedge/partially-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation.

Impacting land-use: agriculture.

For recreational and commercial fishing catch and effort see Mud Creek. A fish habitat area (Burdekin Fish Habitat Area) is present in Plantation Creek.

Table B.19. Habitat and physical/tidal parameters for Plantation Creek.

Habitat	Area/distance
Mangrove (km^2)	10.59
Saltmarsh/Saltflat (km^2)	5.19
Water area (km^2)	3.56
Inter-tidal flats (km^2)	2.20
Tidal sand banks (km^2)	1.12
Floodplain (km^2)	0.10
Barrier backbarrier (km^2)	1.34
Channel (km^2)	2.38
Physical/tidal parameters	
Perimeter (km)	37.06
Bedrock perimeter (km)	0.42
Entrance width (km)	0.07
Maximum length (km)	9.91
Maximum width (km)	0.92
Mean wave height (m)	1.01
Maximum wave height (m)	4.00
Mean wave period (s)	5.41
Maximum wave period (s)	10.20
Tidal range (m)	2.30
Tidal period	Semi Diurnal

Source: OzEstuaries (2001).

12.2.20 Burdekin River

The Burdekin River system is river dominated with a tide-dominated delta and is in a modified condition. Table B.20 shows habitat and physical/tidal parameters for the Burdekin River. The estuary has low sediment trapping efficiency, naturally high turbidity and well-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation.

Impacting land-use: agriculture. Significant hydrological changes have occurred within the river with a sand dam being put across the head of the estuary to keep saltwater out and maintain a freshwater head.

For recreational and commercial fishing catch and effort see Mud Creek. A fish habitat area (Burdekin Fish Habitat Area) is present in the Burdekin River.

Table B.20. Habitat and physical/tidal parameters for Burdekin River.

Habitat	Area/distance
Mangrove (km^2)	46.04
Saltmarsh/Saltflat (km^2)	25.94
Water area (km^2)	32.00
Inter-tidal flats (km^2)	18.47

Habitat	Area/distance
Tidal sand banks (km^2)	2.34
Channel (km^2)	39.14
Physical/tidal parameters	
Perimeter (km)	234.61
Bedrock perimeter (km)	20.13
Flood/ebb delta (km^2)	23.52
Entrance width (km)	3.98
Maximum length (km)	69.36
Maximum width (km)	2.52
Mean wave height (m)	0.48
Maximum wave height (m)	2.10
Mean wave period (s)	5.27
Maximum wave period (s)	11.40
Tidal range (m)	2.30
Tidal period	Semi Diurnal

Source: OzEstuaries (2001).

12.2.21 Rocky Ponds Creek

The Rocky Ponds Creek system is tide dominated and is sub-classified as a tidal flat/creek. It is in a near pristine condition. Table B.21 shows habitat and physical/tidal parameters for Rocky Ponds Creek. The estuary has low sediment trapping efficiency, naturally high turbidity and well-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation. A condition assessment has not been undertaken on this creek.

Table B.21. Habitat and physical/tidal parameters for Rocky Ponds Creek.

Habitat	Area/distance
Water area (km^2)	1.37
Physical/tidal parameters	
Perimeter (km)	19.96
Entrance width (km)	0.56
Maximum length (km)	5.58
Maximum width (km)	0.49
Mean wave height (m)	0.85
Maximum wave height (m)	3.40
Mean wave period (s)	5.42
Maximum wave period (s)	11.20
Tidal range (m)	2.30
Tidal period	Semi Diurnal

Source: OzEstuaries (2001).

12.2.22 Nobbies Creek

The Nobbies Creek system is tide dominated and is sub-classified as a tidal flat/creek. It is in a near pristine condition. Table B.22 shows habitat and physical/tidal parameters for Nobbies Creek. The estuary has low sediment trapping efficiency, naturally high turbidity and well-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation. A condition assessment has not been undertaken on this creek.

Table B.22. Habitat and physical/tidal parameters for Nobbies Creek.

Habitat	Area/distance
Water area (km^2)	6.82
Physical/tidal parameters	
Perimeter (km)	41.99
Entrance width (km)	2.50
Maximum length (km)	9.62
Maximum width (km)	2.51
Mean wave height (m)	0.91
Maximum wave height (m)	3.40
Mean wave period (s)	5.49
Maximum wave period (s)	11.10
Tidal range (m)	2.30
Tidal period	Semi Diurnal

Source: OzEstuaries (2001).

12.2.23 Elliot Creek

The Elliot Creek system is tide dominated and is in a near pristine condition. Table B.23 shows habitat and physical/tidal parameters for Elliot Creek. The estuary has low sediment trapping efficiency, naturally high turbidity and well-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation. A condition assessment has not been undertaken on this creek.

Table B.23. Habitat and physical/tidal parameters for Elliot Creek.

Habitat	Area/distance
Water area (km^2)	2.73
Physical/tidal parameters	
Perimeter (km)	28.86
Entrance width (km)	0.35
Maximum length (km)	7.76
Maximum width (km)	0.54
Mean wave height (m)	0.89
Maximum wave height (m)	3.40
Mean wave period (s)	5.39
Maximum wave period (s)	10.50
Tidal range (m)	2.40
Tidal period	Semi Diurnal

Source: OzEstuaries (2001).

12.2.24 Branch Creek

The Branch Creek system is wave dominated and is sub-classified as a strandplain. It is in a near pristine condition. Table B.24 shows habitat and physical/tidal parameters for Branch Creek. The estuary has low sediment trapping efficiency, naturally low turbidity and negative/salt wedge/partially-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation. A condition assessment has not been undertaken on this creek.

Table B.24. Habitat and physical/tidal parameters for Branch Creek.

Habitat	Area/distance
Water area (km^2)	0.50
Physical/tidal parameters	
Perimeter (km)	8.90
Entrance width (km)	0.43
Maximum length (km)	3.49
Maximum width (km)	0.19
Mean wave height (m)	0.52
Maximum wave height (m)	2.10
Mean wave period (s)	5.47
Maximum wave period (s)	11.80
Tidal range (m)	2.40
Tidal period	Semi Diurnal

Source: OzEstuaries (2001).

12.2.25 Euri Creek

The Euri Creek system is tide dominated and is sub-classified as a tidal flat/creek. It is in a near pristine condition. Table B.25 shows habitat and physical/tidal parameters for Euri Creek. The estuary has low sediment trapping efficiency, naturally high turbidity and well-mixed circulation. Therefore, there is low risk of habitat loss due to sedimentation. A condition assessment has not been undertaken on this creek.

Table B.25. Habitat and physical/tidal parameters for Euri Creek.

Habitat	Area/distance
Water area (km^2)	3.08
Physical/tidal parameters	
Perimeter (km)	30.11
Entrance width (km)	0.92
Maximum length (km)	5.13
Mean wave height (m)	1.03
Maximum wave height (m)	4.00
Mean wave period (s)	5.75
Maximum wave period (s)	11.60
Tidal range (m)	2.30
Tidal period	Semi Diurnal

Source: OzEstuaries (2001).

12.2.26 Don River

The Don River system is wave dominated and is sub-classified as a wave-dominated estuary. It is in a modified condition. Table B.26 shows habitat and physical/tidal parameters for the Don River. The estuary has high sediment trapping efficiency, naturally low turbidity and salt wedge/partially-mixed circulation. Therefore, there is a high risk of sedimentation.

Impacting land-use: agriculture. Aquaculture facilities (including prawn growout and hatchery) are present along the Don River.

Total estimated recreational catch (harvest and released) for the Don River in 1997 was 178,213 fish (0.32% of Qld total) from 26,910 trips (0.25% of Qld total). Estimated catch (top 5 species by number): Spotted Mackerel 26,123; Mud Crab 19,823; Ribbon Fish 18,120; Mackerel 9,887; and Black Bream 8,508. A maximum of six commercial boats fished the Don River in 1999, for a total catch of 3.29 tonnes. The commercial fishing effort was 248 days fished.

Table B.26. Habitat and physical/tidal parameters for Don River.

Habitat	**Area/distance**
Mangrove (km^2)	0.70
Saltmarsh/Saltflat (km^2)	0.90
Water area (km^2)	0.26
Tidal sand banks (km^2)	0.03
Channel (km^2)	0.05
Physical/tidal parameters	
Perimeter (km)	5.10
Bedrock perimeter (km)	0.44
Flood/ebb delta (km^2)	0.50
Barrier backbarrier (km^2)	0.08
Central basin (km^2)	0.18
Entrance width (km)	0.16
Maximum length (km)	1.56
Maximum width (km)	0.41
Mean wave height (m)	1.03
Maximum wave height (m)	4.00
Mean wave period (s)	5.75
Maximum wave period (s)	11.60
Tidal range (m)	2.20
Tidal period	Semi Diurnal

Source: OzEstuaries (2001).

12.3 Appendix C. Weeds relevant to the Dry Tropics of Queensland

The information provided in here was supplied by Tony Grice.

12.3.1 Weeds of National Significance

Twenty Weeds of National Significance (WONS) were identified as part of Australia's National Weed Strategy. They are species that are particularly important weeds at a national scale and their management attracts Commonwealth and Queensland Government funding. Management plans have been prepared for each of the twenty WONS. All WONS are declared plants under *Queensland's Land Protection (Pest and Stock Route Management) Act 2002*. In Queensland it is illegal to trade in any of the WONS species.

Table C.1. Weeds of National Significance that are especially relevant to the dry tropics of Queensland.

SCIENTIFIC NAME	COMMON NAME
Acacia nilotica	prickly acacia
Annona glabra	pond apple
Cabomba caroliniana	cabomba
Cryptostegia grandiflora	rubber vine
Hymenachne amplexicaulis	hymenachne
Lantana camara	lantana
Mimosa pigra	mimosa
Parkinsonia aculeata	parkinsonia
Parthenium hysterophorus	parthenium
Prosopis spp	mesquite
Salvinia molesta	salvinia

12.3.2 Declared Plants (State of Queensland)

A declared plant is a species that has been listed under *Queensland's Land Protection (Pest and Stock Route Management) Act 2002* and is targeted for control because it has or could have serious economic, environmental or social impacts. There are three classes of declared plants in Queensland.

Class 1 pests are not common in Queensland but are recognised as presenting significant economic, environmental or social threats. They are the targets of eradication campaigns that are under State control. Landowners must take reasonable steps to keep their land free from Class 1 pests. They MUST NOT be cultivated.

Class 2 pests are well-established in Queensland and have or could have adverse economic, environmental or social impacts. They are subject to local government, community or landowner-led control programmes. Landowners must take reasonable steps to keep their land free from Class 2 pests. They MUST NOT be cultivated.

Class 3 pests are established in Queensland and have, or could have, adverse economic, environmental or social impacts. A pest control notice can only be issued for Class 3 pests that are growing on or adjacent to environmentally significant areas.

Table C.2. Declared plants that are especially relevant to the Dry Tropics of Queensland.

SCIENTIFIC NAME	COMMON NAME	CLASS
Acacia nilotica	prickly acacia	2
Acacia spp	all non-indigenous acacias	1
Bryophyllum delagoense, *B. daigremontianum*, *B. tubiflorum*	mother of millions	2
Cabomba spp	cabomba	2
Cascabela thevetia = Thevetia peruviana	captain cook bush	3
Chromolaena odorata	siam weed	1
Cryptostegia grandiflora	rubber vine	2
Cryptostegia madagascariensis	purple rubber vine	3
Eichhornia azurea	anchored water hyancinth	1
Eichhornia crassipes	water hyacinth	2
Eriocereus spp	harrisia cactus	2
Hymenachne amplexicaulis	hymenachne	2

SCIENTIFIC NAME	COMMON NAME	CLASS
Jatropha gossypiifolia	bellyache bush	2
Lantana spp	lantana	3
Limnocharis flava	Limnocharis	1
Miconia spp	Miconia	1
Mikania spp	Mikania vine	1
Mimosa pigra	Mimosa	1
Parkinsonia aculeata	parkinsonia	2
Parthenium hysterophorus	parthenium	2
Pistia stratiotes	water lettuce	2
Prosopis spp	mesquites other than *P. glandulosa*, *P. pallida* and *P. velutina*	1
Prosopis glandulosa, *P. pallida*, *P. velutina*	mesquites	2
Salvinia molesta	salvinia	2
Salvinia spp	salvinias other than *S. molesta*	1
Schinus terebinthifolius	broad-leaved pepper tree	3
Senna obtusifolia, *S. hirsute*, *S. tora*	sicklepods	2
Spathodea campanulata	african tulip tree	3
Sphagneticola trilobata	singapore daisy	3
Tecoma stans	yellow bells	3
Thunbergia annua	orange thunbergia	1
Thunbergia fragrans		1
Thunbergia laurifolia	laurel clock vine	1
Ziziphus mauritiana	chinee apple, christ's thorn	1

12.3.3 Environmental Weeds

An environmental weed is a plant species that has, or could have, significant negative environmental impacts in Australian natural ecosystems. Most plant species that are environmental weeds in Australia have been deliberately or accidentally introduced from overseas. Many are plants that have escaped from gardens.

Table C.3. Plant species that should NOT be grown in gardens of the Dry Tropics of Queensland because of the threats they pose to local environments. Some of the species in this list are Class 3 Pests Plants under *Queensland's Land Protection (Pest and Stock Route Management) Act 2002*.

SCIENTIFIC NAME	COMMON NAME
Agave americana	century plant
Agave sisalana	sisal hemp
Albizia lebbek	albizia
Allamanda cathartica	yellow allamanda vine
Aloe spp	aloes
Anredera cordifolia	madeira vine
Antigonon leptopus	coral vine, mexican rose
Arbutus unedo	strawberry tree
Ardisia spp	ardisia
Asparagus densiflorus	asparagus fern
Azadirachta indica	neem
Brillantaisia lamium	brillantaisia
Bryophyllum spp	mother-of-millions
Bauhina variegata	butterfly tree, bauhinia
Cascabela thevetia (= *Thevetia peruviana*)	captain cook bush
Cassia fistula	yellow cascade

SCIENTIFIC NAME	COMMON NAME
Catharanthus roseus	impatiens
Cyperus alternifolius	
Delonix regia	poinciana
Duranta repens	duranta
Eichhornia crassipes	water hyancinth
Elodea canadensis	elodea
Erythrina indica	coral tree
Flacoutia jangomas	flacourtia
Grewia asiatica	grewia
Harungana madagascariensis	harungana
Hemigraphis colorata	hemigraphis
Impatiens walleriana	balsam
Ipomoea hederifolia	
Ipomoea quamoclit	
Khaya sengalensis	african mahogany
Lantana camara	lantana
Lantana montevidensis	creeping lantana
Leucaena leucocephala	leucaena
Macfadyena unguis-cati	cat’s claw creeper
Merremia spp	snake vine
Murraya paniculata	mock orange
Nelumbo nucifera	lotus lily
Nerium oleander	oleander
Palafoxia rosea	
Parmentaria aculeata	cucumber tree
Passiflora coccinea	scarlet passion flower
Passiflora mollisima	banana passionfruit
Passiflora subpeltata	white passion flower
Pennisetum spp	fountain grass etc
Perilepta dyeriana	perilepta
Pinus caribaea	carabbean pine
Pinus halepensis	aleppo pine
Pinus radiata	radiate pine
Piper betle	pepper vine
Samanea saman	raintree
Sansevieria trifac	mother-in-law’s tongue
Scinus terebinthifolius	broad-leaved pepper tree
Senna alata	candle bush
Spathodea campanulata	african tulip tree
Sphagneticola trilobata	singapore daisy
Syngonium podophyllum	white butterfly, syngonium
Syzygium cumini	java plum, jambolan plum
Tabebuia pallida (= *T. rosea*)	pale tabebuia
Tamarix aphylla	athel pine
Tamrindus indicus	tamarind
Tecoma stans	tecoma
Thaumastochloa danielii	prayer plant
Thunbergia alata	black-eyed Susan
Thunbergia annua	orange thunbergia
Thunbergia fragrans	
Thunbergia laurifolia	laurel clock vine
Tithonia diversifolia	japanese sunflower, japanese honeysuckle
Tradescantia spp	wandering Jew
Triplaris americana	triplaris
Turbina coymbosa	turbine vine

12.4 Appendix D. Animal species of conservational significance in the Burdekin Dry Tropics coastal region

Species in this table are: conservation significant species that are listed as rare or threatened under the *Nature Conservation Act 1992* or threatened under *the Environment Protection and Biodiversity Conservation Act 1999*, have a management status of rare or threatened, or are listed under an international agreement (such as JAMBA, CAMBA and Bonn Convention).

Class	Family	Scientific Name	Common Name	NCA	EPBC	End
amphibians	Hylidae	*Litoria nannotis*	waterfall frog	E	E	Q
amphibians	Microhylidae	*Austrochaperina robusta*	robust whistlefrog	R		Q
amphibians	Microhylidae	*Cophixalus mcdonaldi*	Mount Elliot nurseryfrog	R		Q
birds	Accipitridae	*Accipiter novaehollandiae*	grey goshawk	R		QAI
birds	Accipitridae	*Erythrotriorchis radiatus*	red goshawk	E	V	QA
birds	Accipitridae	*Haliaeetus leucogaster*	white-bellied sea-eagle	C		QAI
birds	Accipitridae	*Lophoictinia isura*	square-tailed kite	R		QA
birds	Anatidae	*Anas gracilis*	grey teal	C		QAI
birds	Anatidae	*Anas platyrhynchos*	mallard			IU
birds	Anatidae	*Anas querquedula*	garganey	C		VU
birds	Anatidae	*Nettapus coromandelianus*	cotton pygmy-goose	R		QAI
birds	Anatidae	*Stictonetta naevosa*	freckled duck	R		QA
birds	Anatidae	*Tadorna radjah*	radjah shelduck	R		QAI
birds	Apodidae	*Apus pacificus*	fork-tailed swift	C		QAI
birds	Apodidae	*Collocalia spodiopygius*	white-rumped swiftlet	R		Q
birds	Apodidae	*Hirundapus caudacutus*	white-throated needletail	C		QAI
birds	Ardeidae	*Ardea alba*	great egret	C		QAI
birds	Ardeidae	*Ardea ibis*	cattle egret	C		QAI
birds	Ardeidae	*Egretta sacra*	eastern reef egret	C		QAI
birds	Burhinidae	*Esacus neglectus*	beach stone-curlew	V		QAI
birds	Cacatuidae	*Cacatua leadbeateri*	Major Mitchell's cockatoo	V		QA
birds	Casuariidae	*Casuarius casuarius johnsonii* (southern population)	southern cassowary (southern population)	E	E	Q
birds	Charadriidae	*Charadrius bicinctus*	double-banded plover	C		QAI
birds	Charadriidae	*Charadrius dubius*	little ringed plover	C		VU
birds	Charadriidae	*Charadrius hiaticula*	ringed plover	C		VU
birds	Charadriidae	*Charadrius leschenaultii*	greater sand plover	C		QAI
birds	Charadriidae	*Charadrius mongolus*	lesser sand plover	C		QAI
birds	Charadriidae	*Charadrius veredus*	oriental plover	C		QAI
birds	Charadriidae	*Pluvialis fulva*	Pacific golden plover	C		QAI
birds	Charadriidae	*Pluvialis squatarola*	grey plover	C		QAI
birds	Ciconiidae	*Ephippiorhynchus asiaticus*	black-necked stork	R		QAI
birds	Columbidae	*Geophaps scripta scripta*	squatter pigeon (southern subspecies)	V	V	QA
birds	Cuculidae	*Cuculus saturatus*	oriental cuckoo	C		QAI
birds	Falconidae	*Falco cenchroides*	nankeen kestrel	C		QAI
birds	Falconidae	*Falco hypoleucos*	grey falcon	R		QA
birds	Falconidae	*Falco longipennis*	Australian hobby	C		QAI
birds	Fregatidae	*Fregata ariel*	lesser frigatebird	C		QAI
birds	Fregatidae	*Fregata minor*	great frigatebird	C		QAI

Class	Family	Scientific Name	Common Name	NCA	EPBC	End
birds	Glareolidae	*Glareola maldivarum*	oriental pratincole	C		QAI
birds	Gruidae	*Grus antigone*	sarus crane	C		QAI
birds	Haematopodidae	*Haematopus fuliginosus*	sooty oystercatcher	R		QA
birds	Hirundinidae	*Hirundo rustica*	barn swallow	C		QAI
birds	Hydrobatidae	*Oceanites oceanicus*	Wilson's storm-petrel	C		QAI
birds	Laridae	*Anous stolidus*	common noddy	C		QA
birds	Laridae	*Chlidonias leucopterus*	white-winged black tern	C		QAI
birds	Laridae	*Stercorarius parasiticus*	Arctic jaeger	C		QAI
birds	Laridae	*Sterna albifrons*	little tern	E		QAI
birds	Laridae	*Sterna anaethetus*	bridled tern	C		QAI
birds	Laridae	*Sterna bengalensis*	lesser crested tern	C		QAI
birds	Laridae	*Sterna hirundo*	common tern	C		QAI
birds	Laridae	*Sterna sumatrana*	black-naped tern	C		QAI
birds	Meliphagidae	*Melithreptus gularis*	black-chinned honeyeater	R		QA
birds	Meliphagidae	*Melithreptus gularis laetior*	golden-backed honeyeater	R		QA
birds	Meropidae	*Merops ornatus*	rainbow bee-eater	C		QAI
birds	Motacillidae	*Motacilla cinerea*	grey wagtail	C		VU
birds	Motacillidae	*Motacilla flava*	yellow wagtail	C		QAI
birds	Passeridae	*Neochmia phaeton*	crimson finch	V		U
birds	Passeridae	*Neochmia phaeton iredalei*	crimson finch (eastern form)	V		Q
birds	Passeridae	*Poephila cincta cincta*	black-throated finch (white-rumped subspecies)	V	V	QA
birds	Phaethontidae	*Phaethon lepturus*	white-tailed tropicbird	C		QAI
birds	Procellariidae	*Macronectes giganteus*	southern giant-petrel	E	E	QAI
birds	Procellariidae	*Puffinus griseus*	sooty shearwater	C		QAI
birds	Procellariidae	*Puffinus pacificus*	wedge-tailed shearwater	C		QAI
birds	Procellariidae	*Puffinus tenuirostris*	short-tailed shearwater	C		QAI
birds	Psittacidae	*Cyclopsitta diophthalma macleayana*	Macleay's fig-parrot	V		Q
birds	Rallidae	*Rallus pectoralis*	Lewin's rail	R		QAI
birds	Rostratulidae	*Rostratula benghalensis*	painted snipe	V	V	QAI
birds	Scolopacidae	*Actitis hypoleucos*	common sandpiper	C		QAI
birds	Scolopacidae	*Arenaria interpres*	ruddy turnstone	C		QAI
birds	Scolopacidae	*Calidris acuminata*	sharp-tailed sandpiper	C		QAI
birds	Scolopacidae	*Calidris alba*	sanderling	C		QAI
birds	Scolopacidae	*Calidris alpina*	dunlin	C		VI
birds	Scolopacidae	*Calidris canutus*	red knot	C		QAI
birds	Scolopacidae	*Calidris ferruginea*	curlew sandpiper	C		QAI
birds	Scolopacidae	*Calidris melanotos*	pectoral sandpiper	C		QAI
birds	Scolopacidae	*Calidris ruficollis*	red-necked stint	C		QAI
birds	Scolopacidae	*Calidris tenuirostris*	great knot	C		QAI
birds	Scolopacidae	*Gallinago hardwickii*	Latham's snipe	C		QAI
birds	Scolopacidae	*Heteroscelus brevipes*	grey-tailed tattler	C		QAI
birds	Scolopacidae	*Heteroscelus incanus*	wandering tattler	C		QAI
birds	Scolopacidae	*Limicola falcinellus*	broad-billed sandpiper	C		QAI

Class	Family	Scientific Name	Common Name	NCA	EPBC	End
birds	Scolopacidae	*Limosa lapponica*	bar-tailed godwit	C		QAI
birds	Scolopacidae	*Limosa limosa*	black-tailed godwit	C		QAI
birds	Scolopacidae	*Numenius madagascariensis*	eastern curlew	R		QAI
birds	Scolopacidae	*Numenius minutus*	little curlew	C		QAI
birds	Scolopacidae	*Numenius phaeopus*	whimbrel	C		QAI
birds	Scolopacidae	*Philomachus pugnax*	ruff	C		VU
birds	Scolopacidae	*Tringa glareola*	wood sandpiper	C		QAI
birds	Scolopacidae	*Tringa nebularia*	common greenshank	C		QAI
birds	Scolopacidae	*Tringa stagnatilis*	marsh sandpiper	C		QAI
birds	Scolopacidae	*Xenus cinereus*	terek sandpiper	C		QAI
birds	Strigidae	*Ninox rufa queenslandica*	rufous owl (southern subspecies)	V		Q
birds	Strigidae	*Ninox strenua*	powerful owl	V		QA
birds	Sulidae	*Sula dactylatra*	masked booby	C		QAI
birds	Sulidae	*Sula leucogaster*	brown booby	C		QAI
birds	Sulidae	*Sula sula*	red-footed booby	C		QAI
birds	Threskiornithidae	*Plegadis falcinellus*	glossy ibis	C		QAI
birds	Tytonidae	*Tyto novaehollandiae kimberli*	masked owl (northern subspecies)	V	V	QA
mammals	Delphinidae	*Orcaella brevirostris*	Irrawaddy dolphin	R		QAI
mammals	Delphinidae	*Sousa chinensis*	Indo-Pacific hump-backed dolphin	R		QAI
mammals	Dugongidae	*Dugong dugon*	dugong	V		QAI
mammals	Emballonuridae	*Saccolaimus saccolaimus nudicluniatus*	bare-rumped sheathtail bat	E	CE	QAI
mammals	Emballonuridae	*Taphozous australis*	coastal sheathtail bat	V		QAI
mammals	Hipposideridae	*Hipposideros diadema reginae*	diadem leaf-nosed bat	R		QAI
mammals	Macropodidae	*Petrogale sharmani*	Sharman's rock-wallaby	E		Q
mammals	Petauridae	*Petaurus gracilis*	mahogany glider	E	E	Q
mammals	Pseudocheiridae	*Hemibelideus lemuroides*	lemuroid ringtail possum	R		Q
mammals	Pteropodidae	*Pteropus poliocephalus*	grey-headed flying-fox	C	V	QA
mammals	Rhinolophidae	*Rhinolophus philippinensis*	greater large-eared horseshoe bat	E	E	QAI
mammals	Vespertilionidae	*Kerivoula papuensis*	golden-tipped bat	R		QAI
mammals	Vespertilionidae	*Miniopterus schreibersii oceanensis*	eastern bent-wing bat	C	CD	QAI
reptiles	Cheloniidae	*Chelonia mydas*	green turtle	V	V	QAI
reptiles	Cheloniidae	*Natator depressus*	flatback turtle	V	V	QAI
reptiles	Crocodylidae	*Crocodylus porosus*	estuarine crocodile	V		QAI
reptiles	Elapidae	*Acanthophis antarcticus*	common death adder	R		QA
reptiles	Elapidae	*Simoselaps warro*	robust burrowing snake	R		Q
reptiles	Pygopodidae	*Delma labialis*	striped-tailed delma	V	V	Q
reptiles	Scincidae	*Coeranoscincus frontalis*		R		Q
reptiles	Scincidae	*Glaphyromorphus mjobergi*		R		Q
reptiles	Scincidae	*Lampropholis mirabilis*		R		Q
reptiles	Scincidae	*Lerista karlschmidti*		R		QA
reptiles	Scincidae	*Menetia sadlieri*		R		Q
reptiles	Varanidae	*Varanus semiremex*	rusty monitor	R		Q

Source: Environmental Protection Agency. 2004. *WildNet*. (Database). Environmental Protection Agency, Brisbane. 22 November 2004. **NCA** status – indicates the conservation status of each taxon under the *Nature Conservation Act 1992*. Endangered (E), Vulnerable (V), Rare (R), Common (C). **EPBC** status – indicates the conservation status of each taxon under the *Environment Protection and Biodiversity Conservation Act 1999*. Conservation Dependent (CD), Critically Endangered (CE), Endangered (E), Vulnerable (V) and Threatened (includes taxa listed as CD, CE, E, and V). **End** (Endemicity): Queensland Endemic (Q), Intranational (QA), Not Endemic to Australia (QAI), Vagrant (International) (VI), Vagrant (Unknown) (VU), Introduced (Unknown) (IU), or Unknown (U).

12.5 Appendix E. Plant species of conservational significance in the Burdekin Dry Tropics coastal region

Species in this table are: conservation significant species that are listed as rare (R), vulnerable (V) or endangered (E) under the *Nature Conservation Act 1992*.

Group	Family Name	Status	Botanical Name	Habitat
Angiosperm	Orchidaceae	R	*Habenaria rumphii*	Forest, Woodland (unspecified), open forest, open woodland
Angiosperm	Arecaceae	V	*Livistona drudei*	Freshwater swamp, marsh, soak, seepage, open woodland
Angiosperm	Sapindaceae	R	*Arytera dictyoneura*	Slope, lithosols, rainforest/vine forest, acid intrusive rocks
Angiosperm	Euphorbiaceae	V	*Croton magneticus*	Rainforest, Vine forest, Acid intrusive rocks
Angiosperm	Mimosaceae	R	*Acacia jackesiana*	Ironbark forest, *Eucalyptus* forests, agglomerate
Angiosperm	Asclepiadaceae	V	*Marsdenia brevifolia*	Ironbark forest, *Eucalyptus* forests
Angiosperm	Solanaceae	R	*Solanum sporadotrichum*	Slope or hill, woodland
Angiosperm	Tiliaceae	R	*Grewia graniticola*	Costal dune, beach dune, open woodland
Angiosperm	Convolvulaceae	R	*Bonamia dietrichiana*	Scrub, vine thicket, dry rainforest, acid intrusive rocks
Angiosperm	Caesalpiniaceae	R	*Cassia* sp. (Paluma Range)	Open forest, open woodland
Angiosperm	Asteraceae	R	*Peripleura scabra*	Sandy soil, Eucalyptus open forest
Angiosperm	Myrtaceae	E	*Babingtonia papillosa*	Slope, lithosols, skeletal, rocky soils, acid intrusive rocks
Angiosperm	Tiliaceae	R	*Corchorus hygrophilus*	Lithosols, rainforest, vine forest, acid intrusive rocks
Angiosperm	Euphorbiaceae	R	*Actephila sessilifolia*	Scrub, vine thicket, dry rainforest
Angiosperm	Apocynaceae	R	*Parsonsia lenticellata*	Open forest, open woodland
Angiosperm	Myrtaceae	V	*Eucalyptus paedoglauca*	Slope or hill, lithosols, skeletal, rocky soils, Eucalypt forest
Angiosperm	Scrophulariaceae	R	*Rhamphicarpa australiensis*	Open forest, open woodland
Angiosperm	Hydrocharitaceae	R	*Vallisneria nana*	
Angiosperm	Elaeocarpaceae	V	*Dubouzetia saxatilis*	Lithosols, skeletal, rocky soils
Angiosperm	Hydrocharitaceae	V	*Hydrocharis dubia*	Freshwater lake, lagoon, spring, stream.
Angiosperm	Asteraceae	R	*Peripleura sericea*	Eucalypt forest
Angiosperm	Rubiaceae	R	*Oldenlandia polyclada*	Slope, lithosols, skeletal, rocky soils, acid intrusive rocks
Angiosperm	Acanthaceae	R	*Graptophyllum excelsum*	Scrub, vine thicket, dry rainforest
Angiosperm	Sapindaceae	R	*Atalaya calcicola*	Scrub, vine thicket, dry rainforest

Group	Family Name	Status	Botanical Name	Habitat
Angiosperm	Poaceae	R	*Dichanthium setosum*	
Angiosperm	Aponogetonaceae	R	*Aponogeton queenslandicus*	Freshwater lake, lagoon, spring, stream.
Angiosperm	Fabaceae	R	*Phyllodium pulchellum*	Eucalypt forest, Sclerophyll forest (wet or dry)
Angiosperm	Combretaceae	R	*Macropteranthes leiocaulis*	Slope, lithosols, scrub, vine thicket, dry rainforest

Source: Qld Herbarium (2004).

12.6 Appendix F. Commercial inshore fisheries catch from the Burdekin Dry Tropics coastal region

Fishery	Species Code	Species	Tonnes	Boats	Days	GVP (AUS $)
Trawl	700800	Prawns - Tiger Total	832.8	1235	10907	$12,491,400
Trawl	700900	Prawns - King - Red Spot Total	540.8	811	6563	$5,409,000
All	700900	Shark - unspecified Total	733.3	200	4584	$4,397,500
Pot - Crab	702901	Bugs - Whole Total	341.1	1452	13891	$4,096,200
Trawl - Otter	702901	Crab - Mud Total	173.4	167	9031	$1,820,500
Pot - Crab	702001	Prawns - Endeavour Total	150.1	1055	8779	$1,799,100
Trawl - Otter	602000	Mackerel - Grey Total	217.5	66	1003	$1,304,900
All	602000	Barramundi Total	163.8	154	4452	$1,147,000
Line	351009	Mackerel - Spanish Total	154.1	189	1494	$1,078,200
Net	599000	Prawns - King - Western Total	104.2	335	2238	$1,042,600
Net	296900	Prawns - Banana Total	75.9	134	643	$682,600
Net	350902	Scallops - Saucer (Kg Meat) Total	24.0	288	1623	$482,400
All	441902	Bugs - Balmain Total	44.1	224	1515	$442,600
All	381900	Threadfin - Blue Total	109.8	156	3442	$439,200
Net	381900	Prawns - King Total	32.7	43	195	$390,400
Trawl - Otter	601000	Cod - Coral Trout Total	34.6	130	696	$345,200
All	282901	Crab - Blue Swimmer Total	54.4	770	6007	$339,000
Trawl - Otter	701901	Prawns - King - Eastern Total	25.9	109	311	$309,000
Trawl - Otter	701909	Prawns - Coral Total	32.2	309	1867	$290,200
		Mullet - unspecified Total	84.4	148	2480	$253,200
Trawl - Otter	701903	Queenfish Total	72.6	109	1432	$217,900
All	701903	Garfish - unspecified Total	34.2	40	248	$205,600
Trawl	701904	Grunter - unspecified Total	23.8	94	1984	$118,600
Trawl	701303	Pipefish - unspecified Total	0.6	353	2208	$89,600
Trawl	701303	Trevally - unspecified Total	17.1	87	913	$68,300
		Mackerel - unspecified Total	16.8	10	198	$67,400
All	701910	Emperor - Red Throat Total	12.0	112	410	$59,400
Trawl - Otter	701902	Squid - unspecified Total	9.2	455	2473	$46,900
Net	337905	Fish - unspecified Total	42.2	59	1275	$42,200
Trawl	900204	Threadfin - King Total	10.6	96	722	$42,000
Net	19900	Cuttlefish Total	6.0	343	2060	$29,600
		Flathead - unspecified Total	4.0	60	482	$24,200
Trawl - Otter	600000	Emperor - Red Total	2.4	44	128	$21,200
All	600000	Fish - Mixed Reef Total	3.2	52	202	$16,600
Trawl	600000	Whiting - unspecified Total	3.2	12	90	$12,800
Net	383005	Octopus - unspecified Total	2.4	174	1112	$12,500
Trawl	347000	Threadfin Bream - unspecified Total	4.6	43	239	$9,200
Trawl	347000	Cod - unspecified Total	1.1	24	80	$4,900
		Emperor - Spangled Total	0.6	10	30	$3,800
All	337900	Triple Tail Total	0.8	24	158	$3,800
All	337900	Bream - unspecified Total	0.7	24	100	$3,000

Fishery	Species Code	Species	Tonnes	Boats	Days	GVP (AUS $)
Net	348001	Cod - Barramundi Total	0.2	30	70	$1,200
		Kingfish - Black Total	0.2	12	18	$1,200
		Fish - Mixed Reef B Total	0.2	10	26	$1,000
		Total	**4197.7**	**10252**	**98379**	**$39,663,100**
		All Prawns				**$22,414,300**

Source: DPI&F (2004a). *CHRIS web*. *Fishing Data for Burdekin Dry Tropics Coastal Region for 2003*. Qld Department of Primary Industries and Fisheries. Grids used: I20, J20, I21, J21, K21, L21, L22 and M22. GVP: Gross Value Product.

13 FURTHER READING

ACTFR. Date unspecified. Volume 2, Appendices. *A proposed typological basis for providing new situation-specific water quality advice to resource managers in Queensland's dry and wet-dry tropics*. 143 pp. Australian Centre for Tropical Freshwater Research report no. 04/04. James Cook University, Townsville.

Alongi, D.M. 1998. *Coastal ecosystem processes*. 419 p. CRC Press, Boca Raton.

Andersen, C., Clarke, K., Higgs J. and Ryan, S. 2005. *Ecological assessment of the Queensland coral reef fin fish fishery*. A report to the Australian Government Department of Environment and Heritage on the ecologically sustainable management of a multi-species line fishery in a coral reef environment. Queensland Department of Primary Industries and Fisheries.

Arakel, A.V. 1991. Coastal sedimentation in north Queensland: past and present trends. In: *Proceedings of the land use patterns and nutrient loading of the Great Barrier Reef region workshop*, 17-18 Nov 1990, James Cook University of North Queensland. Pp. 180-191. James Cook University of North Queensland, Townsville.

Baker, J.T. 1994. *An economic/ecological strategy for the Burdekin Dry Tropics coastal regions: a study based on long-term planning for the Burdekin Dry Tropics region*. Final report. 94 pp. Australian Institute of Marine Science.

Beare, S., Bell, R., Blias, A., Gooday, P., Heaney, A., Hooper, S., Langenkamp, D., Love, G., Levantis, C., Mues, C., Qureshi, E. and Riley, C. 2003. *Natural resource management in the Burdekin River catchment*. *Integrated assessment of natural resource management at the catchment scale: a case study*. 66 pp. ABARE eReport 03.18. Australian Bureau of Agricultural and Resource Economics, Canberra.

Beumer, J.P. and Mayer, D.R. 1993. Protection of coastal wetlands in Queensland: a fisheries perspective. In: *Fifteenth Australian water and wastewater association*, *federal convention*, 18-23 Apr 1993, Gold Coast. Pp. 841-847. Australian Water and Wastewater Association, Canberra.

BIFMAC. 2000. *A community based natural resource management strategy for the Burdekin-Bowen floodplain sub-region*. 48 pp + maps. BIFMAC, Ayr.

BIFMAC. 2000. *A community based natural resource management strategy for the Burdekin-Bowen floodplain sub-region*. *Appendix B: strategy implementation manual*. 106 pp. BIFMAC, Ayr.

Bird Observers Club of Australia. 2003. *Birding Spots Around the Townsville Region*. http://www.birdobservers.org.au/townsville_birding_spots.htm

Blackman, J.G., Gardiner, S.J. and Morgan, M.G. 1995. Framework for biogeographic inventory, assessment, planning and management of wetland systems: the Queensland approach. In: *Proceedings of the wetland research in the Wet-Dry Tropics of Australia workshop*, 22-24 Mar 1995, Jabiru NT. Supervising Scientist Report; No. 101. Pp. 114-122. Environmental Research Institute of the Supervising Scientist, Barton.

Bradford, K. 2003. *Wetlands to the reef: how to manage critical wetland habitats*. Wetlands to the reef forum, 10 November 2003, Townsville. WetlandCare Australia.

Brunskill, G.J., Zagorskis, I. and Pfitzner, J. 2002. Carbon burial rates in sediments and a carbon mass balance for the Herbert River region of the Great Barrier Reef continental shelf, North Queensland, Australia. *Estuarine, Coastal and Shelf Science* **54**: 677–700.

Bryce, S., Larcombe, P. and Ridd, P. 2003. Hydrodynamic and geomorphological controls on suspended sediment transport in mangrove creek systems, a case study: Cocoa Ck, Townsville, Australia. *Estuarine Coastal and Shelf Science* **56**: 415-431.

Cassells, D.S., Gilmour, D.A. and Gordon, P. 1982. The impact of plantation forestry on stream sedimentation in tropical and sub-tropical Queensland: an initial assessment. In: *Agricultural engineering conference: resources-efficient use and conservation*, 22-24 Aug 1982, Armidale NSW. National Conference Publication No 82/8. Pp. 138-142. Institution of Engineers, Australia, Barton.

Chartres, C., Stewart, B., Bowmer, K., Ryan, S. and Moore, C. 2004. *Scientific advice on natural resource management: a report to the natural resource management ministerial council by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Australian Bureau of Meteorology (BOM)*. 65 pp. CSIRO and BOM.

Choy, S.C. and Thompson, P. 1996. River bioassessment and monitoring using benthic macroinvertebrate community structure: the monitoring river health initiative. In: *Downstream effects of land use: national conference*, 26-28 April, 1995, Rockhampton. H.M. Hunter, A.G. Eyles and G.E. Rayment (eds). Pp. 53-55. Queensland Department of Natural Resources, Brisbane.

Christianos, N. and McClurg, J. 2003. *Land resources of the lower Burdekin River delta: north Burdekin and south Burdekin water board areas*, *north Queensland*. Final report: project 23. 18 pp. J&A Land and Soil Services, Mackay.

Clarke, K. and Ryan, S. 2004. *Assessment of the Queensland blue swimmer crab fishery*. Queensland Department of Primary Industries and Fisheries.

Coles, R.G., McKenzie, L.J. and Yoshida, R.L. 2001. *Validation and GIS of seagrass surveys between Cairns and Bowen – October/November 1987*. CD Rom GIS DPI&F Cairns.

Congdon, R.A. and Lukacs, G.P. 1995. Limnology and classification of tropical floodplain wetlands, with particular reference to the effects of irrigation drainage. Part 1 temporal changes in water quality. 96 pp. Australian Centre for Tropical Freshwater Research report no. 95/12. James Cook University, Townsville.

Environment Australia. 2001. *A directory of important wetlands in Australia*. Department of the Environment and Heritage, Australian Government. http://www.deh.gov.au/water/wetlands/database/directory/

EPA. 2004. *Draft Queensland water quality guidelines 2004*. 44 pp. Queensland Environment Protection Agency, Brisbane.

EPA. 2004. *Integrating coastal and marine park management into regional NRM plans*. Module 11. 9 pp. EPA, Queensland Government.

EPA. 2004. *Integrating wetlands management into regional NRM plans*. Module 26. 8 pp. EPA, Queensland Government.

EPA. 2004. *Ecoaccess: coastal development*. http://www.epa.qld.gov.au/ecoaccess/coastal_development/

EPA. 2004. *Environmental management: coast and oceans*. http://www.epa.qld.gov.au/environmental_management/coast_and_oceans/

Furnas, M.J. 1991. The nutrient status of Great Barrier Reef waters. *Proceedings of the land use patterns and nutrient loading of the Great Barrier Reef region workshop*, 17-18 Nov 1990, James Cook University of North Queensland. Pp. 162-179. James Cook University of North Queensland, Townsville.

Furnas, M.J. and Brodie, J. 1996. Current status of nutrient levels and other water quality parameters in the Great Barrier Reef. In: *Downstream effects of land use: national* *conference*, 26-28 April, 1995, Rockhampton. H.M. Hunter, A.G. Eyles and G.E. Rayment (eds). Pp. 9-21. Queensland Department of Natural Resources, Brisbane.

Greiner, R., Stoeckle, N., Stokes, C., Herr, A. and Bachmaier, J. 2003. *Natural resource management in the Burdekin Dry Tropics: social and economic issues*. *Report for the Burdekin Dry Tropics NRM Board*. 177 pp. CSIRO Sustainable Ecosystems, Townsville.

Hausler, G. 1991. Hydrology of north Queensland coastal streams and their groundwaters. In: *Proceedings of the land use patterns and nutrient loading of the Great Barrier Reef region workshop*, 17-18 Nov 1990, James Cook University of North Queensland. Pp. 90-107. James Cook University of North Queensland, Townsville.

Intergovernmental Coastal Advisory Group. 2004. *Framework for a national cooperative approach to integrate coastal zone management: discussion paper on implementation*. 23 pp. Intergovernmental Coastal Advisory Group, Canberra.

JCU. 2005. *December: Central Queensland University – contract research: southern Halifax Bay ecosystem health monitoring program*. http://www.jcu.edu.au/office/research_office/funding/external/recent_contracts.html

Kaly, U.L., Eugelink, G. and Robertson, A.I. 1997. Soil conditions in damaged north Queensland mangroves. *Estuaries* **20**:291-300.

Kapitzke, I.R., Smithers, S., Lowry, J.B. and Sands, L.B. 1996. *Review of bank stability conditions for north Queensland coastal streams: phase 1 report*. 28 pp. Land and Water Resources Research and Development Corporation, Canberra. Research and Development Final Report; JCU9.

Kingston A. 2004. *Ecological assessment of the Queensland river and inshore (beam) trawl fishery*. A report to the Australian Government Department of Environment and Heritage on the ecologically sustainable management of a multi-species microscale fishery. Queensland Department of Primary Industries and Fisheries.

Kinhill Cameron McNamara. 1996. *Burdekin River improvement trust strategic plan for management and improvement of the lower Burdekin River*. *Part 1 planning report*. Kinhill Cameron McNamara Pty Ltd, Milton.

Kinsey, D.W. Water quality and its effects on reef ecology. In: *Proceedings of the land use patterns and nutrient loading of the Great Barrier Reef region workshop*, 17-18 Nov 1990, James Cook University of North Queensland. Pp. 192-196. James Cook University of North Queensland, Townsville.

Lee Long, W.J., Mellors, J.E., and Coles, R.G. 1993. Seagrasses between Cape York and Hervey Bay, Queensland, Australia. *Australian Journal of Marine and Freshwater Research* **44**: 19-32.

Marshall, P.A. and Baird A.H. 2000. *Bleaching of corals in the central Great Barrier Reef: variation in assemblage response and taxa susceptibilities*. *Coral Reefs* **19**: 155-163.

McKinnon, A.D. and Klumpp, D.W. 1998. Mangrove zooplankton of North Queensland, Australia, I: plankton community structure and environment. *Hydrobiologia* **362**:127-43.

Natural Resource Management Ministerial Council. 2003. *Framework for a national cooperative approach to integrate coastal zone management*. 12 pp. Natural Resource Management Ministerial Council, Canberra.

Perna, C. 2003. *Fish habitat assessment and rehabilitation in the Burdekin delta distributary streams*. Report No. 03/22. A report to the Natural Heritage Trust for projects 992077 and 2012148.

Pfitzner, J., Brunskill, G. and Irena Zagorskis, I. 2004. ^{137}Cs and excess ^{210}Pb deposition patterns in estuarine and marine sediment in the central region of the Great Barrier Reef Lagoon, north-eastern Australia. *Journal of Environmental Radioactivity* **76**: 81-102.

Poplawski, W.A. and Gourlay, M.R. 1987. Wash load estimation for rivers in North Queensland. *Third conference on hydraulics in civil engineering*, 12-14 Oct 1987, Melbourne. Pp. 169-170. Institution of Engineers, Australia, Barton. National Conference Publication; 87/14.

Radke, L.C., Smith, C.S., Ryan D.A., Brooke, B., Heggie, D. and contributors. 2003. (OzEstuaries). *Coastal indicator knowledge and information system I: biophysical indicators*. Web document. Canberra: Geoscience Australia. http://www.ozestuaries.org/indicators/indicators.html

Ridd, P., Renagi, S., Hollins, S. and Brunskill, G. 1997. Water, salt and nutrient fluxes of tropical tidal salt flats. *Mangroves and Salt Marshes* **1**: 229-238.

Robertson, A.I. and Alongi, D.M. (eds). 1992. *Tropical mangrove ecosystems*. 329 pp. Coastal and estuarine studies, series 41. American Geophysical Union, Washington D.C.

Roelofs, A. 2004. *Ecological assessment of Queensland's east coast beche-de-mer fishery*. A report to the Australian Government Department of Environment and Heritage on the ecologically sustainable management of a highly selective dive fishery. Queensland Department of Primary Industries and Fisheries.

Roth, C.H., Prosser, I.P., Post, D.A., Gross, J.E., Webb, M.J., O'Reagain, P.J., Shepherd, R.N. and Nelson, B.S. 2004. Keeping it in place – controlling sediment loss on grazing properties in the Burdekin River catchment. A discussion paper. 24 pp. Meat and Livestock Australia Limited.

Ryan, S. 2004. *Ecological assessment of the Queensland east coast spanish mackerel fishery*. A report to the Australian Government Department of the Environment and Heritage on the sustainable management of a pelagic troll fishery. Queensland Department of Primary Industries and Fisheries.

Smith, T.J., Boto, K.G., Frusher, S.D. and Giddins, R.L. 1991. Keystone species and mangrove forest dynamics: the influence of burrowing by craps on soil nutrient status and forest productivity. *Estuarine*, *Coastal and Shelf Science* **33**:419-32.

Sutton, C.A. and Hewitt, C.L. 2004. *Detection kits for community-based monitoring of marine pests*. Final Report for NHT/C&CS project 21247. http://www.marine.csiro.au/crimp/reports/publications.html

Tait, J. 2003. *Biodiversity and native vegetation management issues in the BBIFMAC NRM planning subregion*. Draft issues paper prepared by Jim Tait of Econcern Environmental Consulting for the BBIFMAC NRM strategy review – October 2003.

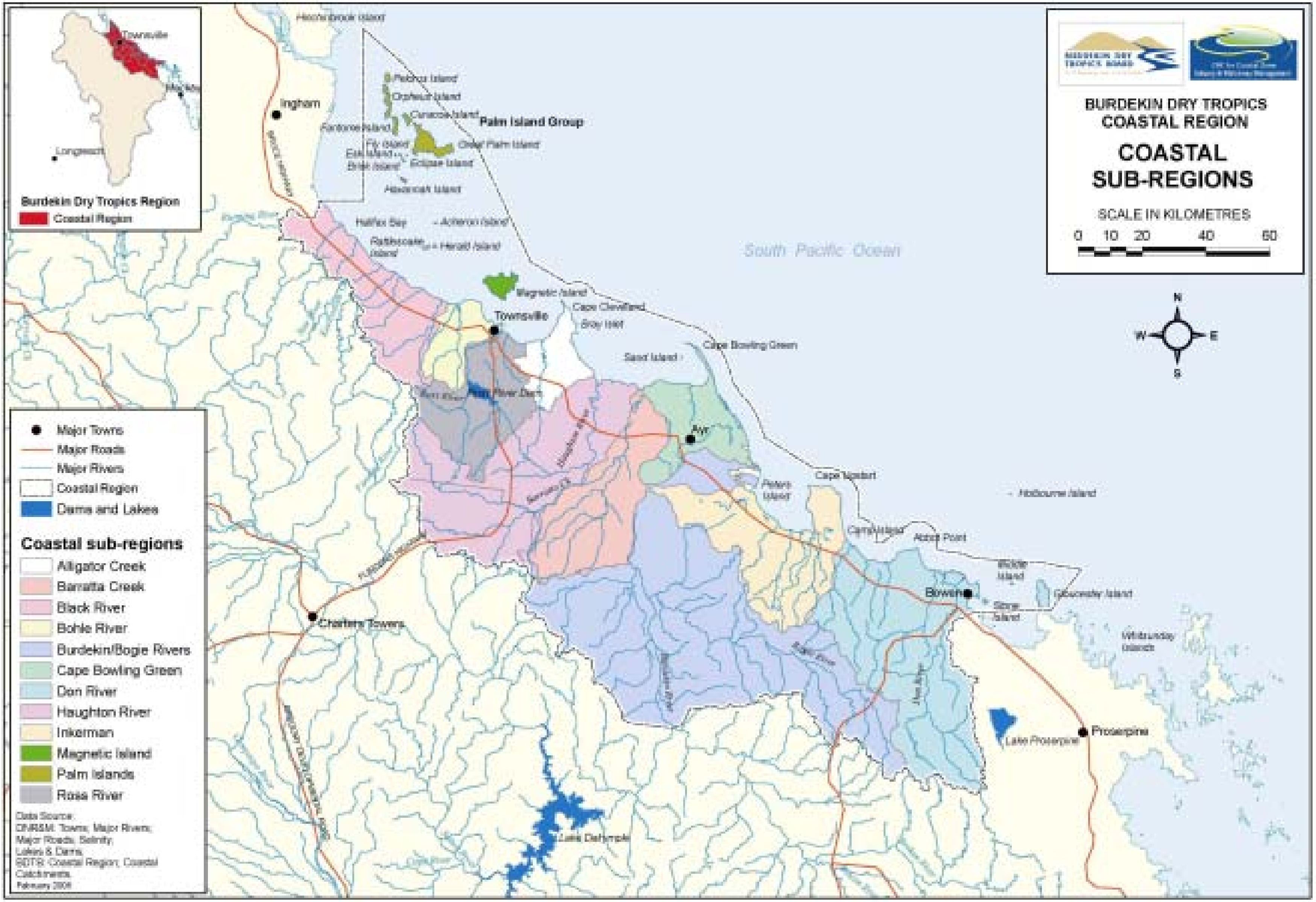
The State of Queensland and Commonwealth of Australia. 2003. *Reef water quality protection plan: for catchments adjacent to the Great Barrier Reef world heritage area*. 44 pp. Queensland Department of Premier and Cabinet, Brisbane.

Young, B. and Challen, S. 2004. *Ecological assessment of Queensland's east coast trochus fishery*. A report to the Australian Government Department of Environment and Heritage on the ecologically sustainable management of a highly selective dive fishery. Queensland Department of Primary Industries and Fisheries.

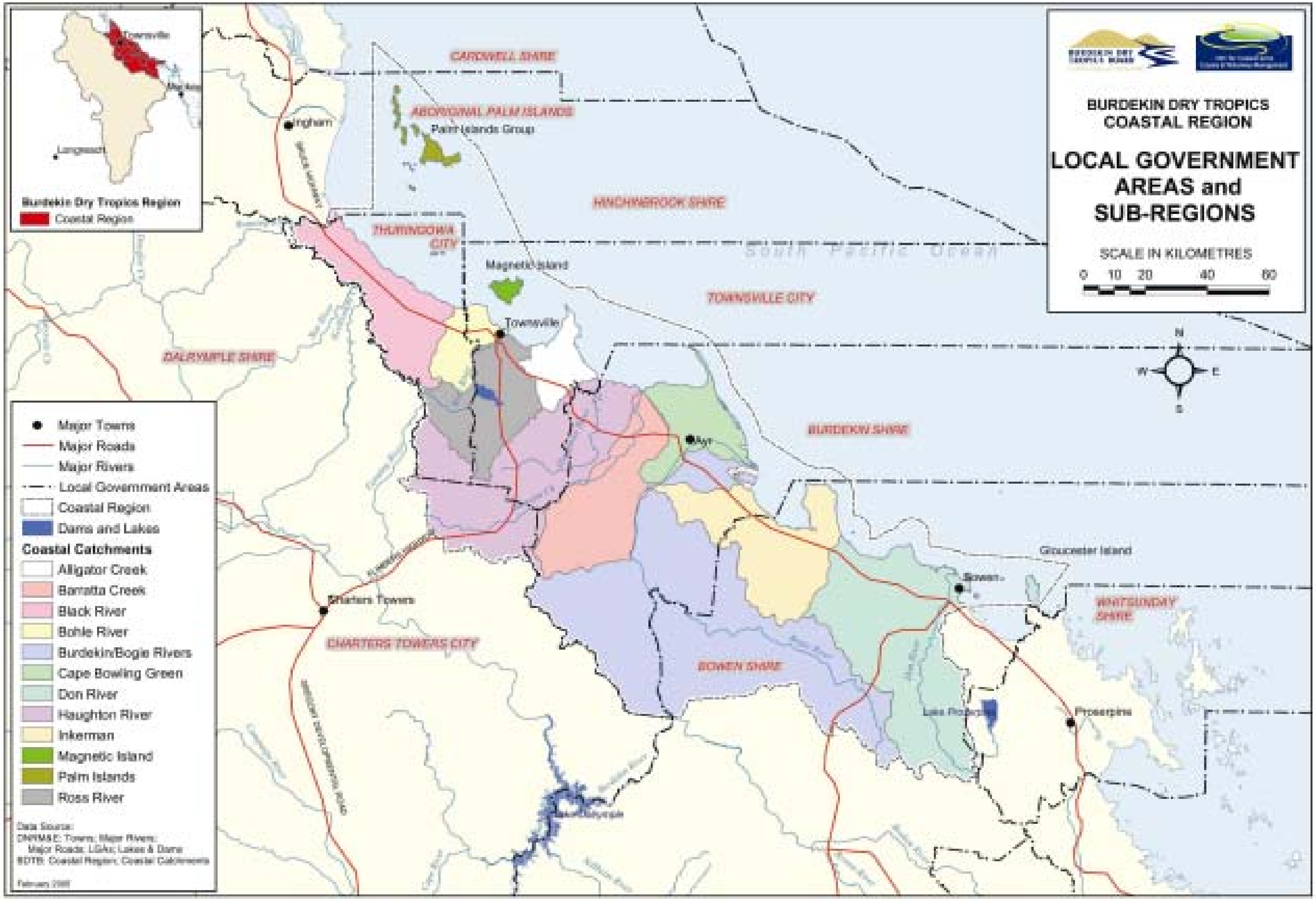
Zeller, B. 2004. *Ecological assessment of the Queensland east coast otter trawl fishery*. A report to Environment Australia on sustainable management of a multispecies macro-scale fishery ecosystemQueensland Department of Primary Industries and Fisheries.

14 MAPS

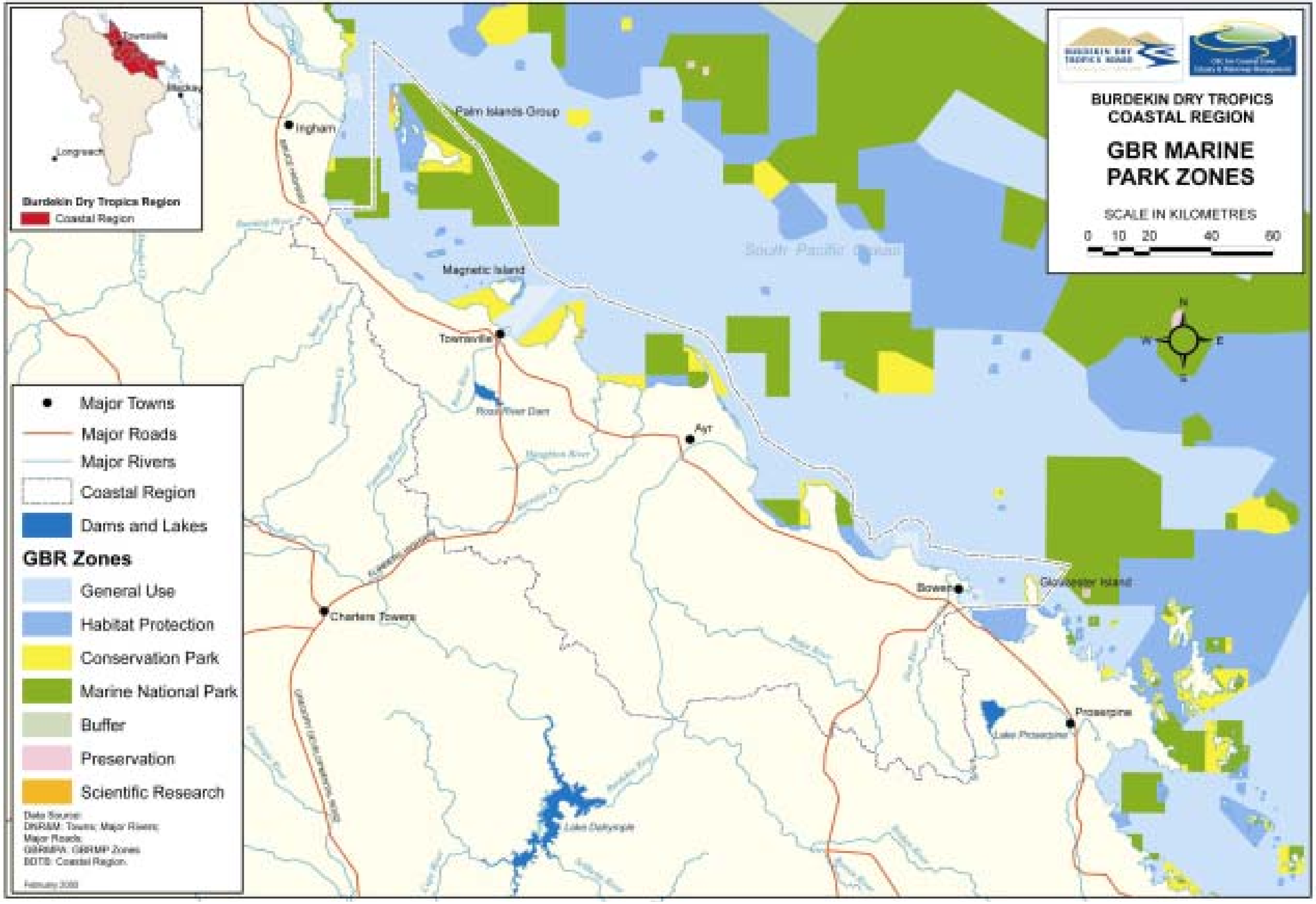
List of Maps



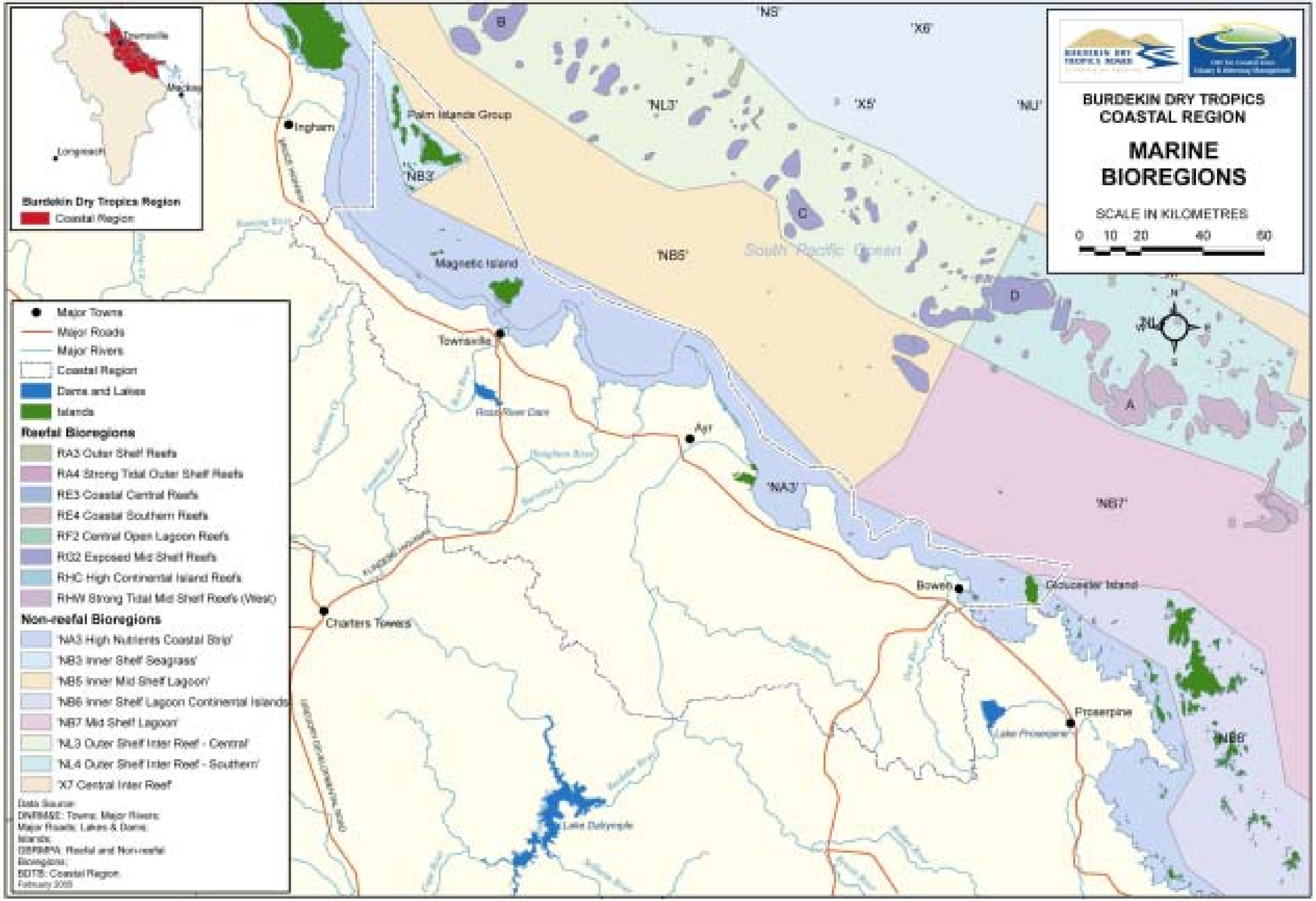
Map 1. Coastal catchments and islands.



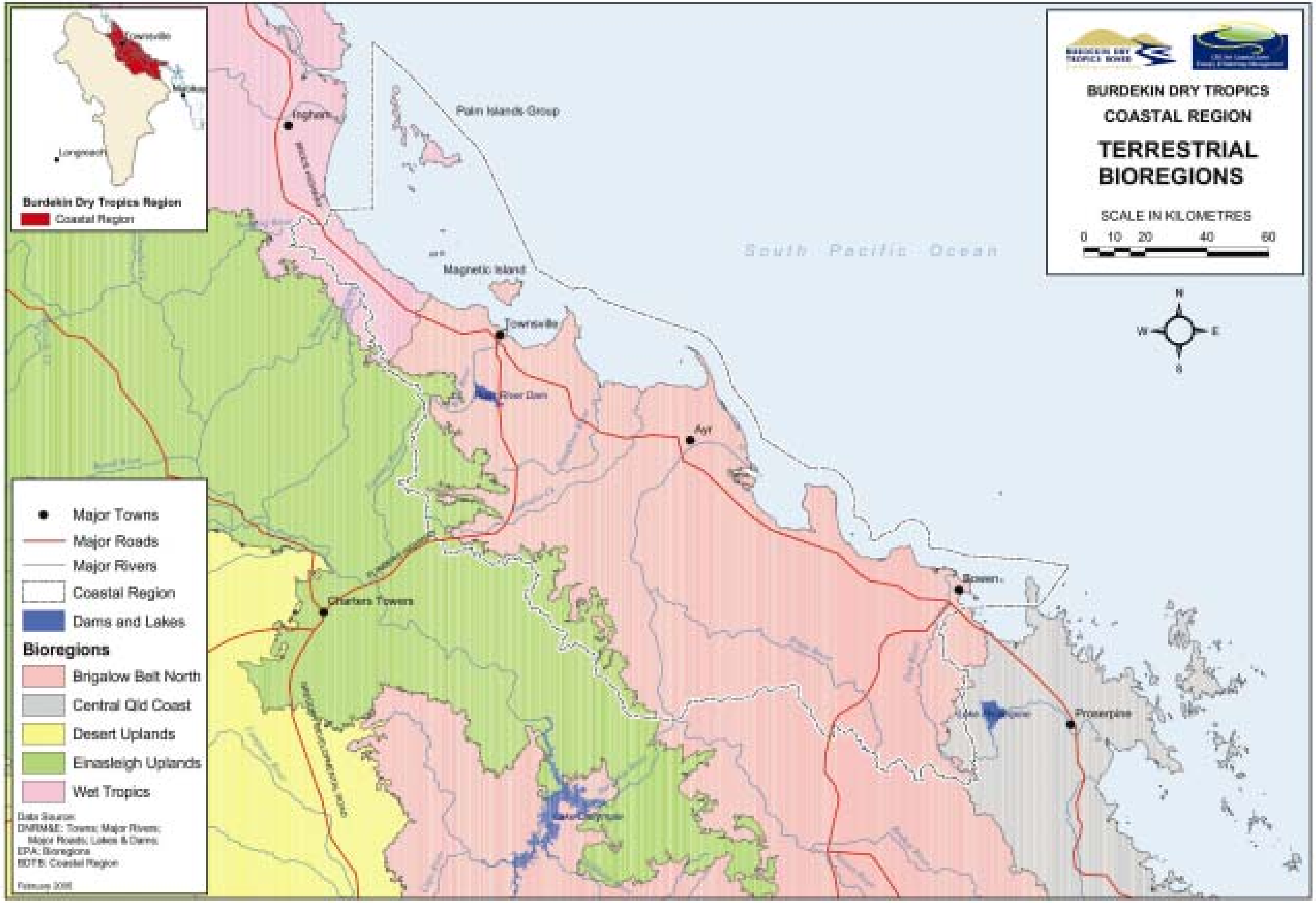
Map 2. Local government areas.



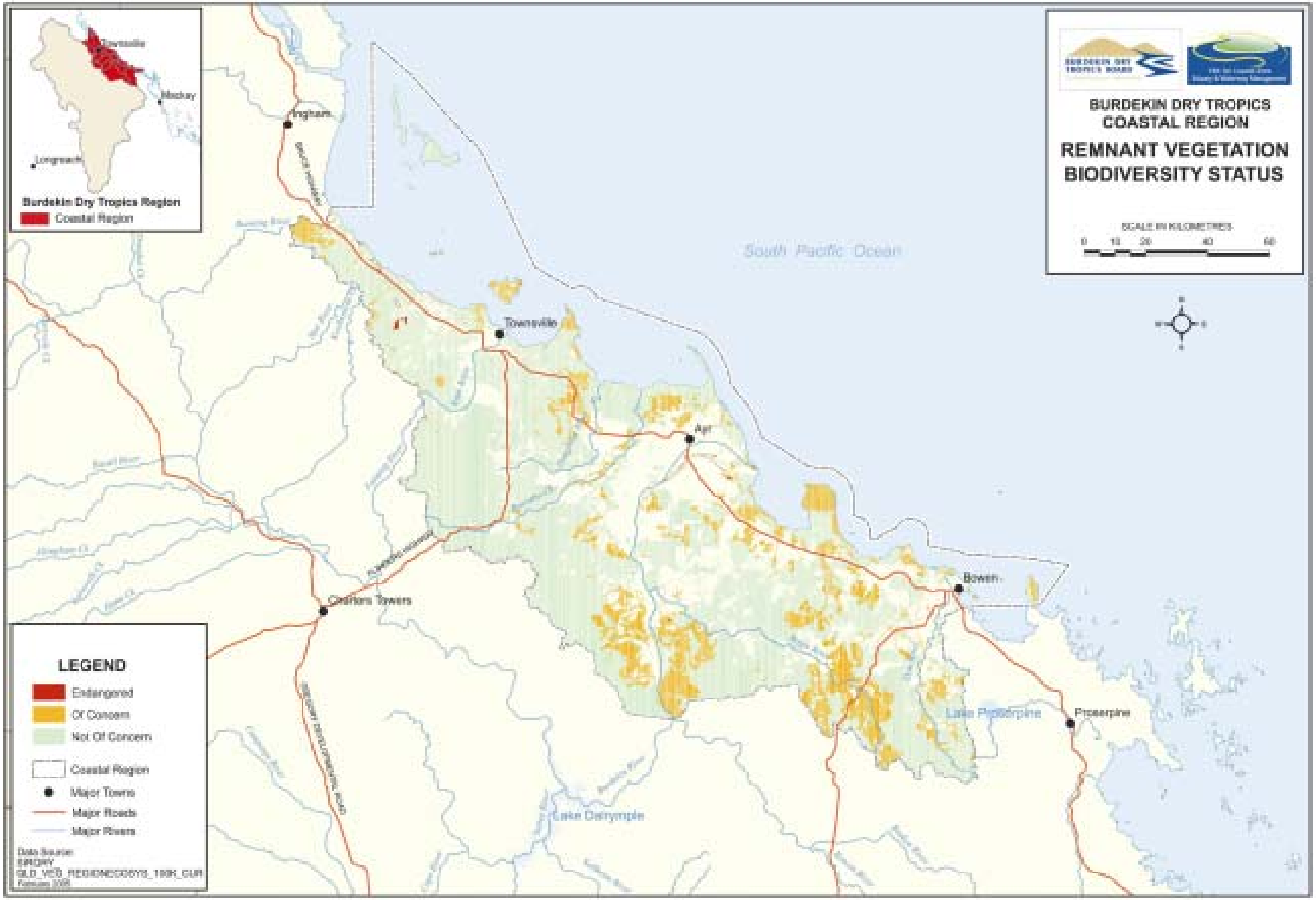
Map 3. Great Barrier Reef Marine Park zoning.



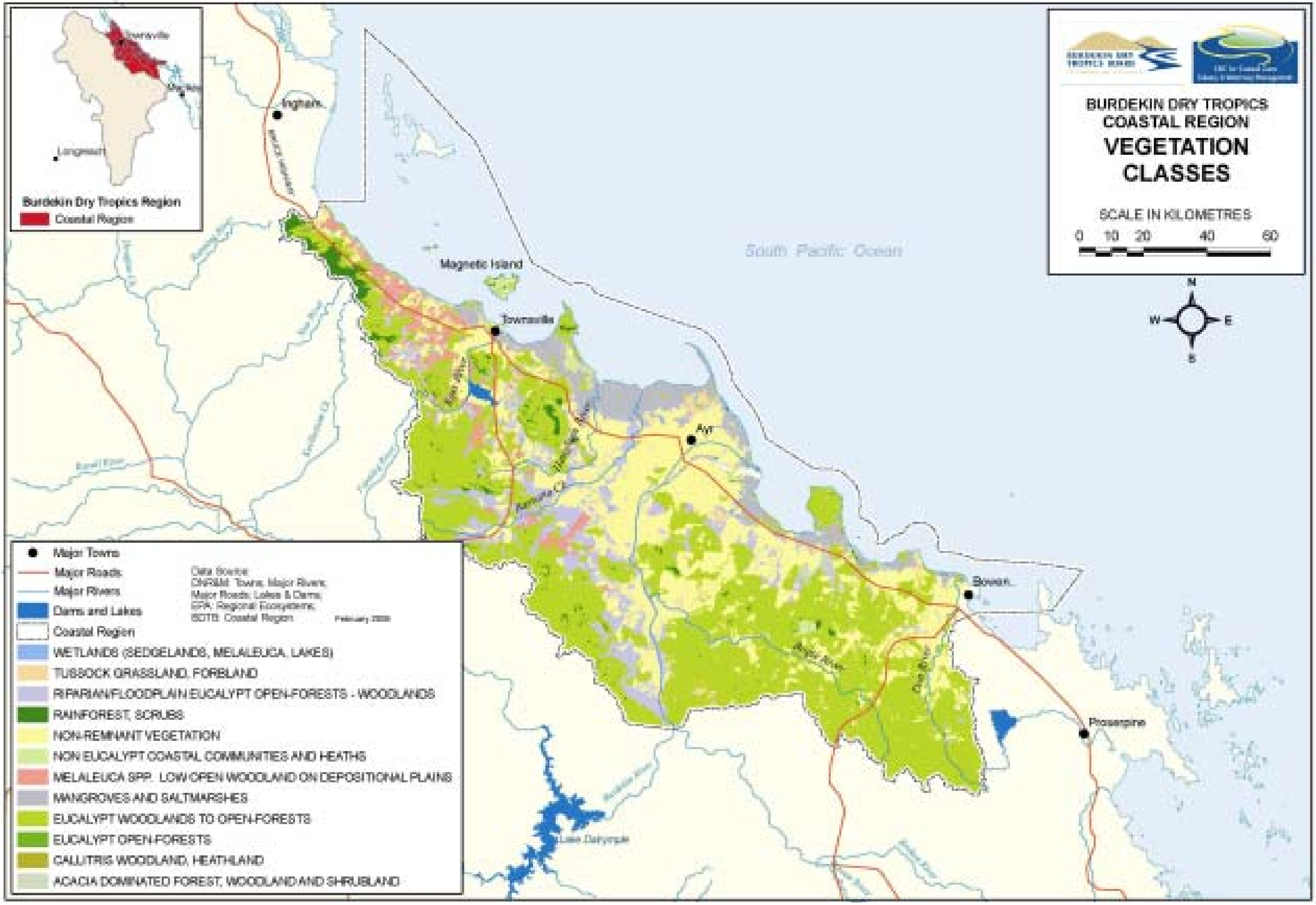
Map 4. Marine bioregions.



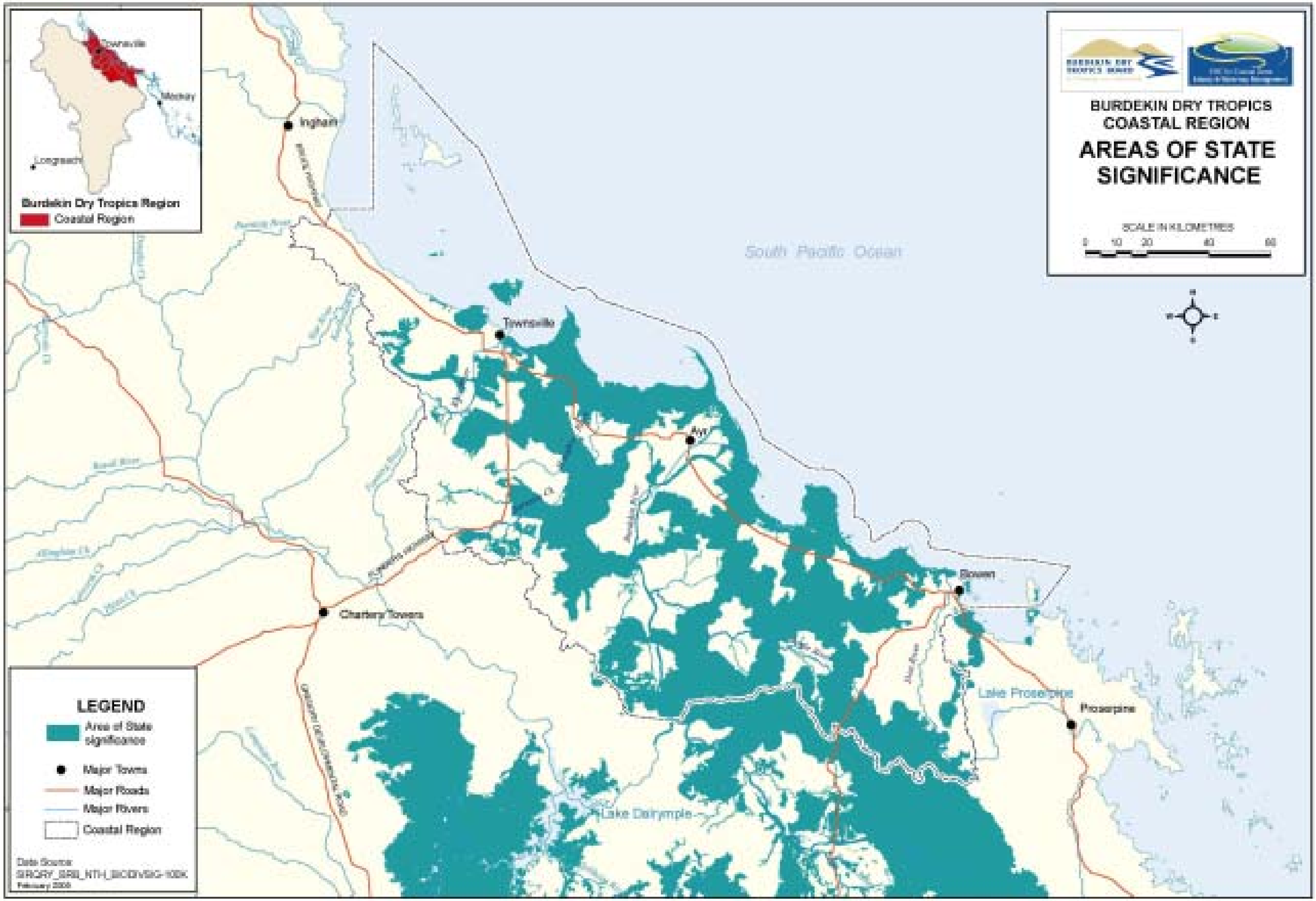
Map 5. Terrestrial bioregions.



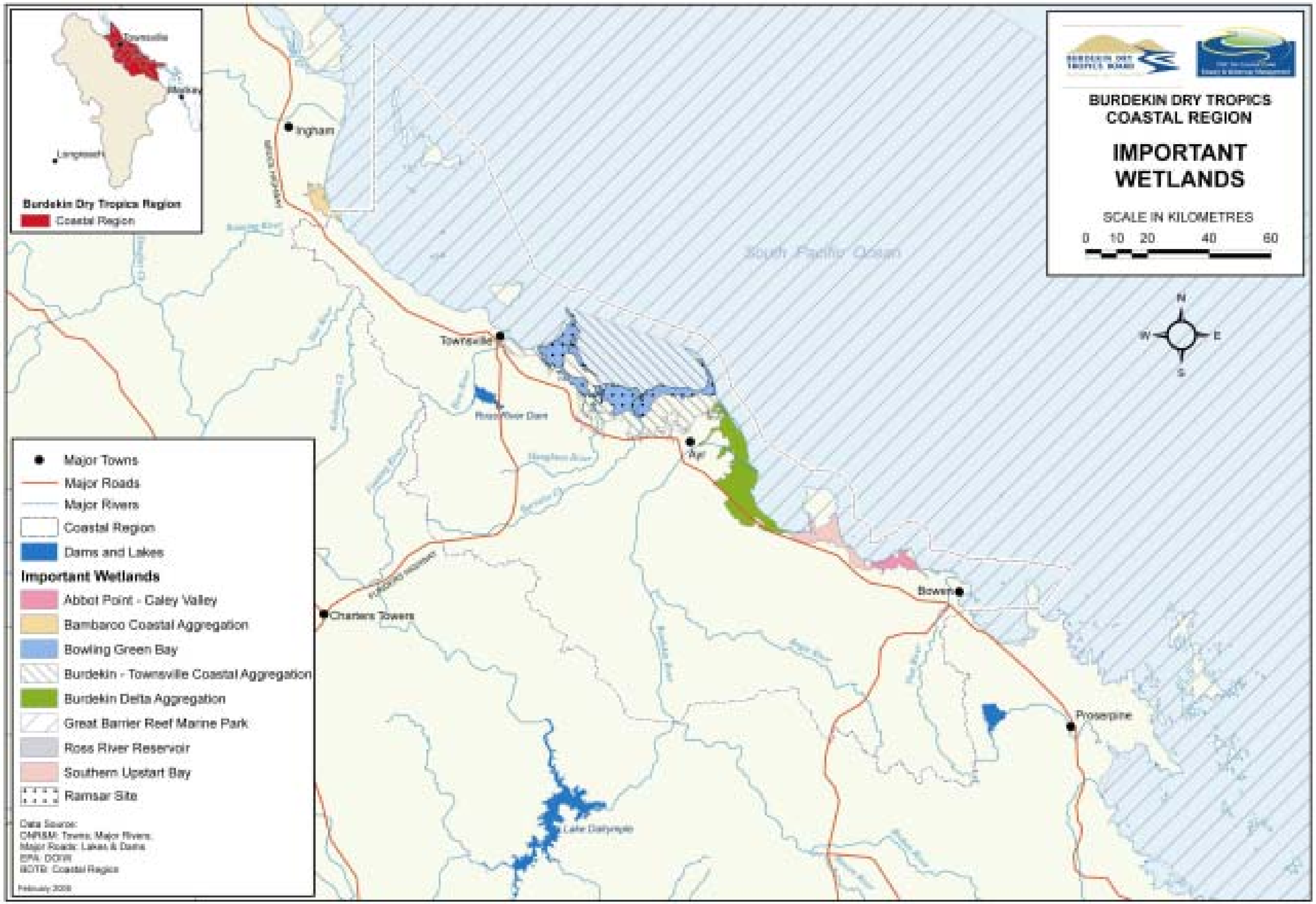
Map 6. Remnant vegetation biodiversity status.



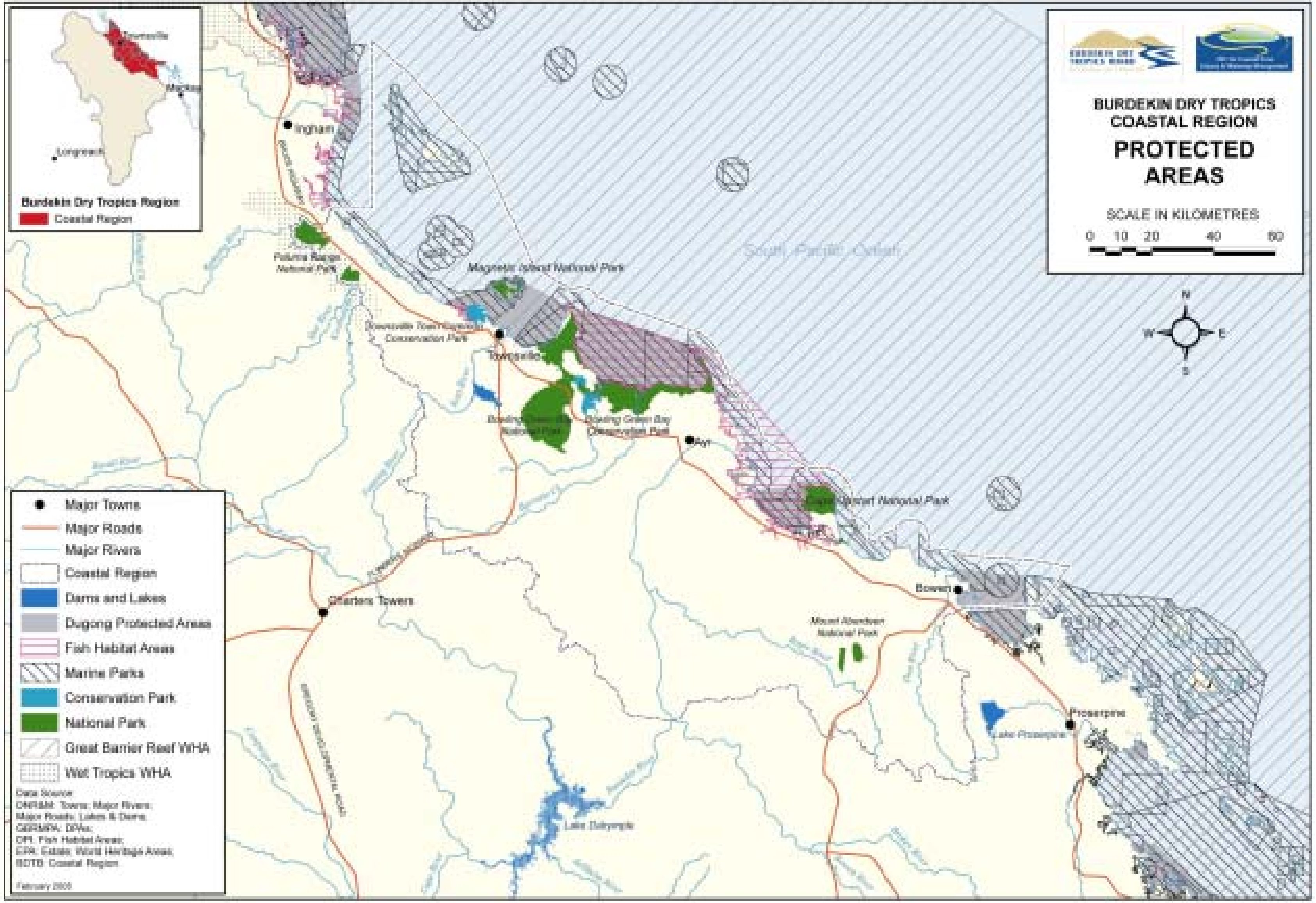
Map 7. Vegetation classes.



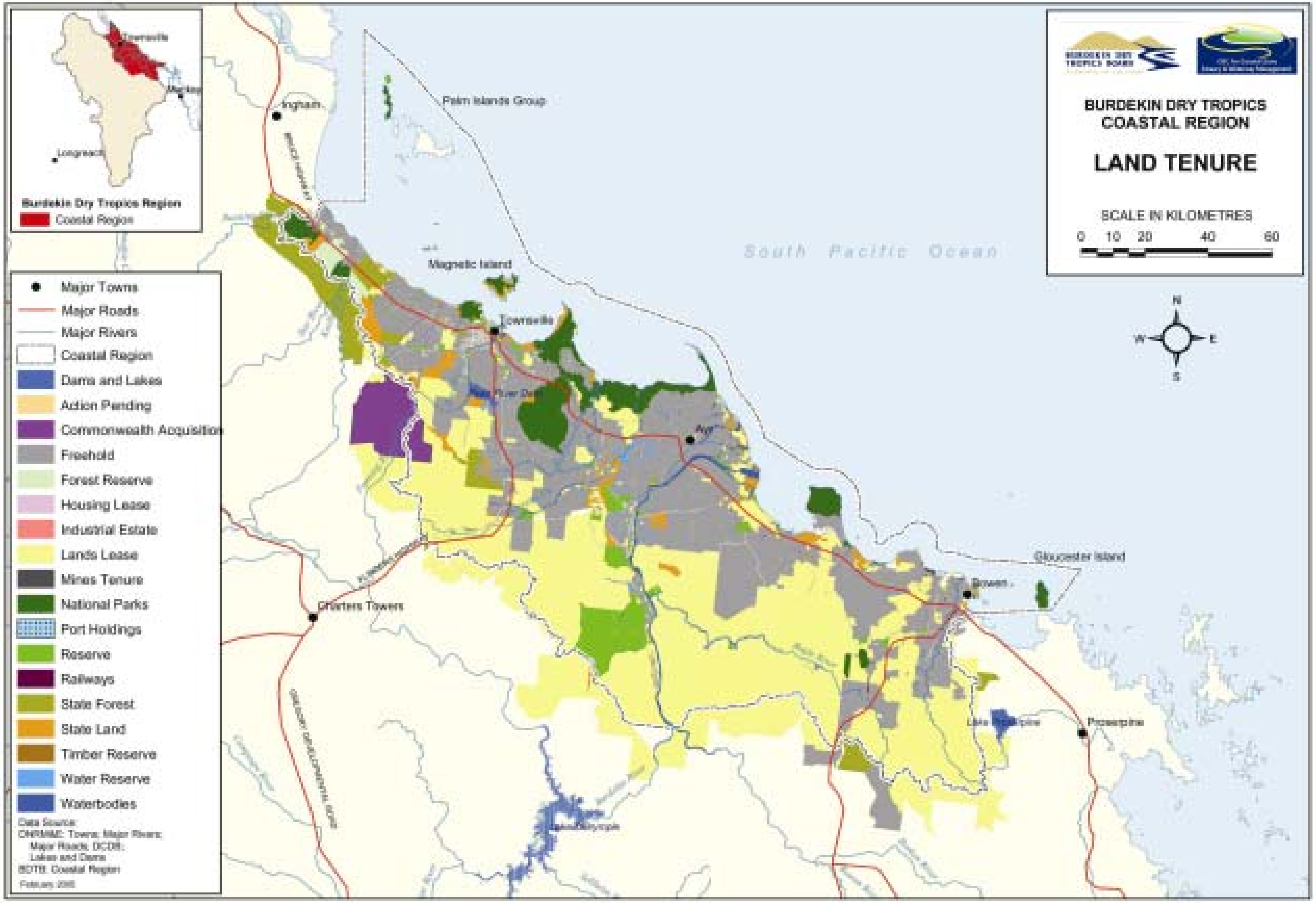
Map 8. Areas of State significance.



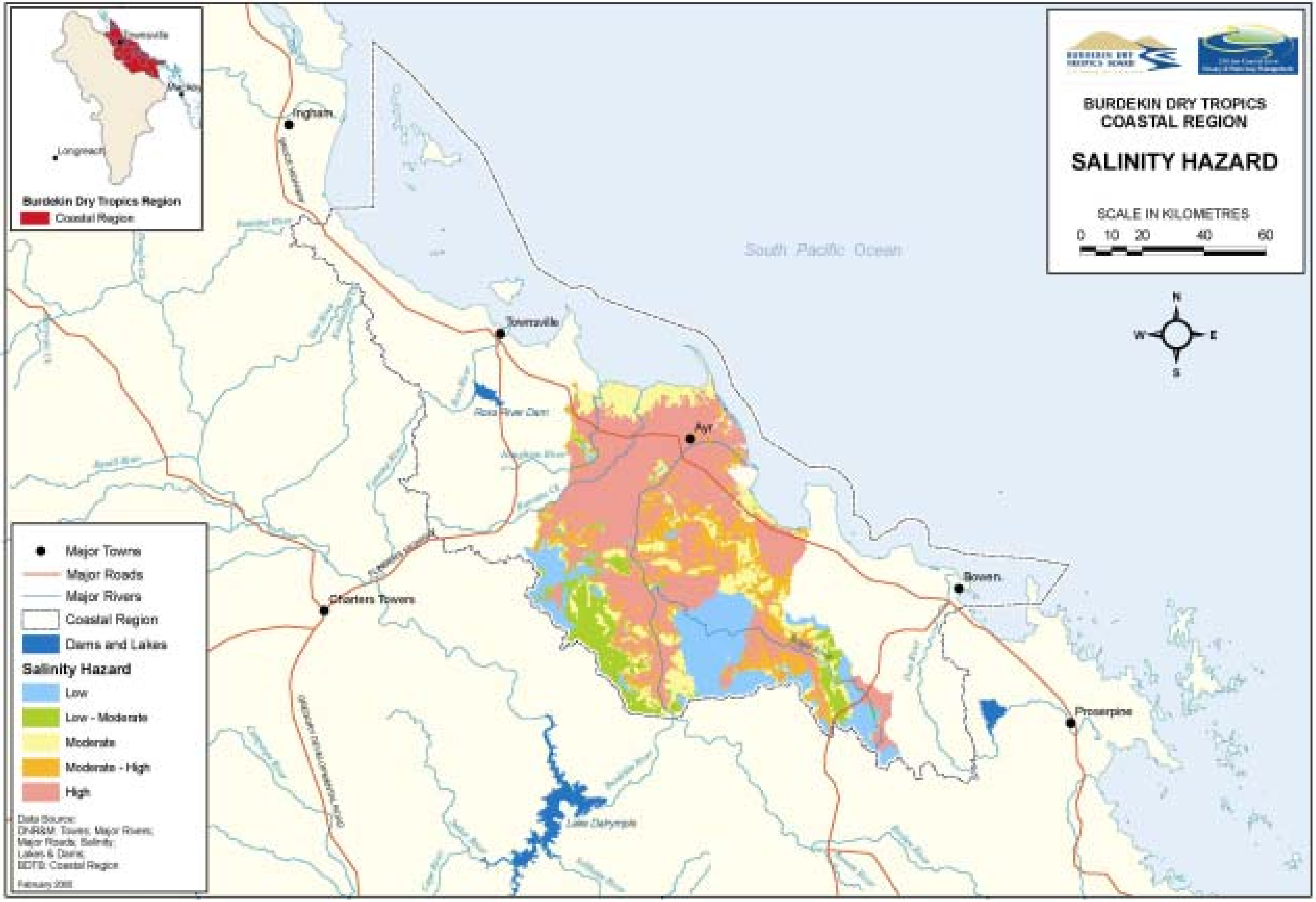
Map 9. Wetlands in the Directory of Important Wetlands and Ramsar site.



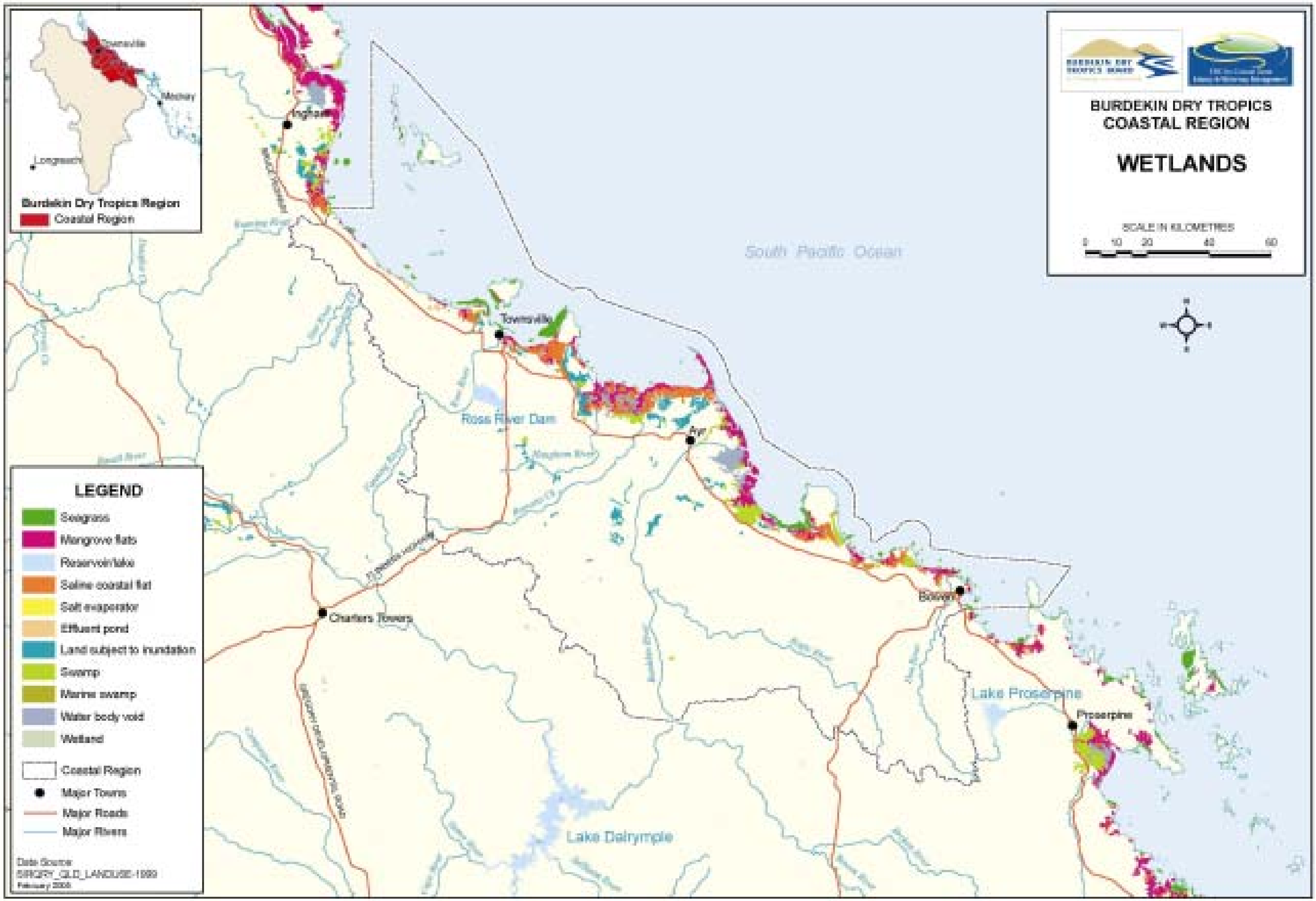
Map 10. Protected areas.



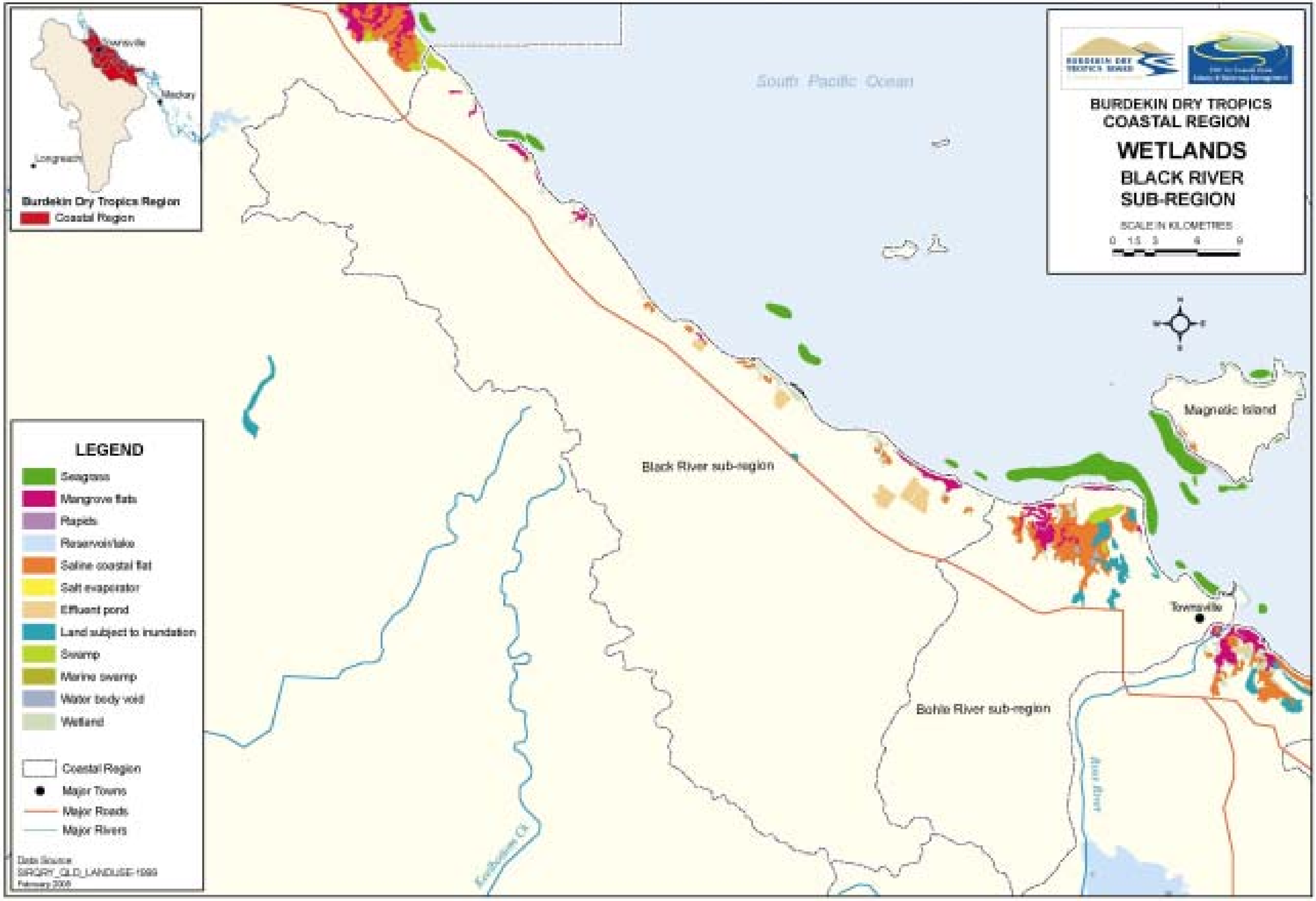
Map 11. Land tenure.



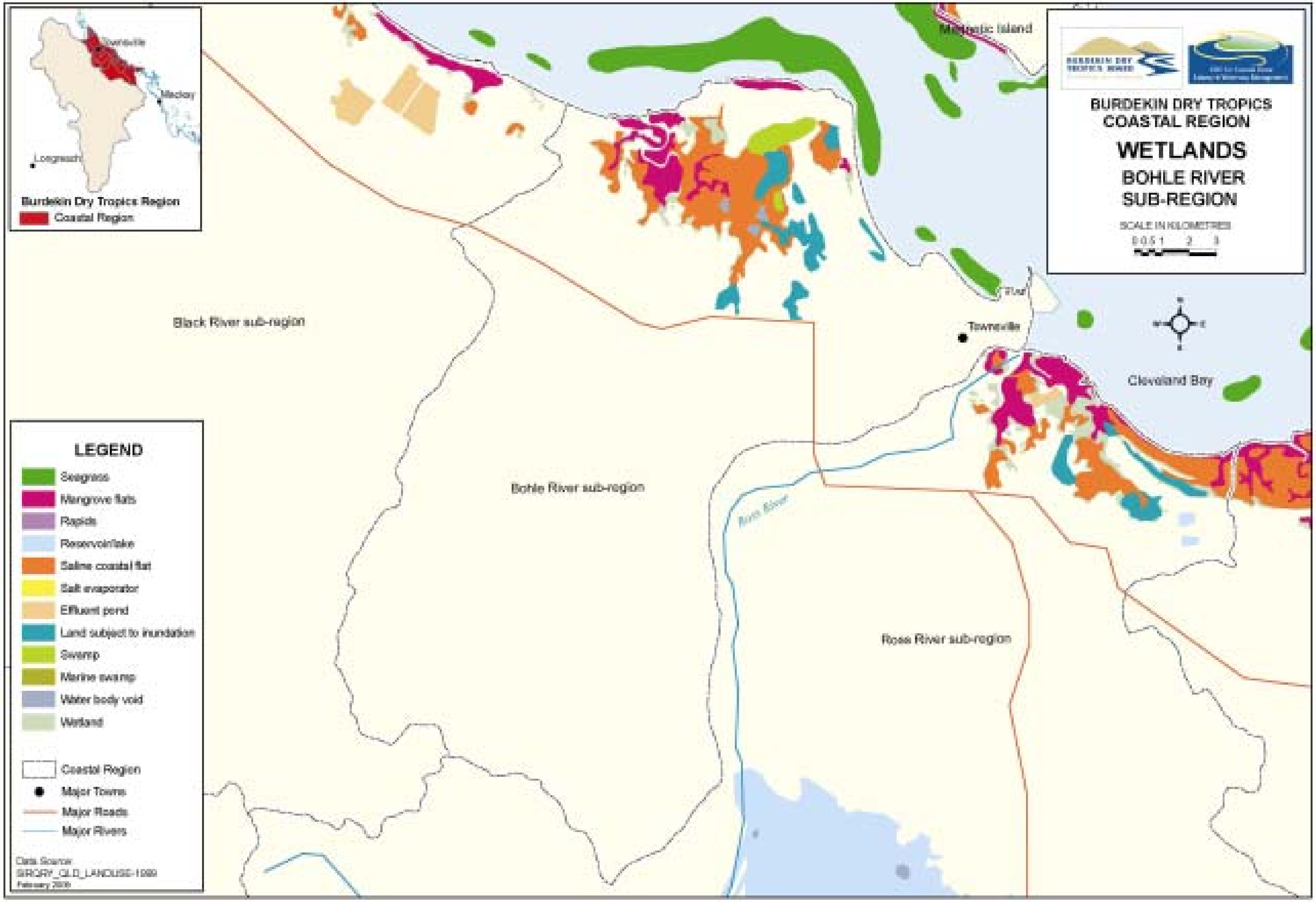
Map 12. Salinity hazard.



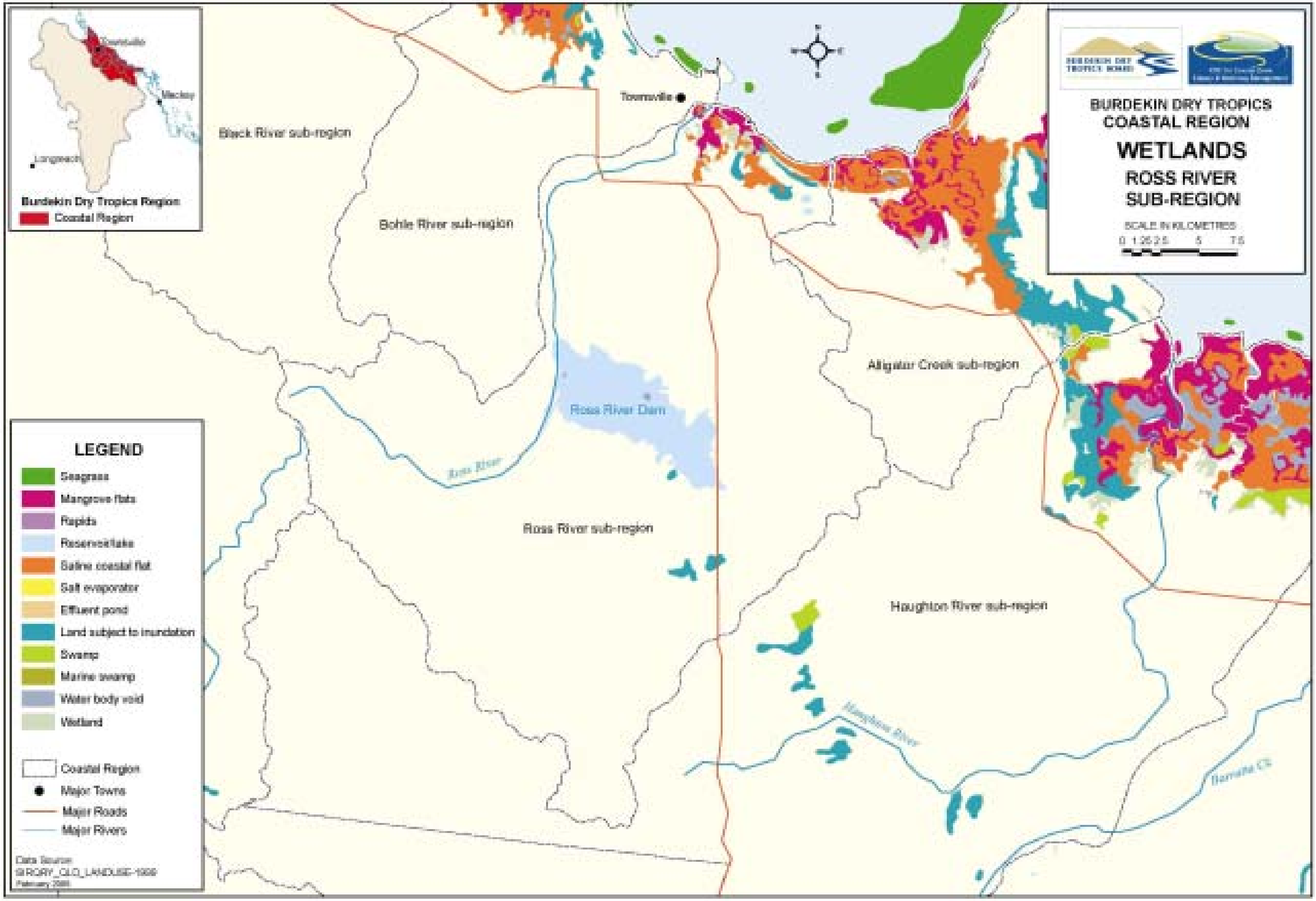
Map 13. Wetlands habitats – coastal region overview.



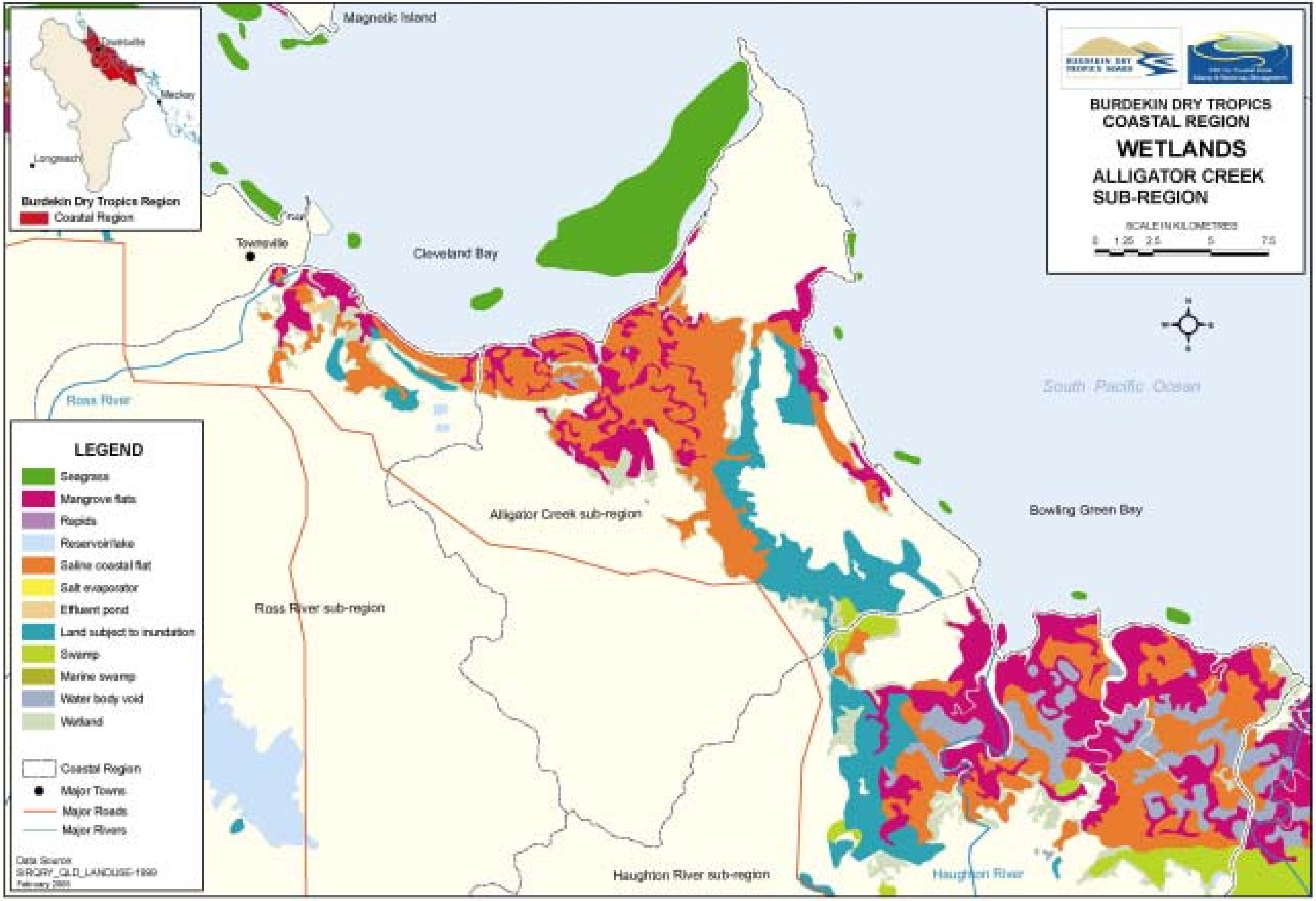
Map 14. Wetlands habitats – Black River sub-region.



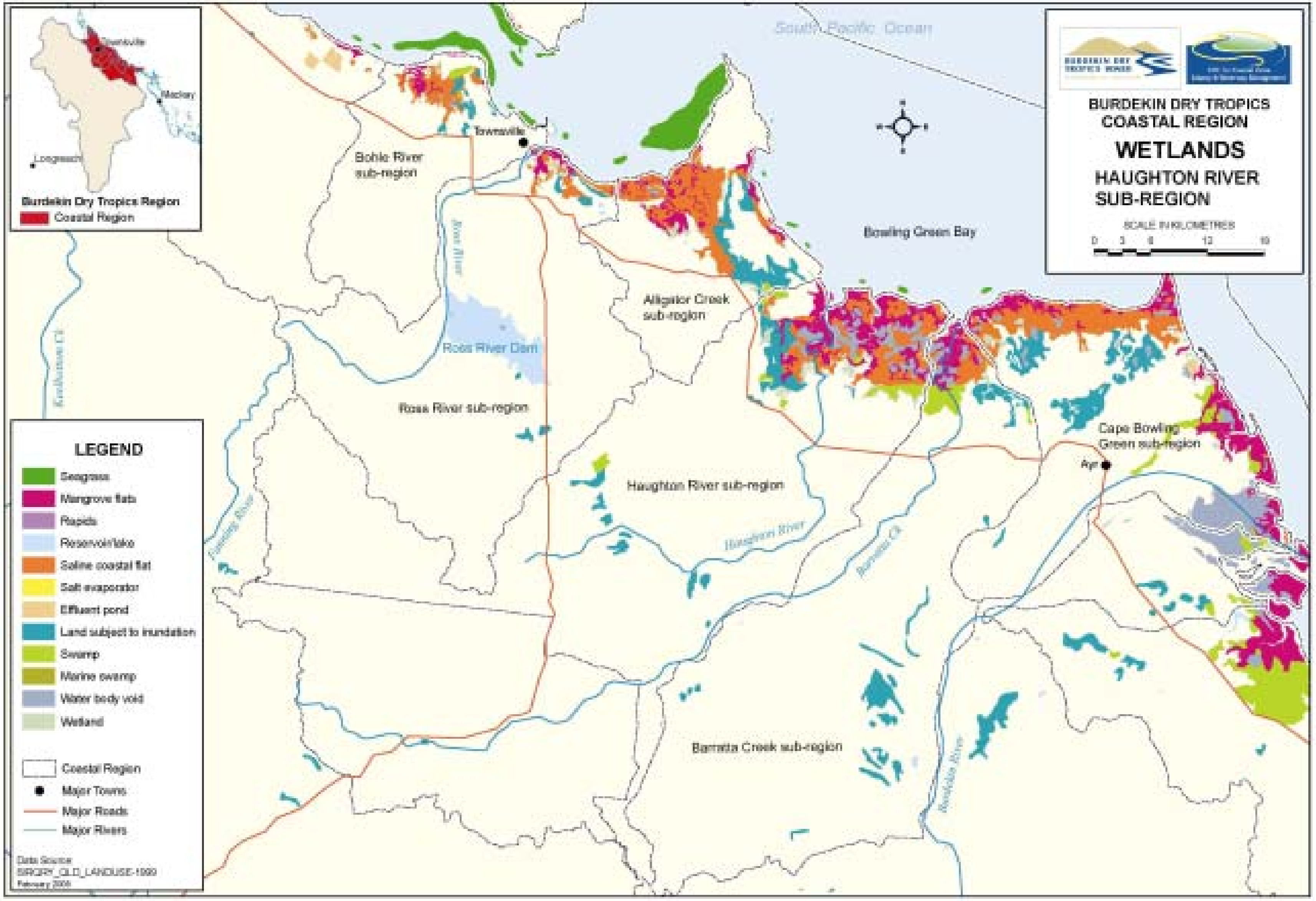
Map 15. Wetlands habitats – Bohle River sub-region.



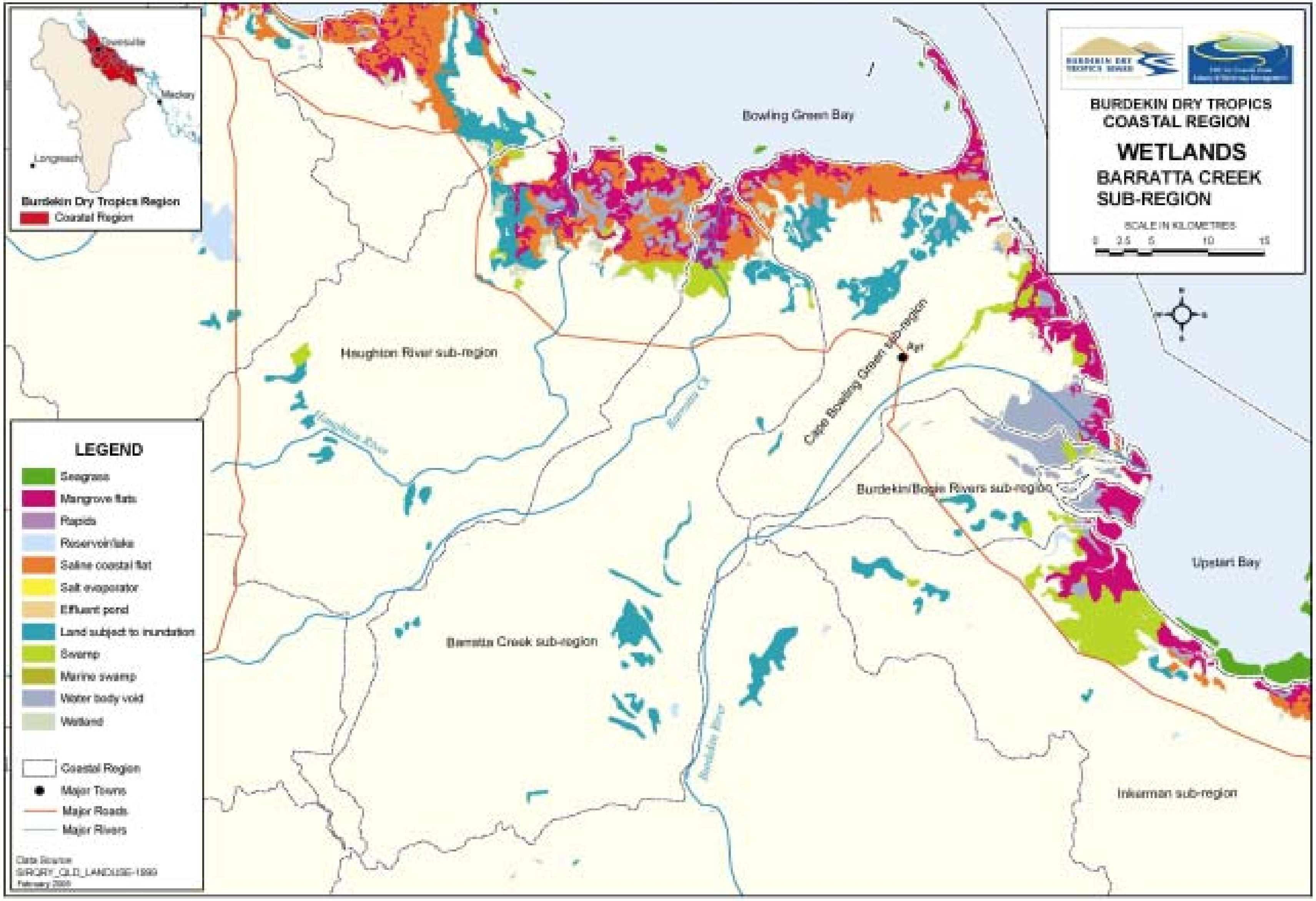
Map 16. Wetlands habitats – Ross River sub-region.



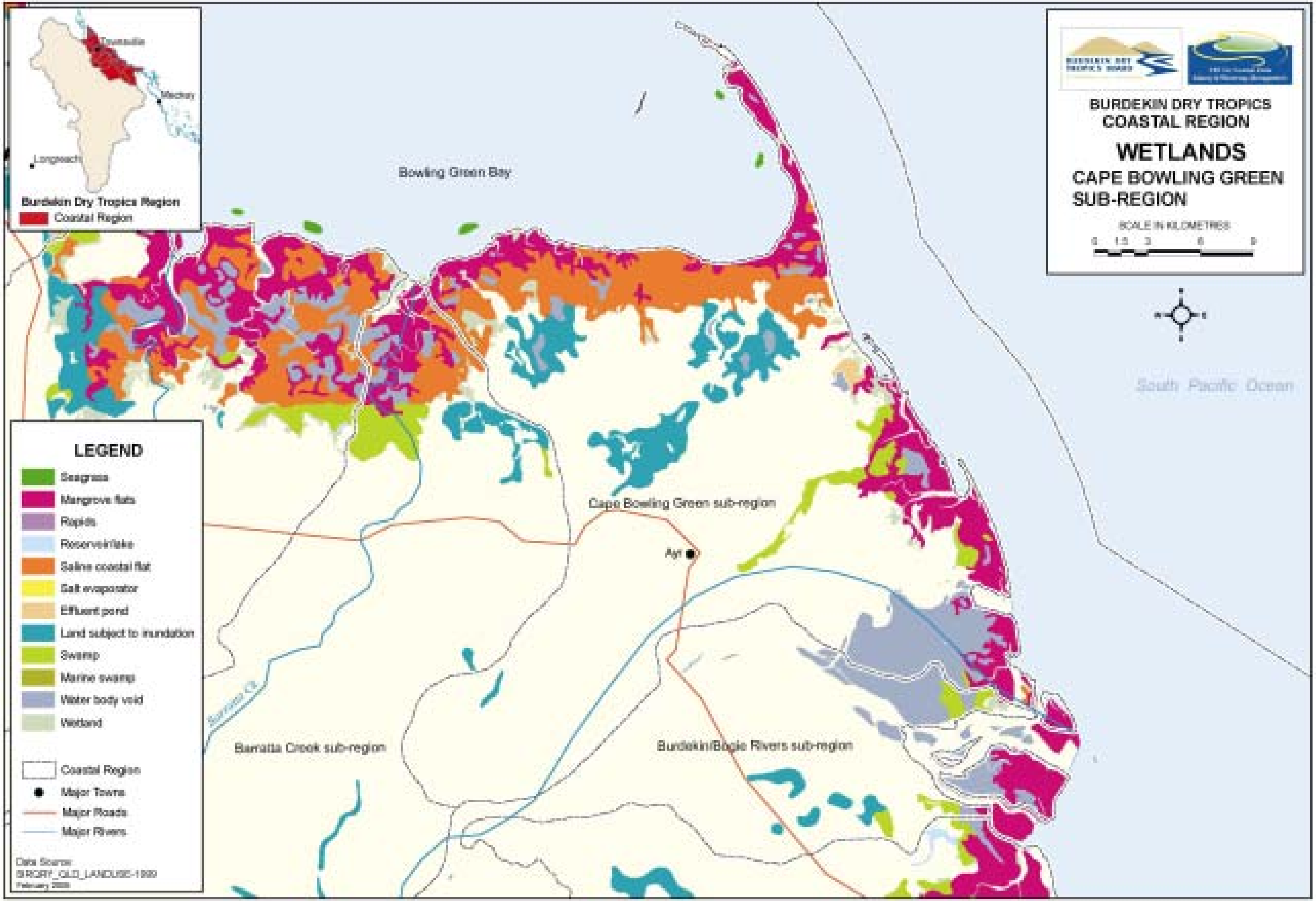
Map 17. Wetlands habitats – Alligator Creek sub-region.



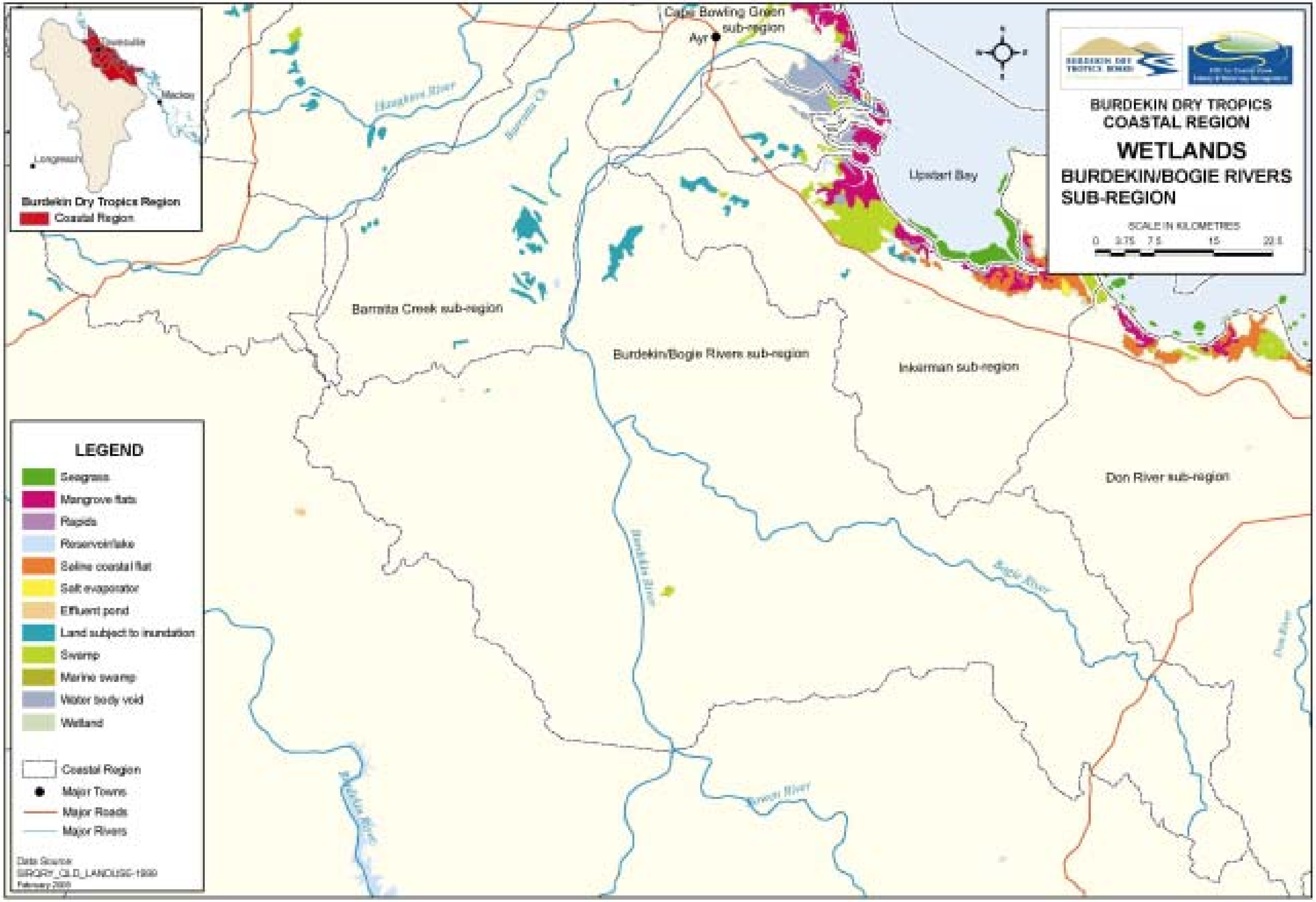
Map 18. Wetlands habitats – Haughton River sub-region.



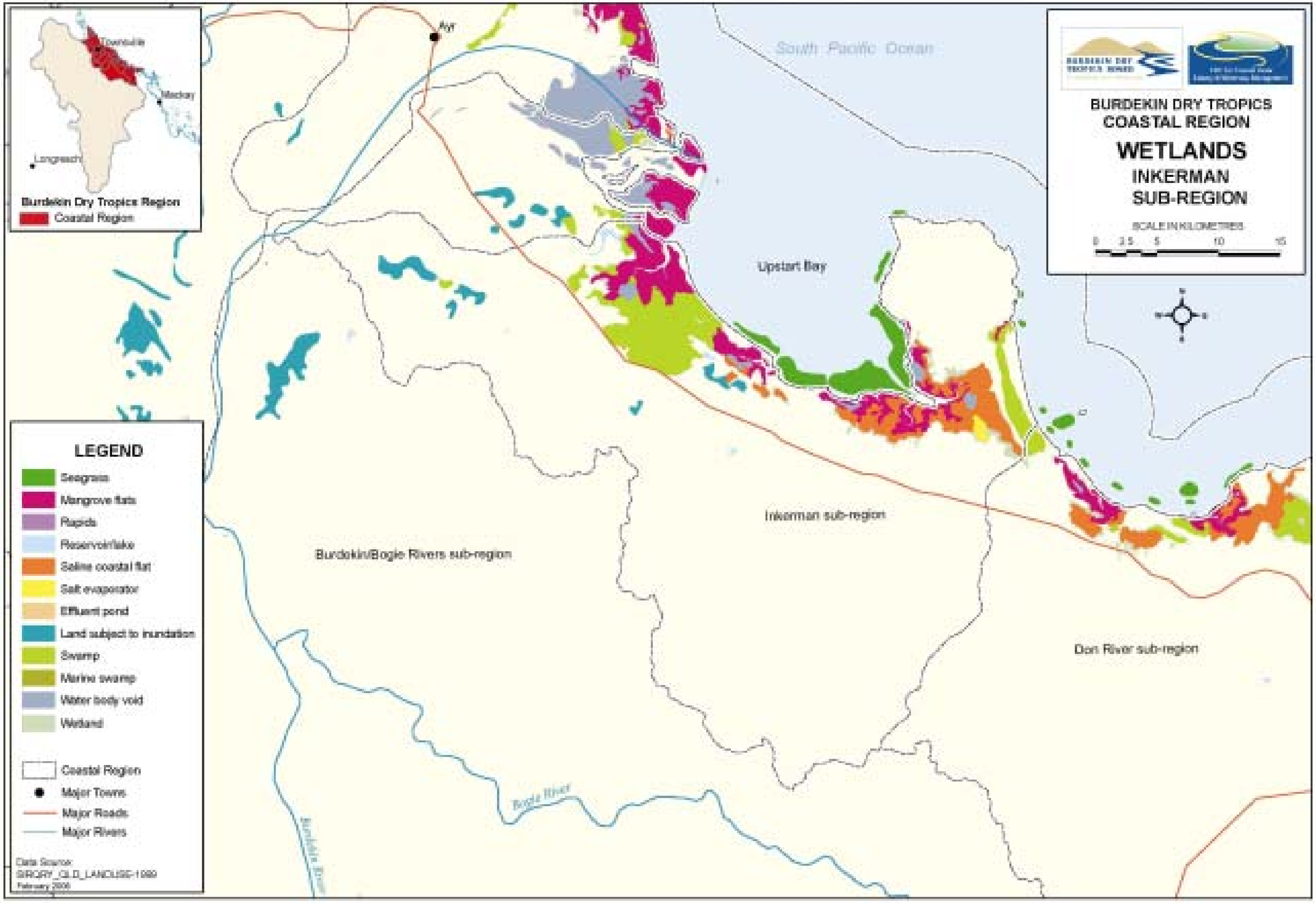
Map 19. Wetlands habitats – Barratta Creek sub-region.



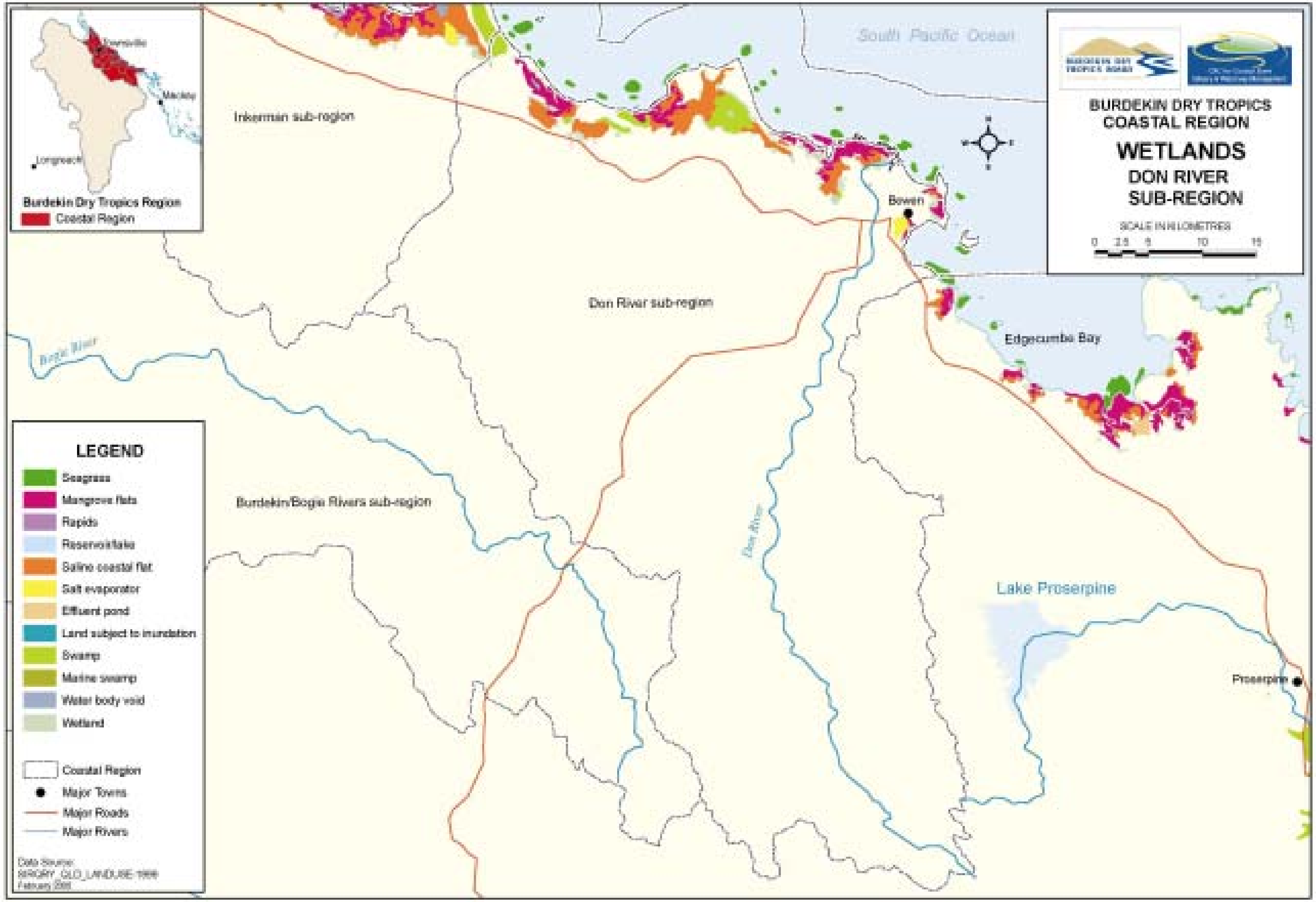
Map 20. Wetlands habitats – Cape Bowling Green sub-region.



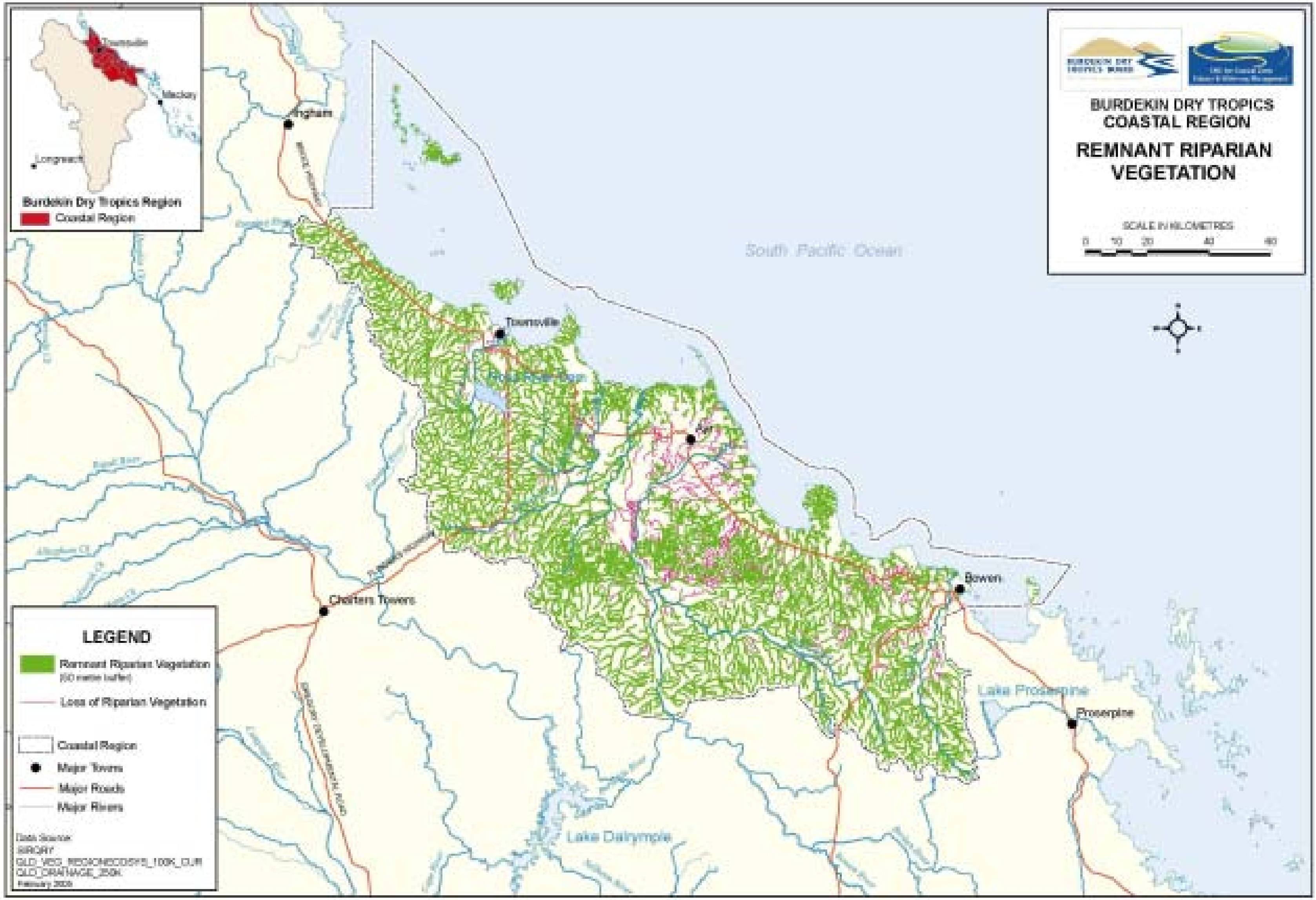
Map 21. Wetlands habitats – Burdekin/Bogie Rivers sub-region.



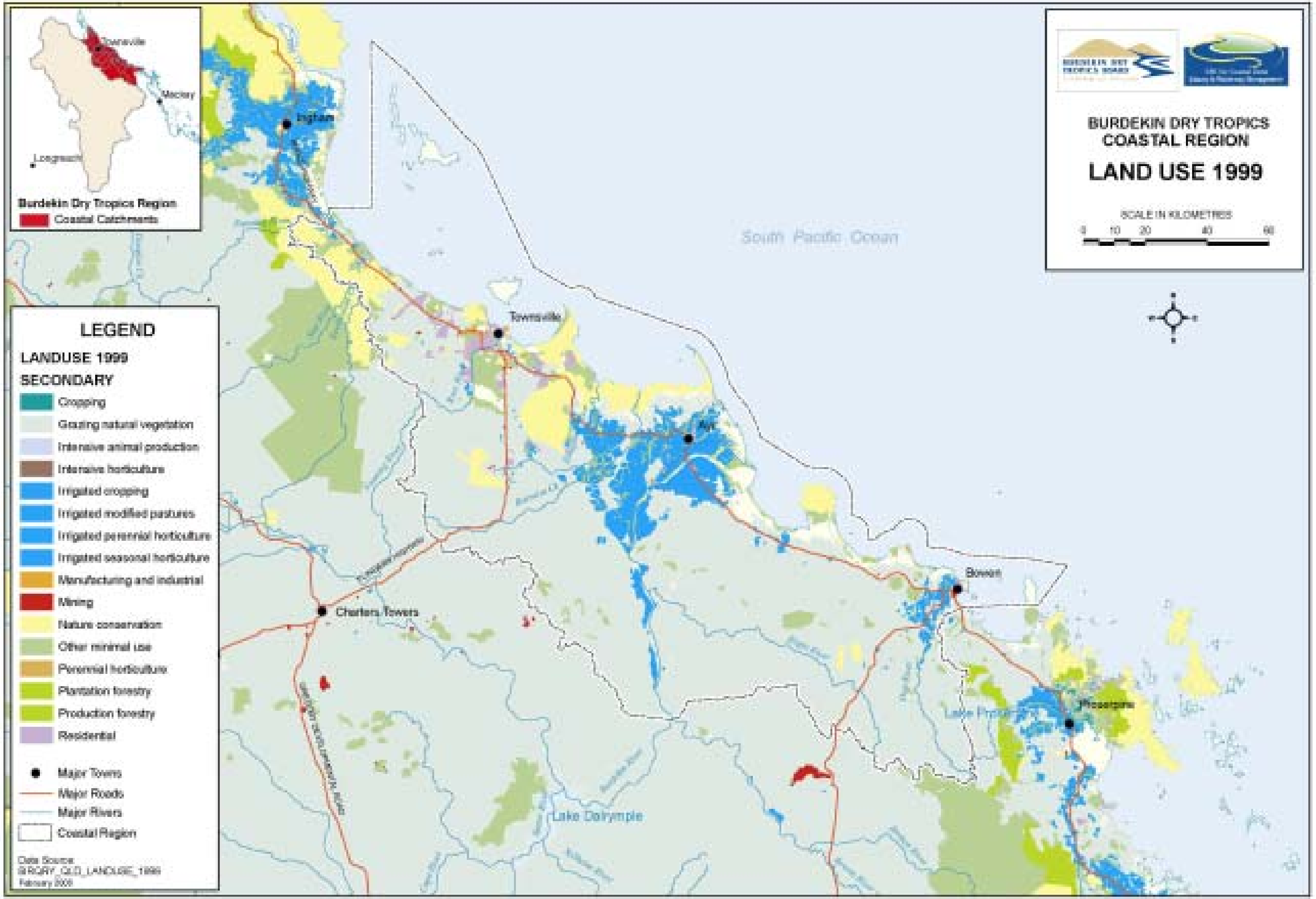
Map 22. Wetlands habitats – Inkerman sub-region.



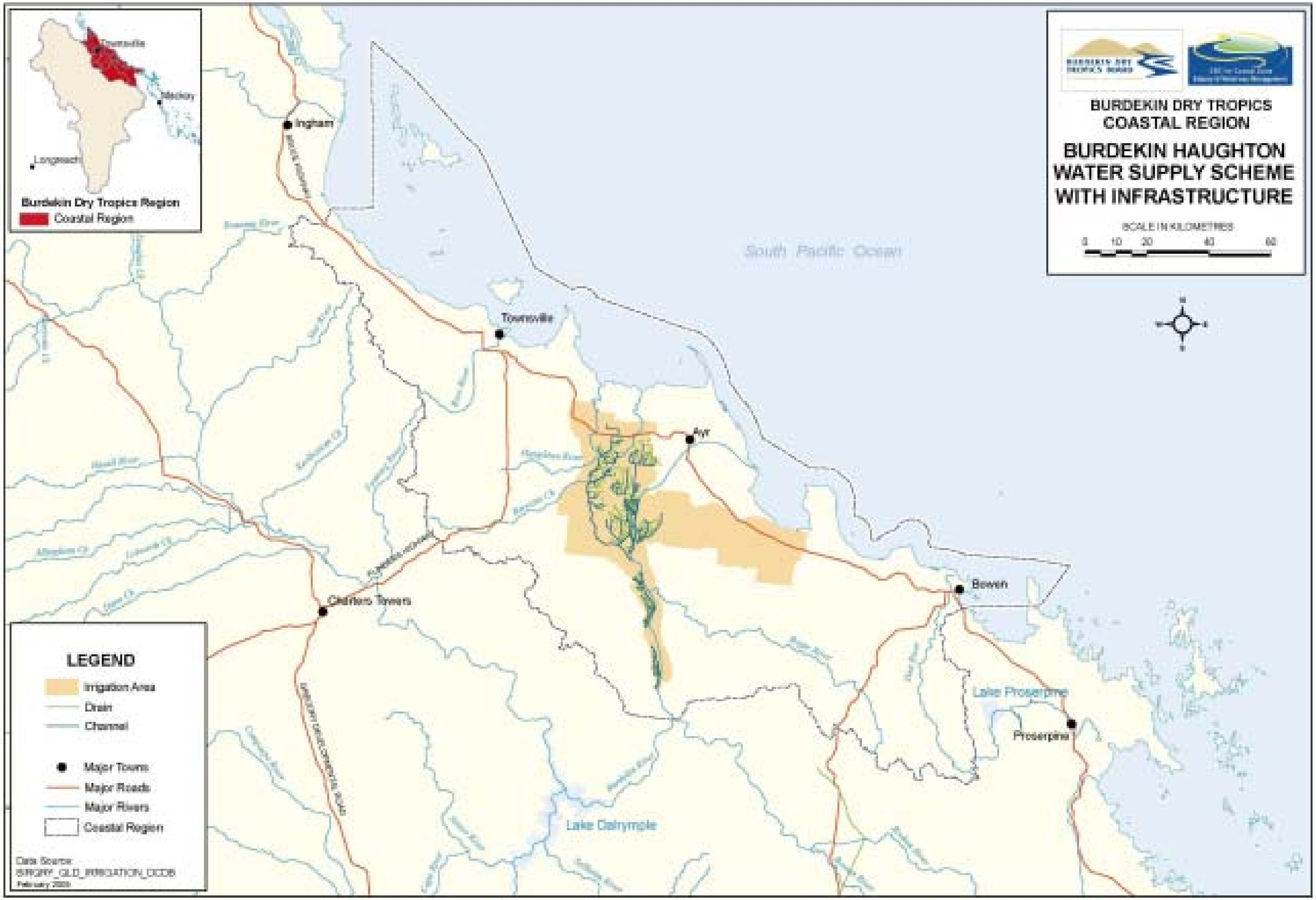
Map 23. Wetlands habitats – Don River sub-region.



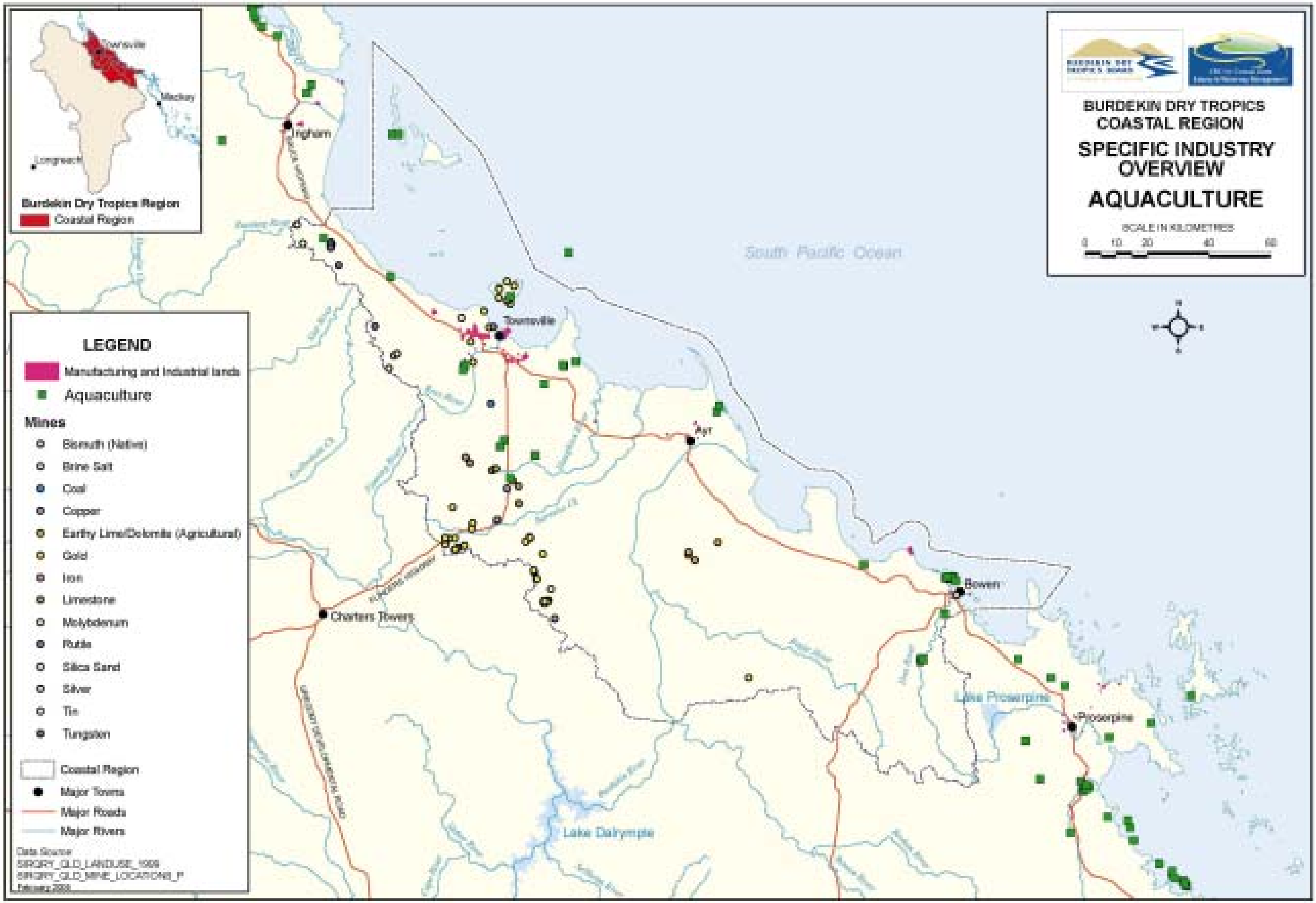
Map 24. Remnant riparian vegetation.



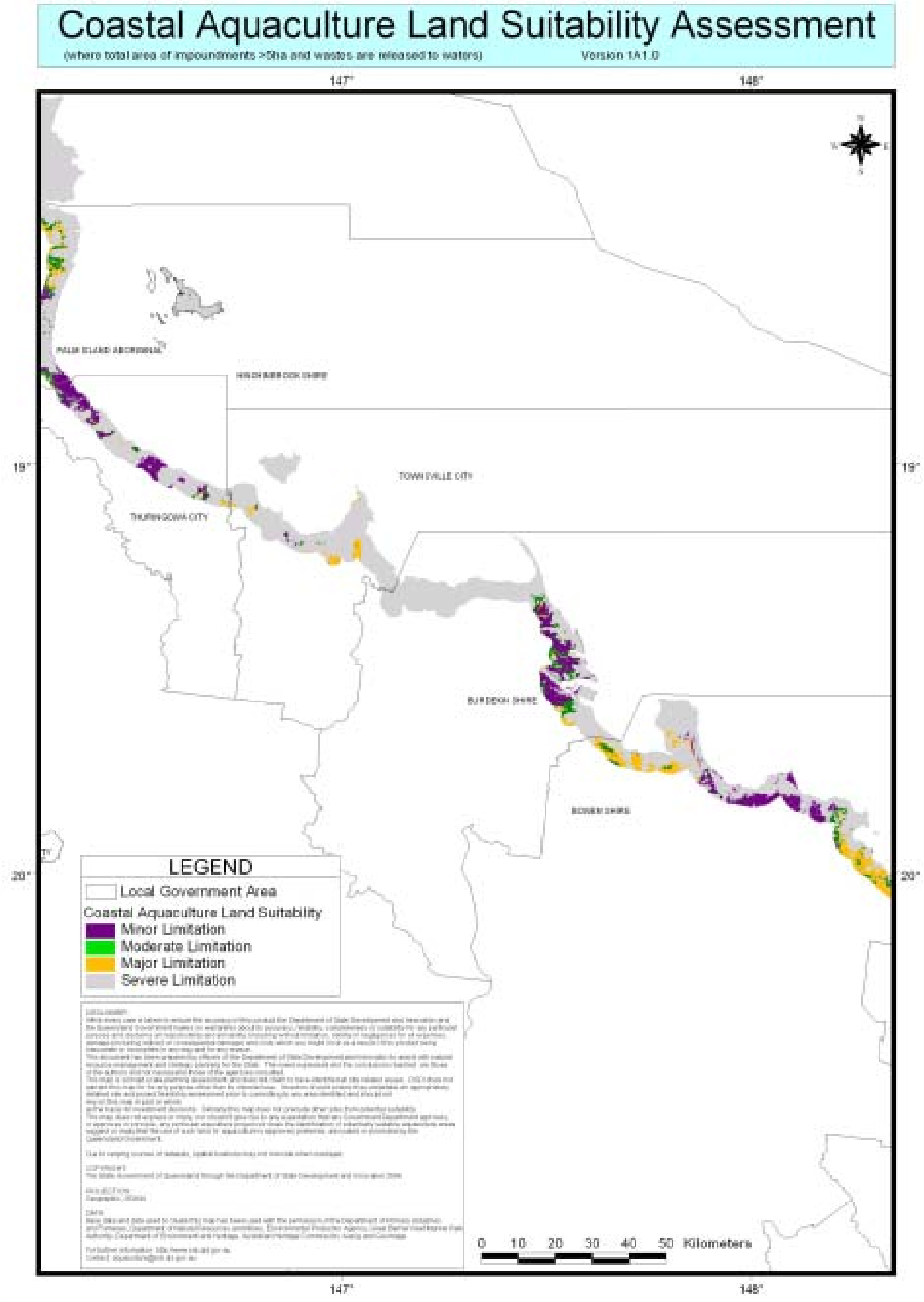
Map 25. Land-use.



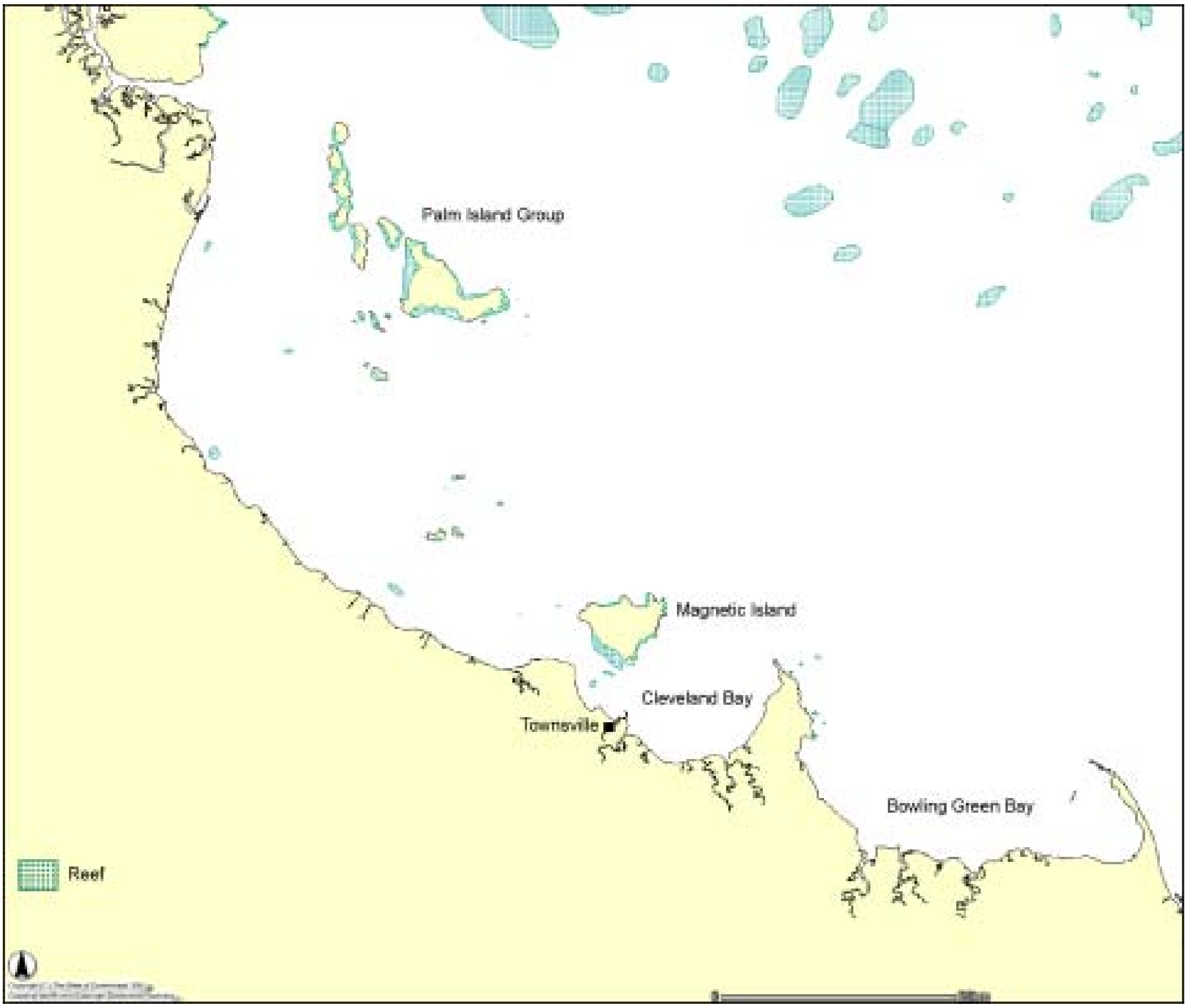
Map 26. Burdekin Haughton Water Supply Scheme (Burdekin River Irrigation Area).



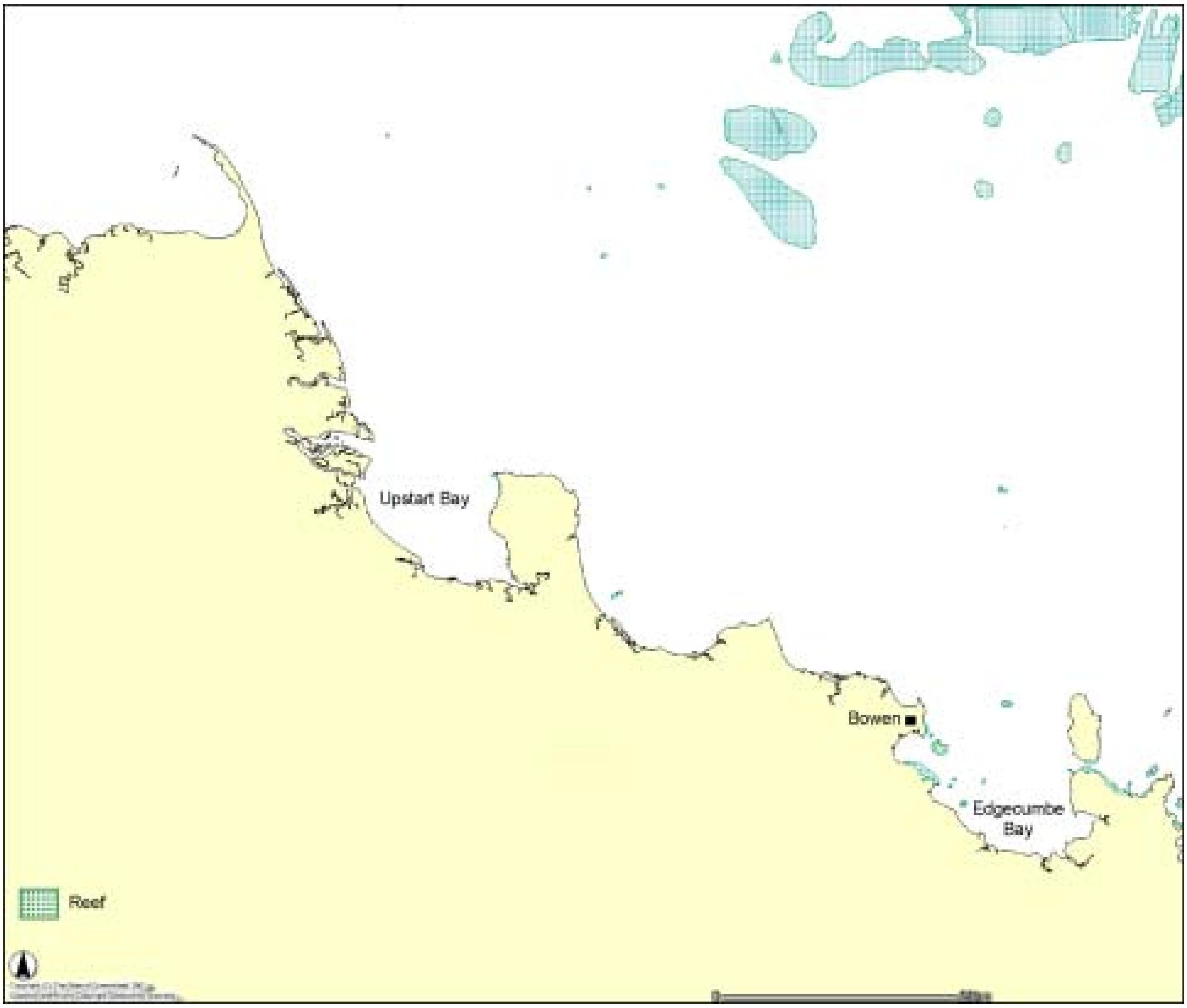
Map 27. Industry overview.



Map 28. Aquaculture land suitability.



Map 29. Northern Reefs.



Map 30. Southern Reefs.