Photo: Jim Tait

Australian Government

Great Barrier Reef
Marine Park Authority

Fitzroy Basin Assessment

Fitzroy Basin Association Natural Regional Management Region

Assessment of ecological functions within the Fitzroy basin focusing on understanding and improving the health and resilience of the Great Barrier Reef

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Great Barrier Reef Marine Park Authority
Department of Sustainability, Environment, Water, Population and Communities

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Great Barrier Reef Marine Park Authority
2-68 Flinders Street (PO Box 1379)
Townsville QLD 4810, Australia

Phone: (07) 4750 0700
Fax: (07) 4772 6093
Email: info@gbrmpa.gov.au

www.gbrmpa.gov.au

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EXECUTIVE SUMMARY

Context

A healthy and resilient Great Barrier Reef World Heritage Area (the World Heritage Area) is reliant upon the ecological integrity of the adjacent Great Barrier Reef catchment and its coastal ecosystems.

The Fitzroy basin provides habitat for many important marine, estuarine, freshwater and terrestrial species with lifecycles that have connections to the World Heritage Area. The coastal ecosystems in the basin also provide a range of ecological functions that support the health and resilience of the marine environment.

Within the marine environment, coastal waters provide high value marine areas including around islands and inshore coral reefs. To protect representations of these areas, there are many coastal and inshore Marine National Park Zones adjacent to this basin.

This Report is part of a series of similar reports investigating the nature, condition, connectivity and management of coastal ecosystems within basins that form the catchment of the World Heritage Area. The purpose of this Report on the Fitzroy basin is to:

- Review coastal ecosystems in the basin, assess their state and consider the pressures that they are facing now, and into the future.
- Understand the connections between coastal ecosystems and the World Heritage Area, and how changes to these connections are impacting on the ecological functions they provide to the Marine Park.
- Empower communities and stakeholders by providing information that can support on-ground actions.

Maps shown in this basin assessment were derived from a range of data sources, and should only be used as a guide.

The Fitzroy basin

The Fitzroy basin is a large, diverse and productive area stretching from the 'range to reef' and contributes several billion dollars annually to the Australian economy.[1] The basin estuaries make up 7.7 per cent of the extent of estuaries in the Great Barrier Reef catchment. The estuary supports a variety of commercial fisheries and recreational fishing.[1]This amounts to an estimated $4.6 million worth of annual recreational and commercial fisheries catch[*].

The Fitzroy basin has undergone significant changes over the past few decades, including changes in the way water and land resources are being used[1], with many coastal ecosystems modified or removed. However, the Fitzroy Basin Association, Fitzroy River and

[*] This figure was derived from the annual catch in the Great Barrier Reef of fish and invertebrate species that use estuaries for part or all of their life histories. This amounted to approximately $20,000 per square kilometre of estuary (assuring all estuaries are equally productive and using Gross Value of Production figures from the east coast inshore finfish fishery, mud crab fishery and other trawl fishery).[2]

Coastal Catchments, and landholders are working together to improve management with the aim to minimise disturbance[1] which will improve water quality and ultimately the health of the World Heritage Area.

Key issues

The Fitzroy basin contains a diverse range of floodplain habitats, near pristine estuarine systems, sandstone tablelands regions, coastal headlands, Brigalow scrub, and rainforested ranges.[3] Much of the rainforest, forest, woodland, forested floodplain, and grass and sedgeland of the Fitzroy basin has been heavily modified or removed over the last century. This has resulted in impacts to inshore marine areas from increases in sediment, nutrient and contaminant loads that are transported from the Fitzroy River.

Land use is dominated by grazing, with smaller areas of cropping and a number of irrigation areas.[4] Irrigated cropping has expanded following the construction of several large reservoirs.[1] Land use impacts include changes in hydrology, declining water quality, removal of riparian vegetation, and the installation of fish barriers.[3] These changes are difficult to reverse and will require adaptive and innovative management to return ecological function and services to the World Heritage Area.

Many of the streams in the Fitzroy basin have been extensively modified, due to agricultural activity.[3] These changes have resulted in modifications to the natural hydrology (quality and quantity of water, alterations to the topology of the basin altering the way water flows) and in-stream ecology which has resulted in declining water quality and loss of ecosystem connectivity. Upstream the agricultural land uses has generated elevated loads of sediment, nutrients and pesticides for the Fitzroy River estuary.

The Fitzroy basin contains numerous freshwater wetlands, floodplains and lagoon systems that are fertile nursery areas for fish species such as barramundi. Wetlands have suffered degradation with only a few of these systems remaining in good condition.[3] The construction of the Fitzroy Barrage has shortened the length of the Fitzroy estuary resulting in loss of habitat and changing its natural hydrodynamic characteristics. Barrages on the Fitzroy estuary have modified the natural tidal freshwater exchange, limiting access for species requiring fresh and saltwater connections under normal weather conditions. Recent reoccurring flood events in this basin have seen improved fish connection resulting in greater number of species migrating further up the basin (B Sawynok (InfoFish Services) 2013, pers. Comm., 16 May).

Potential management actions

This report has been developed as a baseline for the Fitzroy basin. In order to ensure that the basin is best represented, consideration of additional finer scale data, local knowledge and information will further enhance this assessment.

Ensuring the long-term health of the Reef requires greater protection and restoration of important ecological processes and functions provided by Fitzroy basin coastal ecosystems. Actions that would increase protection and restore processes and function include:

1. The inclusion of rehabilitation plans into the life of a mining project and audited by management agencies to ensure compliance.
2. Greater protection, restoration and management of remnant and riparian vegetation to reduce bank erosion and to filter nutrients and sediments.
3. Greater protection, restoration and management of wetlands and their floodplains that recycle and trap nutrients and sediments and provide important nursery areas for fish species.
4. Restore connectivity of streams, rivers and waterways to promote hydrological connectivity and improve fish passage.
5. Manage modified coastal ecosystems to provide ecological functions and values that support the health of the World Heritage Area through the continued improvement in land management practices (grazing, dryland and irrigated production).
6. Encourage strategic vegetation management, including planting of climate change adapted species and plants designed to address the modified landscape (e.g. deep rooted trees planted on floodplain to assist in managing rising groundwater and salinity).
7. Plan and manage new land use to have no net impact on the World Heritage Area.

INTRODUCTION

Background

The Great Barrier Reef Marine Park (Marine Park) covers an area of approximately 348,000 km^2 and extends from Cape York in the north to Bundaberg in the south. The Great Barrier Reef World Heritage Area was accepted in 1981 for inclusion in the World Heritage List, meeting all four of the natural heritage criteria (aesthetics and natural phenomena; geological processes and significant geomorphic features representing major stages of earth's history; ecological and biological processes; and habitats for the conservation of biological diversity, including threatened species). The World Heritage Area includes additional areas outside of the Marine Park. The World Heritage Area extends from the low water mark on the Queensland coast to up to 250 km offshore past the edge of the continental shelf and includes coastal and island ecosystems, as well as some port and tidal areas, outside of the Marine Park.

The adjacent Great Barrier Reef catchment encompasses an area of 424,000 km^2 with all water flowing from the catchment into the World Heritage Area. The catchment contains a diverse range of terrestrial, freshwater and estuarine ecosystems. These coastal ecosystems include rainforests, forests, woodlands, forested floodplains, freshwater wetlands, heath and shrublands, grass and sedgelands, and estuaries.

Coastal ecosystems support the health and resilience of the World Heritage Area. The ecological functions provided by coastal ecosystems include physical processes (such as sediment and water distribution and cycling), biogeochemical processes (such as nutrient and chemical cycling) and biological processes (such as habitat and food provisioning).

This Report assesses the Fitzroy basin's current land use, remaining extent and pressures on coastal ecosystems, and how this basin supports and maintains the health and resilience of the World Heritage Area.

Purpose

The purpose of a basin assessment is to assess at the landscape scale the ecological functions, the risks to these functions and the cumulative impacts that are affecting the long-term health of the World Heritage Area. The focus area for this Report is the Fitzroy basin, which includes ecosystems extending from the inshore areas of the Marine Park to the upper extent of the Fitzroy basin. The information collected, collated and analysed provides a rapid summary of the state of the basin's ecological assets and highlights pressures and threats, ecological condition and the social response to threats and pressures that are influencing the health of the World Heritage Area. More influencing factors – and consequently more pressures – are at work at finer scales of analysis and should be considered when planning or managing these areas.

The Great Barrier Reef catchment is made up of 35 basins draining directly into the World Heritage Area, as shown in Table 1.

Table 1: Basins in the Great Barrier Reef catchment

Great Barrier Reef catchment	NRM regions	Basins	Coastal zone as defined by Queensland State Coastal Management Plan 2011
	Cape York NRM region (managed by Cape York NRM)	Jacky Jacky	
		Olive-Pascoe	
		Lockhart	
		Stewart	
		Normanby	
		Jeanie	
		Endeavour	
	Wet Tropics NRM region (managed by Terrain)	Daintree	
		Mossman	
		Barron	
		Mulgrave-Russell	
		Johnstone	
		Tully	
		Murray	
		Herbert	
	Burdekin Dry Tropics NRM region (managed by NQ Dry Tropics)	Black	
		Ross	
		Haughton	
		Burdekin	
		Don	
	Mackay Whitsunday NRM region (managed by Reef Catchments)	Proserpine	
		O'Connell	
		Pioneer	
		Plane	
	Fitzroy NRM region (managed by Fitzroy Basin Association)	Styx	
		Shoalwater	
		Waterpark	
		Fitzroy	
		Calliope	
		Boyne	
	Burnett-Mary NRM region (managed by Burnett Mary Regional Group)	Baffle	
		Kolan	
		Burnett	
		Burrum	
		Mary	

Methodology

The methods underpinning this basin assessment are detailed in the Coastal Ecosystems Assessment Framework[5], a tool developed in partnership with the Queensland Government (available at www.gbrmpa.gov.au). The Coastal Ecosystems Assessment Framework was developed and used as the basis of the *Informing the Outlook for Great Barrier Reef coastal ecosystems*[6] report, and provides a holistic approach to assessing and understanding ecological functions provided by coastal ecosystems and the pressures affecting them.

The catchment in its current state is a mosaic of natural and modified ecosystems with a suite of values and functions of importance to the World Heritage Area. The methodology used to understand the values and functions provided by natural and modified coastal ecosystems are outlined in the Coastal Ecosystem Assessment Framework[5] and have been used as a basis to assess the Fitzroy basin assessment. Figure 1 below describes the methodology used to rapidly assess the ecological functions and values to conduct the Fitzroy basin assessment.

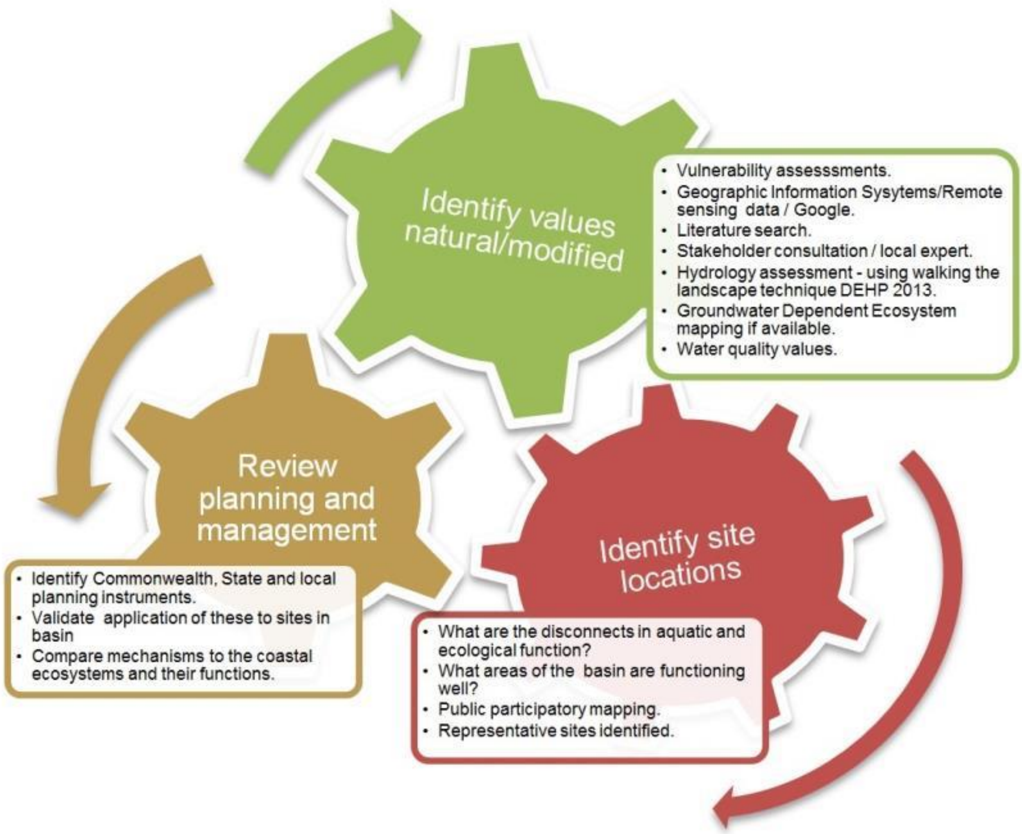

Figure 1: Summary of the methodology for conducting a basin scale assessment

Stakeholder engagement and verification of assessment information has been crucial to the development of this basin assessment. Building on the information collected and collated for the *Informing the Outlook for coastal ecosystems*[6] report, the methodology for preparing this Report incorporated the following steps:

1. Local experts were consulted to identify areas of interest to visit in the field as part of a 'rapid assessment'.
2. Research was conducted on the basin using available information.
3. Sites of interest were identified using coastal ecosystem maps and Google earth (GPS identification for sites to be visited for field work).
4. Collaboration with local stakeholders (i.e. consultants, natural resource management bodies, local land owners) helped to verify the issues affecting the basin, as well as additional field sites.
5. Field investigations were conducted using the field site assessment template forms (Appendix A) to capture site locations and reference photos at basin sites (Figure 2).
6. GPS coordinates from field assessments were imported into Google earth to assist with report preparation.
7. Preliminary basin assessments were compiled to facilitate stakeholder input.
8. Workshops were conducted to bring stakeholders together to present information and incorporate feedback into the basin assessment.
9. Draft basin assessments were prepared as a basis to further stakeholder input.
10. Basin assessments finalised and published.

Due to the size of the Fitzroy basin, the field assessment focused on the lower Fitzroy floodplain, with the expectation that future assessment will be conducted on the remaining upper Fitzroy basin (Figure 2).

Figure 2: Study sites for the Fitzroy basin assessment

PART A: VALUES OF THE GREAT BARRIER REEF REGION – FITZROY BASIN

Chapter 1: Fitzroy basin – background to changes affecting matters of national environmental significance

1.1 Background and history of the Fitzroy basin

The Fitzroy basin is located in central Queensland and includes the major towns of Rockhampton, Emerald, Blackwater, Yeppoon and Biloela. It is the largest basin in Queensland (Figure 1.1.1). The Fitzroy Basin Association is the main community NRM in the basin, supported by a number of sub-catchment groups such as Fitzroy River and Coastal Catchments, and Central Highlands Regional Resource Use Planning cooperative. The Fitzroy basin has an area of approximately 14,261,316 hectares and is the largest river system draining into the World Heritage Area. The region has a sub-tropical, semi-arid climate with variable rainfall, high evaporation rates and prolonged dry periods followed by floods.[1,3] The mean annual rainfall varies from 600 mm in the west, to 800 mm in the east, while peaking at 1000 mm in the northern coastal. There are six major sub-basins in the Fitzroy basin including Nogoa, Comet, Isaac-Connors, Mackenzie, Dawson, and Fitzroy River.

Figure 1.1.1: Map of the Fitzroy basin and its proximity to the Great Barrier Reef catchment and the Great Barrier Reef Marine Park

The Fitzroy basin has a long history of agriculture and mining (Table 1.1.1). An estimated 60 per cent of the catchment has been cleared mostly for rural development.[7] The Fitzroy basin's alluvial plain provides fertile soil that supports a prosperous farming industry. The dominant land use in the Fitzroy basin today is grazing, followed by dryland production (cotton and grain). Coal mining covers less than one per cent of the Fitzroy basin area, however coal mining is the basin's largest economic asset. In 2007-2008, Queensland coal exports generated $16.5 billion, 85 per cent of which came from the Fitzroy basin.[8]
The hydrology and drainage of the Fitzroy basin has been highly modified with the construction of 29 dams and weirs providing water security for agriculture, mining, industries and urban use.[8] The major pressures to the World Heritage Area from the Fitzroy basin today include declining water quality (nutrients and sediments), removal of riparian vegetation, heavy metals, and fish barriers.
Point sources of pollution occur in the lower Fitzroy basin as the Fitzroy River passes through Rockhampton urban areas and receives treated effluent from three sewage treatment plants. There is also discharge from one abattoir further downstream.[8] Industrial sources of potential poor water quality in the Fitzroy River estuary include the Port Alma Shipping Terminal and the associated commercial shipping activities. Additionally, small settlements are found scattered along the coast.

The long history of development and land use has changed the coastal ecosystems in the Fitzroy basin (Table 1.1.1).

Table 1.1.1: Historical timeline for the Fitzroy basin[8]

Year	Event
1858	Rockhampton declared a municipality.
1867	Railway line to Rockhampton.
1877	Railway from Rockhampton to Blackwater. Branch lines to Springsure Mount Morgan opened in 1880s-90s, Blair Athon and Theadore 1910s-20s.
1879	Mount Orange Copper Smelter erected for the treatment of ore.
1882	Copper, gold and silver mining begins at Mount Morgan (formerly known as Ironside Mountain).
1916	Flash flood washed away Clermont's central business district and claimed at least sixty-five lives. It is still known as Australia's second worst flood it terms of loss of life.
1927	Fire destroys the underground workings of Mount Morgan mine. Workings were deliberately flooded and mine went into liquidation.
1928	Mount Morgan mine re-established using open cut methods.
1951	Rockhampton regional power supply was connected.
1960	Rockhampton district cattle industry expanded providing two-fifths of Queensland's beef cattle.
1960	Coal-fired power station built at Callide mine.
1960	Fitzroy Basin Brigalow land development area extended from Nebo to Taroom and from Rolleston to Moura. Clearing of Brigalow lands to increase grazing areas. The process involved scrub pulling, burning and hormone retardant spraying.
1962	By 1962 Rockhampton area held 1.08 million head of beef cattle, which at the time was 18.4 per cent of Queensland's total. In 1993 the equivalent area had 1.67 million head of cattle.
1970	The Fitzroy Barrage completed to supply the long-term water needs of Rockhampton to separate freshwater from the tidal reaches of the river. It had a capacity of 81,300 megalitres.
1971	Callide Creek Dam completed providing irrigation water and supply for the Callide power station.
1991	Cyclone Joy produced a river peak of 9.3 metres.

Year	Event
1990s-2000s	Increased land clearing in the lead up to the introduction of a moratorium on land clearing with the introduction of the *Vegetation Management Act 1999.*[8]
2000s-Present	Expansion of coal mining, planning for intensive Agricultural Corridor, planning for major new water storages.[8]

Chapter 2: Values and their current condition and trend

The values that are considered in this report include:

- Inshore marine ecosystems that underpin the outstanding universal value of the World Heritage Area (such as coral reefs, seagrasses and associated species).
- Terrestrial, freshwater and estuarine coastal ecosystems that provide ecological functions to the World Heritage Area and other matters of national environmental significance.

A conceptual model of these ecosystems and the functions they provide is shown in Figure 2.1.

The ecosystems examined in this report also provide habitat for a range of other matters of national environmental significance. The matters of national environmental significance in the Fitzroy basin are outlined in Section 2.1 below and the values and their elements that underpin matters of national environmental significance for the Fitzroy basin and adjacent waters are shown in Appendix C.

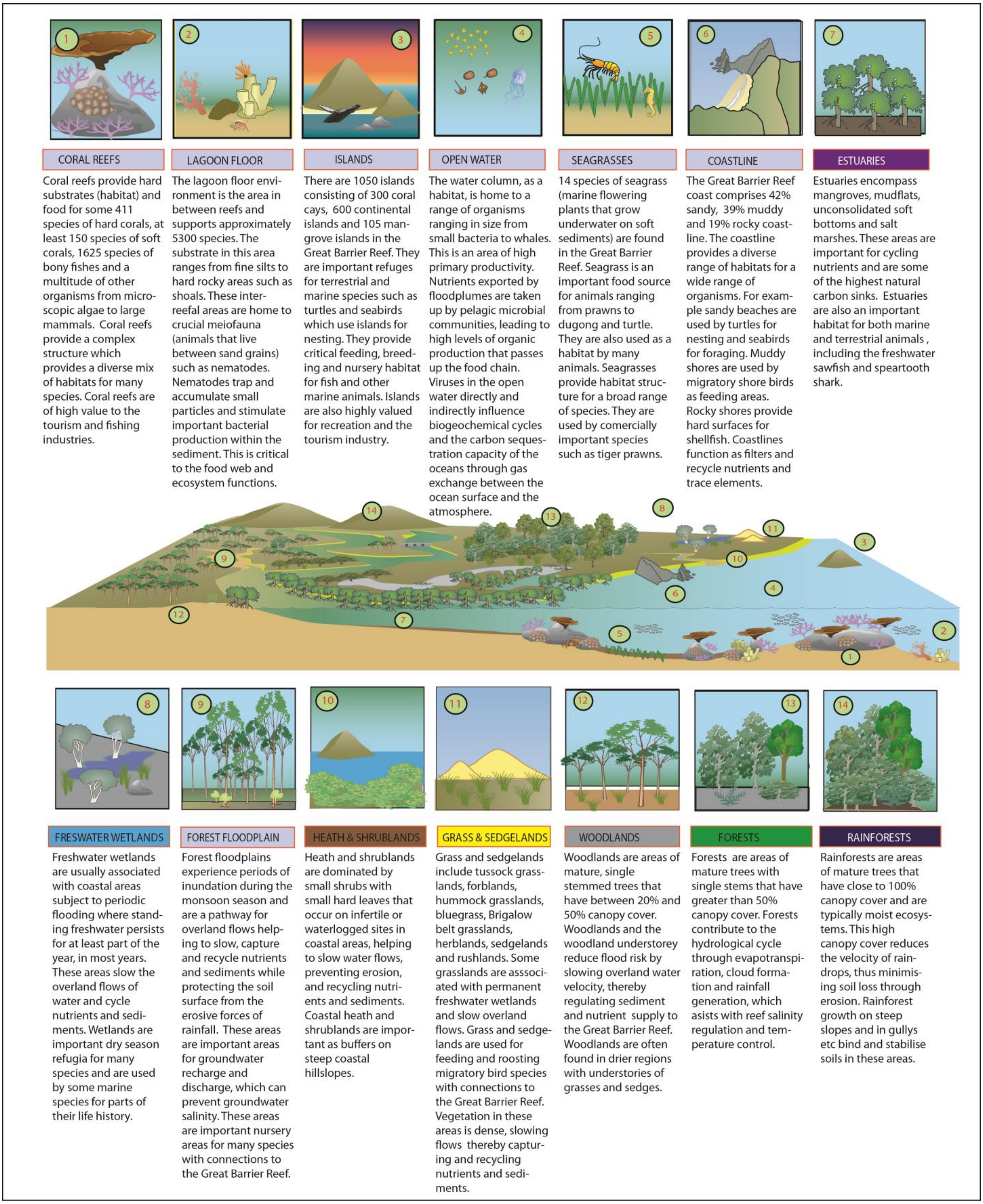

Figure 2.1: Conceptual model for categorizing the Great Barrier Reef coastal, catchment and inshore ecosystems and assessing the ecological functions and services of those ecosystems to the cumulative impacts of development

2.1 Matters of National Environmental Significance in the basin

Under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), actions that have, or are likely to have, a significant impact on a matter of national environmental significance require referral to the Australian Government Environment Minister. The Minister will decide whether assessment and approval may be required under the EPBC Act. There are eight matters of national environmental significance protected under the EPBC Act. These are:

- World heritage properties
- National heritage places
- Wetlands of international importance (listed under the Ramsar Convention)
- Listed threatened species and ecological communities
- Migratory species protected under international agreements
- Commonwealth marine areas
- The Marine Park
- Nuclear actions (including uranium mines).

There are also a number of species that are not listed under the EPBC Act, including the snubfin dolphin, which is of concern because of its limited home range.

World heritage properties

The Great Barrier Reef was inscribed in the World Heritage List in 1981 and meets all four natural criteria. Parts of the Fitzroy basin to mean low water and all of the adjacent marine areas fall within the World Heritage Area.

National heritage properties

The EPBC Act provides for the listing of natural, historic or indigenous places that are of outstanding national heritage value. Within the Fitzroy basin only the Great Barrier Reef World Heritage Area is listed as a National Heritage Property (for its natural values).

Wetlands of international importance (declared Ramsar wetlands)

The EPBC Act provides for the management and protection of Australia's Ramsar wetlands. The Fitzroy basin is adjacent to the Shoalwater and Corio Bays area which was listed on the Wetlands of International Importance (Ramsar sites) in 1996.[9]

Listed threatened species

Nine species of birds, two species of frog, seven species of mammal, 45 species of plant, and 12 species of reptiles have been identified as listed threatened species within the Fitzroy basin and adjacent waters (Appendix D). Key threatened marine species in the World Heritage Area include six of the seven species of marine turtle and humpback whales.

Ecological communities

There are nine threatened ecological communities within the Fitzroy basin. These are detailed in Table 2.1.1. Semi-evergreen vine thickets can be found on Balaclava Island within the World Heritage Area (Figure 2.1.1).

Figure 2.1.1: Endangered semi-evergreen vine thickets on Balaclava Island

Table 2.1.1: Threatened ecological communities within the Fitzroy basin

Community	Status	Occurrence
Brigalow (*Aracia harpophylla* dominant and co-dominant)	Endangered	Known to occur
Broad leaf tea-tree (*Melaleuca viridiflora*) woodlands in high rainfall coastal north Queensland	Endangered	Known to occur
Coolibah – Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions	Endangered	Considered likely to occur
Lowland Subtropical Rainforest on Basalt Alluvium	Critically endangered	Known to occur
Natural Grasslands of the Queensland Central Highlands and the northern Fitzroy basin	Endangered	Considered likely to occur
Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions	Endangered	Considered likely to occur
The community of native species dependent on natural discharge of groundwater from the Great Artesian basin	Endangered	Considered likely to occur
Weeping Myall Woodlands	Endangered	Considered likely to occur
Whit Box-Yellow Box-Blakely's Red Gum Woodland and Derived Native Grassland	Critically endangered	Considered likely to occur

Listed migratory species

The EPBC Act lists of migratory species include those species listed in the:

- Japan-Australia Migratory Bird Agreement (JAMBA)
- China-Australia Migratory Bird Agreement (CAMBA)
- Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention).

The wetlands in this region represent important habitat and transport corridors for migratory bird species with the adjacent marine waters. There are 10 migratory marine birds, two species of migratory mammals (dugong and humpback whale) and seven migratory reptiles (marine turtles and the saltwater crocodile) occurring within the Fitzroy basin (Appendix E).

The Great Barrier Reef Marine Park

The Marine Park is recognised as a matter of national environmental significance under the EPBC Act to enhance the management and protection of the ecosystems in the Great Barrier Reef Region. The *Great Barrier Reef Marine Park Zoning Plan 2003* (the Zoning Plan) is the overarching plan that provides for a range of ecologically sustainable recreational, commercial, and research opportunities and for the continuation of traditional activities. Each zone has different rules for the activities that are allowed (as of right), prohibited, and those that require permission. Zones may also place restrictions on how some activities are conducted.

2.2 Other protected areas and values in the basin

Although not matters of national environmental significance, there are other areas within the Fitzroy basin that have intrinsic values and may also have significance for the long-term health and resilience of the World Heritage Area as detailed below.

Dugong Protection Areas

While there are no Dugong Protection Areas (DPA) mapped within the Fitzroy basin, DPA A and B occur in two basins adjacent to the Fitzroy; the Shoalwater and Calliope basins.

Nationally important wetlands (Directory of Important Wetlands in Australia)

Nationally important wetlands in the Fitzroy basin or adjacent to the basin include:

- Boggomoss Springs
- Fairbairn Dam
- Port Alma
- Fitzroy River Delta
- Fitzroy River Floodplain
- Great Barrier Reef Marine Park
- Hedlow Wetlands
- Lake Elphinstone
- Lake Nuga Nuga
- Palm Tree and Robinson creeks
- Shoalwater Bay Training Area Overview C
- The Narrows.

These are shown in Figure 2.2.1. All of these wetlands are of high value for the health and resilience of the World Heritage Area.

Conservation parks, national parks and forest reserves

There are 165 protected areas covering six per cent of the Fitzroy basin. These are shown in Appendix F.

Fish Habitat Areas

Declared fish habitat areas (FHA) are areas protected under the *Fisheries Act 1994* (Qld) against physical disturbance associated with coastal development and are selected on the basis of their respective values. The Fitzroy River is the only FHA in this basin and is described in Table 2.2.1.

Table 2.2.1: Fish Habitat Areas in the Fitzroy basin[10]

FHA	Location	Habitat Values	Fisheries Values	Unique Values
Fitzroy River (declared in 2008)	Approximately 29,253 hectares in size, parts of the Fitzroy River estuary, Raglan Creek and wetland systems on North Curtis Island.	Extensive saltpans and saline grasslands fed by mangrove-lined creeks; closed mixed-species mangrove forests mud and sand flats; rocky headlands and brackish lagoons.	Commercial, recreational and Indigenous fisheries resources	Southern distributional limit of *Acanthus ilicifolius* (mangrove holly.

Nature refuges

A nature refuge is a class of protected area under the *Nature Conservation Act 1992* that acknowledges a commitment to manage and preserve land with significant conservation values while allowing compatible and sustainable land uses to continue. Although a nature refuge agreement may be entered into voluntarily, a nature refuge agreement is legally binding. There are 46 nature refuges in the Fitzroy basin (Appendix G). These are shown in Figure 2.2.1.

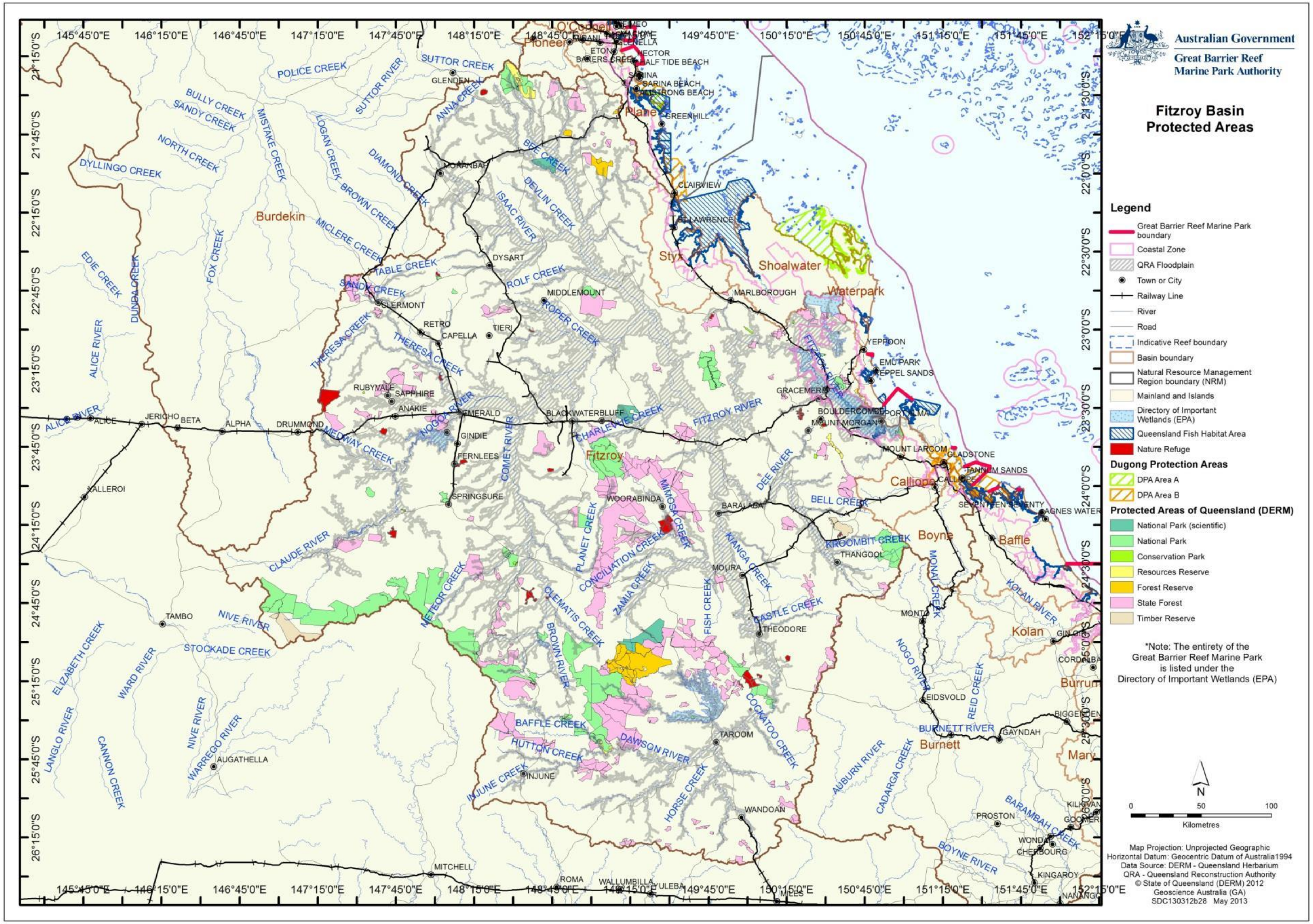

Figure 2.2.1: This map shows the spatial extent of some values in the Fitzroy basin that may underpin matters of national environmental significance, including Nationally Important wetlands, National Parks, Conservation Parks, forest reserves, FHA and Nature Refuges

2.3 Coastal ecosystems

The Great Barrier Reef inshore ecosystems are made up of many complex components, including estuarine and marine ecosystems such as mangroves, seagrasses and inshore coral reefs, which are closely linked to adjacent coastal ecosystems. These include coastal freshwater wetlands, coastlines and forested floodplains (Figure 2.3.1). These coastal ecosystems are interconnected and reliant on one another for their ongoing health and resilience. Species that form part of the amazing biodiversity of the Marine Park live in and move between these ecosystems throughout their life cycles.

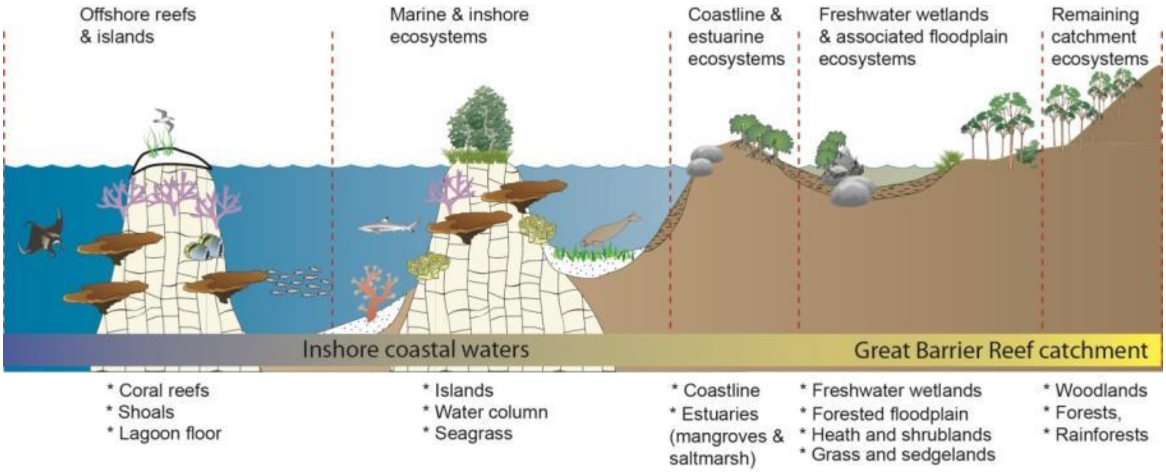

Figure 2.3.1: Broad groupings of coastal ecosystems illustrating the general level of importance for the ongoing health and resilience of the Marine Park

Coastal ecosystems are not easily separated and defined, as functionally they are all connected one way or another. Each component provides specific ecological functions that together make up and support the health and resilience of the ecosystem as a whole.

Inshore marine coastal ecosystems

The inshore coastal waters adjacent to the Fitzroy basin are home to a range of marine flora and fauna, many of which are of conservation concern. Figure 2.3.2 shows the bioregions in the area that were used as the basis for the Great Barrier Reef Marine Park Authority Zoning Plan (further information on bioregions and reefal and non-reefal areas can be found at http://www.gbrmpa.gov.au/zoning-permits-and-plans/rap). Figure 2.3.3 shows the Marine Park Zoning Plan, used to manage and conserve marine values.

Anecdotal evidence provided by local residents suggests that the Capricorn coastline was once rich in coral communities, however these mainland fringing reefs have disappeared and coastal island reefs within Keppel Bay are under threat.[11]

According to the First Reef Plan Report Card[12], corals in the Fitzroy region are in moderate condition, with moderate coral cover and good settlement of juvenile corals. However, the abundance of juvenile corals is poor and there is a high cover of macroalgae.[12] Although the reefs have recovered from significant disturbances over the last decade, their resilience to further disturbances is uncertain.[12] Increases in sediment loads can impact corals through smothering, decreasing light availability, coral photosynthesis and growth. This can result in changes to coral population, structure, colony size, decreased growth and survival. [13] Following further extreme weather in 2011 the Third Report Card[14] now shows the coral communities are in poor condition.

Seagrass abundance in the Fitzroy region in 2011 to 2012 decreased from moderate to poor, but prior to this finding has generally remained stable in coastal and estuarine locations for some years. However, seagrass abundance was decreasing in reef locations.[12] A reduction in resilience to disturbances has been indicated by the low numbers of reproductive structures such as flowers on seagrasses. The coastal seagrasses in Shoalwater Bay were the least impacted meadows that occur along the urban coast of the Marine Park. The seagrass meadows support populations of dugongs (and green turtles), but recent monitoring has shown that the dugong population has experienced a significant decline over the last decade, considered to be a direct response of seagrass declines as a result of extreme weather events and larger than average wet season rains. Between aerial surveys conducted in November 2005 and November 2011, estimates of the dugong population in waters between the Daintree River and the southern extent of the Marine Park declined from approximately 2500 animals to 600.[15] In addition, the survey conducted in November 2011 found that there were no calves in the remaining population, which is another indication that seagrasses were still recovering and that mature females were not able to maintain enough body condition to support offspring.

The Fitzroy River estuary and Keppel Bay provide critical habitat for the Australian snubfin dolphin and are one of only three know areas where large aggregations (50-100 animals) have been recorded.[16,17,18] In fact, this area is recognised as the most southern extent for this species on the east coast of Australia[17] and population estimates for the entire Central Queensland coast region is only 100 individuals. The Great Barrier Reef Marine Park Authority considers the Australian snubfin dolphin (and the sympatric Indo-Pacific humpback dolphin) the highest priority for management because of their small, localised populations, exposure to high levels of human activity, and concerns that they are declining in number.[19]

During large flood events, flood plumes discharged from the Fitzroy River have covered approximately 10,000 km^2 of marine area, reaching the Capricorn Bunker Group and Townsend Island.[11] As a result, the reefs in the inshore area are at risk from exposure to sediment, nutrients and chemicals.[11] Dissolved matter is transported across and along the Reef lagoon, and contaminants are widely dispersed throughout the Marine Park. The capacity of the marine environment to store, transform and transport contaminants that reach Keppel Bay determines the degree to which coral reefs and seagrass meadows are impacted. Initial flood pulses last several weeks, however the breakdown of contaminants is a long-term process and the marine environment can have chronic exposure to contaminants through tidal re-suspension.[20] During acute flood events it has been estimated that almost all sediments and nutrients in catchment run-off are delivered to the Fitzroy River estuary and Keppel Bay and that the majority of nutrient material transported down the river is in particulate organic form attached to fine sediment particles.

The water quality measured in 2010-2011 supports the conclusion that extreme weather events lead to unusually elevated levels of pollutants, particularly in the Fitzroy region.[21] Water quality changes driven by extreme weather events can reduce the resilience of the

Reef through sub-lethal and lethal effects on ecosystems that result in a lowered ability to recover.[22] The extent and duration of these conditions in the 2010-11 wet season also show that the water quality conditions can be reduced over a period of months and cover a distance of hundreds of kilometres.[21]

The Reef Water Quality Protection Plan (Reef Plan) was developed to facilitate the improvement of catchment water quality released into the Reef and to ensure that the quality of water entering the Marine Park is not negatively impacting the health and resilience of the Reef by 2020.[12] Actions include engaging land managers in farm planning, risk assessment and training in nutrient and groundcover management, the protection of wetlands of high ecological significance, and developing partnerships between natural resource management groups and farmers to accelerate the voluntary adoption of best management practices that will benefit Reef water quality.[12]

Modelling and monitoring studies have shown that discharge from the Fitzroy River transports contaminants into the World Heritage Area.[23,24] Sediments delivered to the Reef from the Fitzroy basin was 3,326,000 tonnes in 2008, which was 74,000 tonnes less than the 3 years prior.[11] The majority of suspended sediments released from the Fitzroy River into the Reef are deposited near the river mouth, while dissolved nutrients are transported with the plume into the Reef lagoon.[25] Annual average nitrogen and phosphorus loads have decreased by 193 and 56 tonnes, respectively since 2005.[8] These improvements in water quality within Keppel Bay have been associated with improved management of agriculture. Research and monitoring also shows that continuing actions, such as maintaining good ground cover can reduce these loads.[26]

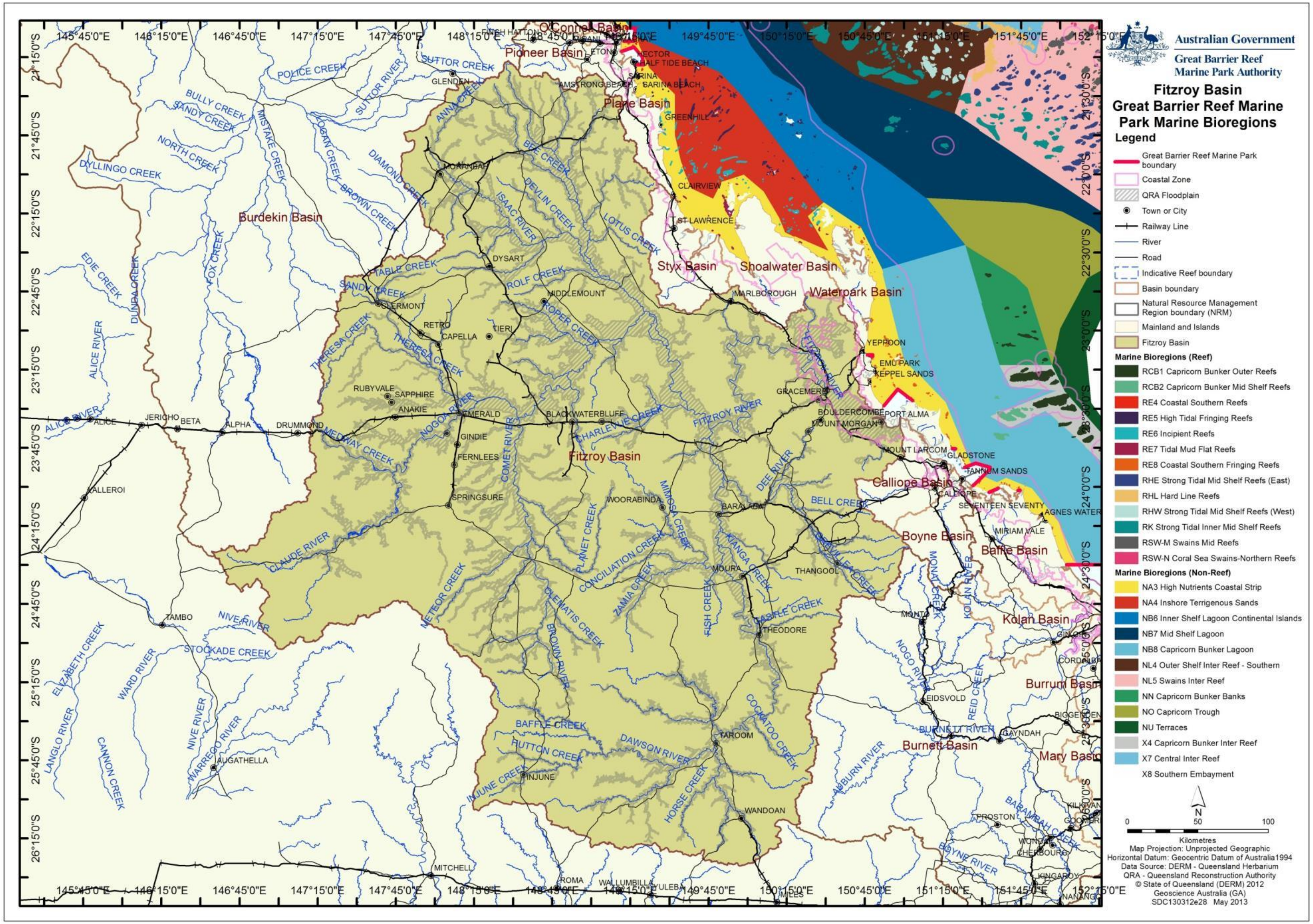

Figure 2.3.2: Marine bioregions adjacent to the Fitzroy basin

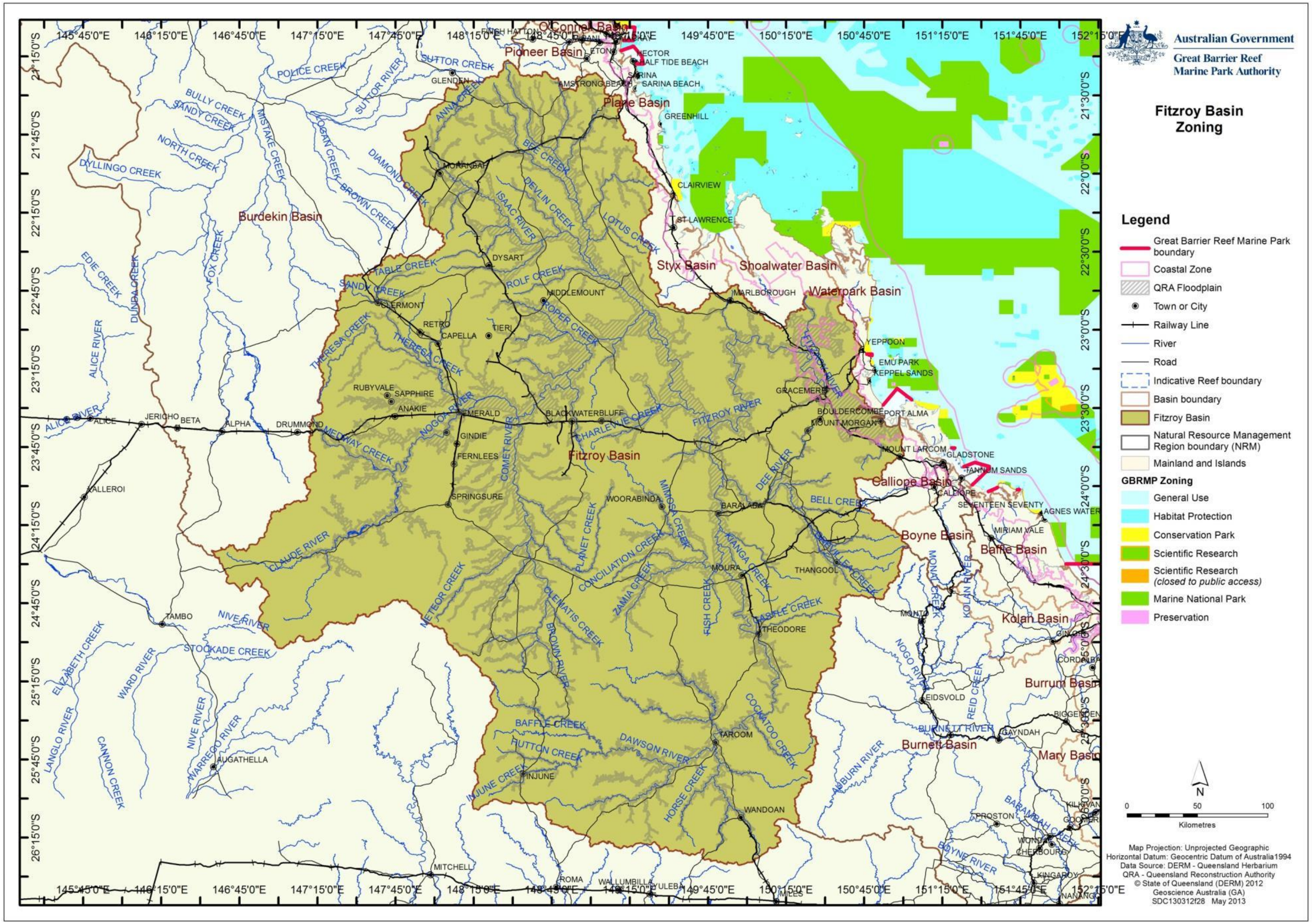

Figure 2.3.3: Zoning within the Marine Park adjacent to the Fitzroy basin

Changes to coastal ecosystems

Coastal ecosystems in the Fitzroy basin have been substantially modified or cleared. Significant changes include:

- Broadscale clearing of forests, woodlands, and modified grass and sedgelands under the Brigalow Scheme.
- Modifications to river banks including straightening, channelisation and removal of riparian vegetation, which has impacted upon terrestrial and in-water biodiversity.
- Broadscale changes to overland and underground hydrology through river straightening and groundwater management for irrigation. These have impacted upon terrestrial and in-water biodiversity by removing or modifying habitat, simplifying niches available for species or changing climax communities. Changes to the seasonality of water flows are further impacting on both aquatic and terrestrial biodiversity.

Fish barriers, such as the Fitzroy Barrage and Eden Bann Weir, impact on fish migration between marine and freshwater habitats. These barriers can contribute to the loss of species diversity within fish communities and severely impact the health of the region's aquatic ecosystems.[3]

- Introduction of pasture grasses have changed the flora biodiversity and natural fire regimes. These introduced grasses (such as grader grass (*Themeda quadrivalvis*) or guinea grass (*Megathyrsus maximus*)) often burn hotter and faster causing changes to biodiversity (such as the loss of forested canopy) and exposure and loss of soils. Risks to biodiversity can be reduced through sustainable grazing management.
- Aquatic biodiversity has declined in some parts of the basin as a result of landscape changes, fish barriers, in-stream structures and land use.

Ongoing legacy issues as a result of changed land use, such as ponded pasture bunds, continue to impact on the life history of local aquatic and terrestrial species with connections to the Reef (such as migratory fish and migratory birds). This has led to an ongoing decline in populations of key species, such as mangrove jack and barramundi[6] due to reduced resilience.

In pre-European times, the Fitzroy basin was dominated by forests and woodlands (Figure 2.3.4) especially on extensive floodplains. Since European settlement, these forested areas have been thinned for grazing and in some areas cleared for intensive agriculture (Figure 2.3.5).

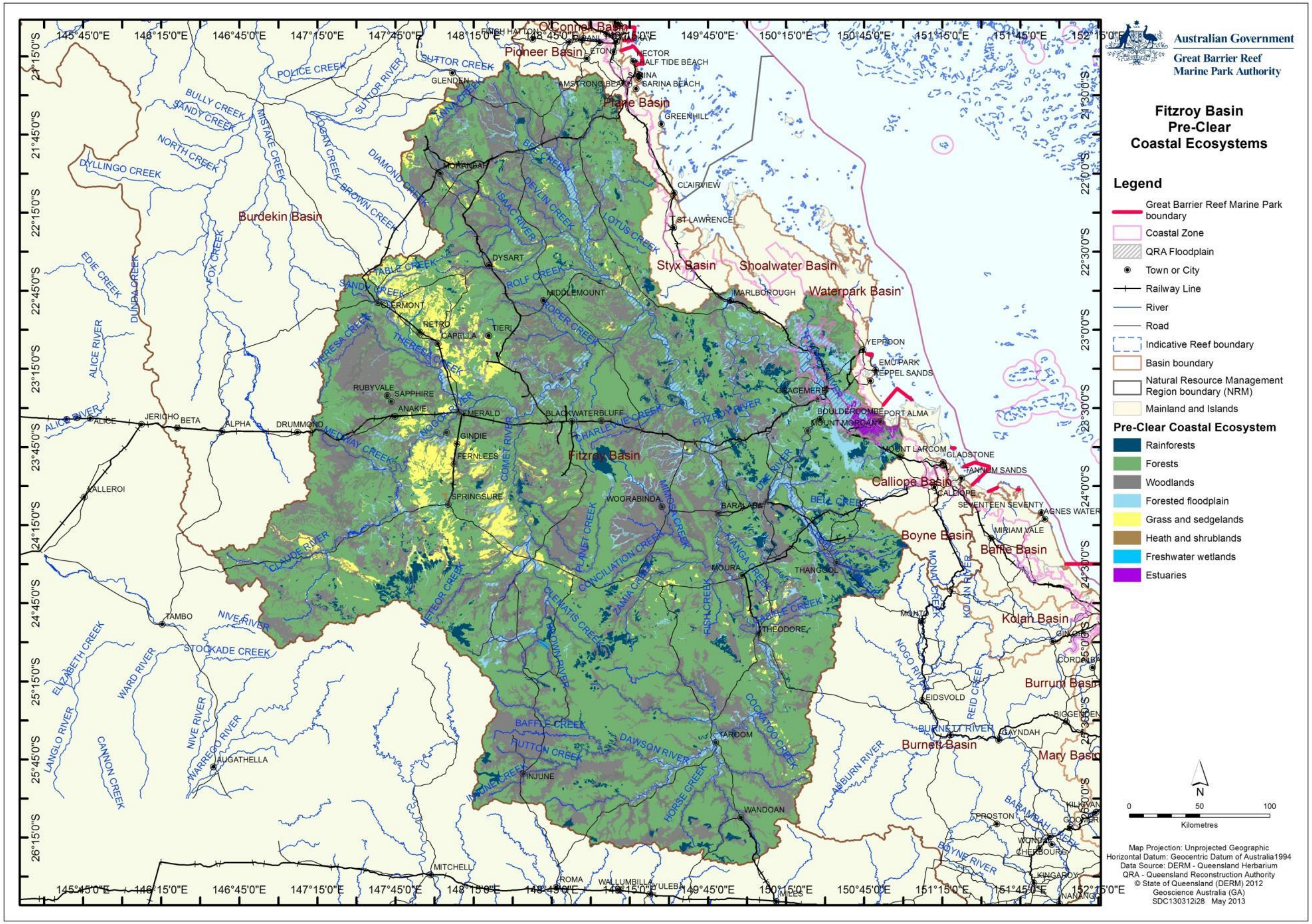

Figure 2.3.4: This map shows the pre-clear coastal ecosystems in the Fitzroy basin

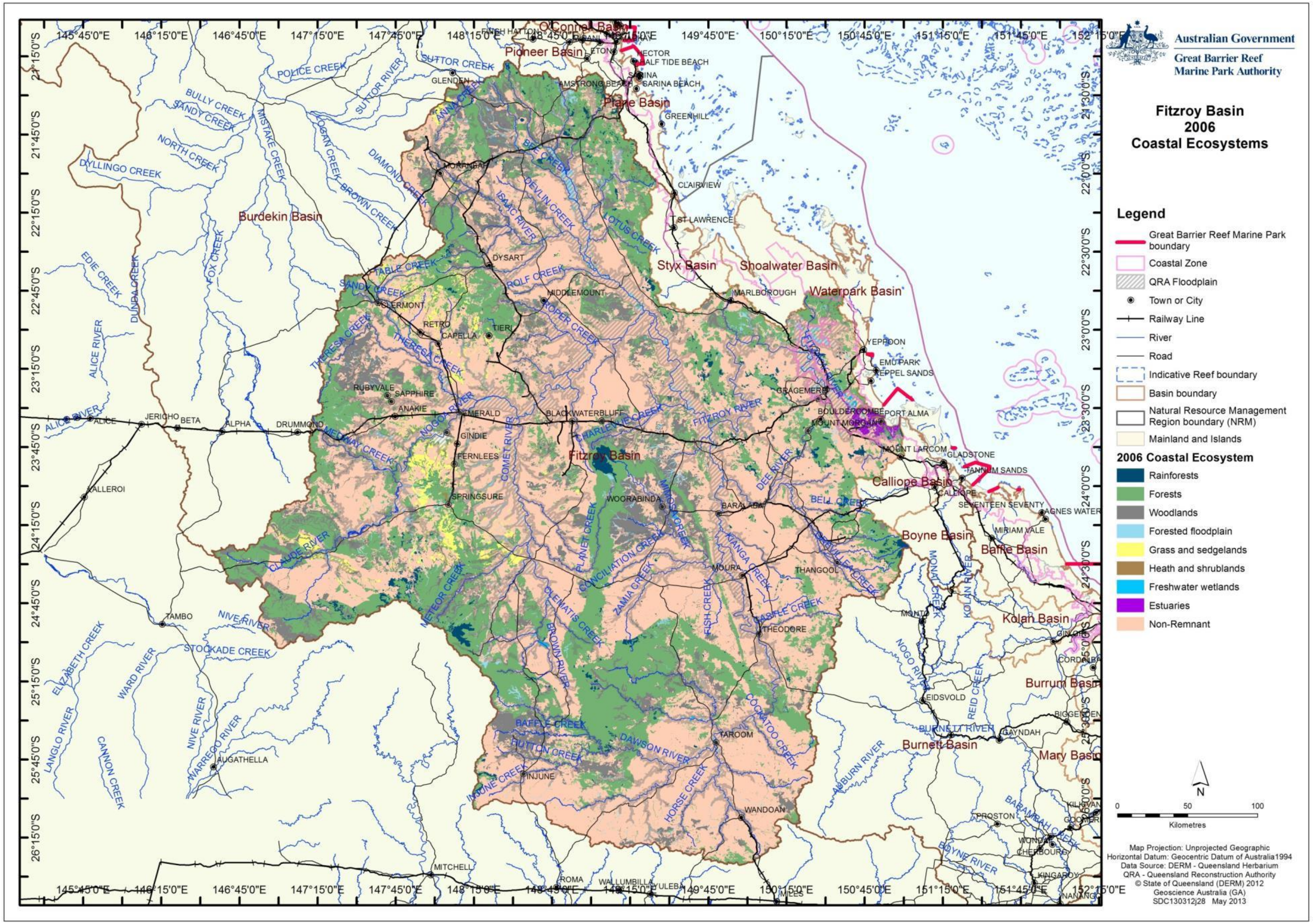

Figure 2.3.5: This map shows the post-clear coastal ecosystem assemblages in the Fitzroy basin (derived from 2006 Queensland Government Regional Ecosystem data)

Changes to coastal ecosystems (Table 2.3.1) show that the greatest proportion of modification to terrestrial biodiversity has occurred to rainforests (loss of 64 per cent, – 331,306 hectares), woodlands (loss of 61 per cent – 2,219,496 hectares), forested floodplain (61 per cent – 62,638 hectares) and forests (loss of 57 per cent – 4,844,567 hectares). Forests have had the greatest area of loss followed by woodlands. The combined loss of forests and woodlands and the reduction of the ecological values and functions provided by them have had the greatest impact on the World Heritage Area. These ecosystems are important in controlling the erosion of sediments, protecting soil from erosive impacts of rainfall and in trapping sediments. They also recharge groundwater resources and replenish natural river flows.[6]

For information in regard to the categorisation of the Reef's coastal, catchment and inshore ecosystems and the ecological functions and services of those ecosystems please refer to Table 2.1.1.

Table 2.3.1: Area (ha) of pre-clear and post-clear coastal ecosystems based upon Queensland Government Regional Ecosystem mapping

	Ecosystem	Pre-clear	2006	2009	% remaining
	Rainforests	514,758	183,635	183,452	36
	Forests	8,426,409	3,588,115	3,581,842	43
	Woodlands	3,654,430	1,442,606	1,434,934	39
	Forested floodplain	987,444	390,114	389,649	39
	Grass and sedgelands	607,991	196,660	196,072	32
	Heath and shrublands	13,690	11,345	11,290	82
	Freshwater wetlands	18,323	13,661	13,645	74
	Estuaries	33,274	28,675	28,626	86
	Non Remnant	0	8,388,202	8,403,505	na
	Not Mapped	4,996	18,301	18,301	na
	Total Area (h)	14,261,316	14,261,316	14,261,316	

Coastline and estuarine coastal ecosystems

Estuaries are highly productive fish nursery areas providing a range of ecological functions for species with connections to the Reef. Animals such as prawns, crabs and many popular commercially and recreationally fished species (such as barramundi and mangrove jack) use estuaries for part of their life history. Approximately 7.7 per cent of the estuaries in the World Heritage Area occur in the Fitzroy basin which equates to approximately $4.6 million of gross value of production of fisheries harvest.

The extent of estuaries in the Fitzroy basin has remained relatively unchanged (86 per cent remains) according to the Queensland Government's Regional Ecosystem mapping. The current health of these ecosystems has not been assessed since 2000 as part of the Australian Estuarine Database Survey[27], where the Fitzroy basin condition was listed as modified (Table 2.3.2), which indicates modification of coastal ecosystems in the vicinity of the ecosystem.

Table 2.3.2: Australian Natural Resource Atlas (ANRA) classification of estuaries for the Fitzroy basin[27]

Name of estuary	Class	Sub-class	Condition
Fitzroy River	Tide Dominated	Tide-Dominated Estuary	Modified

The system was still in a modified condition when assessed during fieldwork undertaken in March 2013. Extensive modifications have occurred due to human influences over the last 150 years. The Fitzroy River estuary was originally 106 km long however, in 1970 the Fitzroy Barrage (Study Site 5) was constructed and has effectively halved the length of the Fitzroy River estuary tidal extent to 56 km (Figure 2.3.7). The Barrage not only blocks fish passage but has also modified tidal influence[28] which affects surrounding habitats. Twenty three of the 29 freshwater fishes found in the Fitzroy Basin Association region require unrestricted access to estuarine or marine waters to successfully complete their life cycles.[3] Though the Barrage has been modified to allow for greater fish access, there are still a number of fish species and sizes that cannot pass the Barrage to successfully complete their life cycles. If fish passage is prevented year after year, fish populations can be severely diminished and can lead to localised species extinction.[3] For example, barramundi became locally extinct in the lower Dawson and Mackenzie rivers, but when the Barrages were modified to include a fishway, barramundi along with sea mullet and mangrove jack were found in the lower parts of these river systems again.[3] Impacts caused by fish barriers could be minimised with the construction of effective fishways, for example, Kinka Wetlands (Study Site 3).

Study Site 3 - Kinka Wetlands

The Kinka Wetlands are part of the Yeppoon Keppel Sands tidal wetland. The wetlands consist of salt flats, mangroves, salt marshes, brackish and hypersaline lagoon and fresh to brackish wetland. The Kinka Wetlands were part of the Great Barrier Reef Coastal Wetlands Protection Program Pilot. This program delivered on-ground actions for the sustainable management of 22 priority wetlands in the Great Barrier Reef catchment. Previously the Kinka Wetlands provide poor tidal connectivity with the Great Barrier Reef lagoon due to constructed bund walls and road crossings across the wetland acting as a barrier between tidal and freshwater systems (Figure 2.3.6). To improve fish passage a culvert was installed under a roadway and a fishway was constructed on the lower side of the bund wall (Figure 2.3.7). The wetland is considered critical in the protection of water quality, nursery habitat for fish, enhancing biodiversity, and contributing to regional landscape values.

Figure 2.3.6: A road crossing located at Kinka Wetlands acting as a fish barrier (left) and freshwater wetland created due to the road crossing

Figure 2.3.7: Fish passages constructed at Kinka Wetlands as part of the Great Barrier Reef Coastal Wetlands Protection Program Pilot

The Barrage and other human impacts including dredging, land use, and increased sediment export have changed the hydrodynamics of the system, creating a poorly flushed zone downstream of the Barrage, and changes in mangrove areas around the mouth of the lower estuary (Figure 2.3.8 and Figure 2.3.9).[1,7] The connectivity between marine, freshwater lagoons and wetland habitats is vitally important to life cycles and the productivity of natural populations.[11]

Figure 2.3.8: Fitzroy River estuary, Thomsons Creek (Study Site 4)

Figure 2.3.9: Fitzroy River estuary Barrage (Study Site 5) (photo courtesy Jim Tait)

Generally the health of the lower Fitzroy has been reduced since the Barrage was installed. In the last decade, the system has been considered stable, although degraded.[1] Many smaller barriers installed for ponded pasture are found in the lower Fitzroy, mainly bunding across minor creeks and through wetland areas.[1,3] Other barriers to fish migration include poor water quality, chemicals, dissolved oxygen and weeds.[29]

Twelve Mile Creek (located near Marmor) has a bunded area which has been slightly modified to improve connectivity. The modification allows high tides to connect the 12 Mile Creek aquatic ecosystem for two to three times a year at spring tide, improving aquatic species connectivity and connection to breeding and nursery habitats. The system is now more productive, and provides important ecological functions for the downstream environments (Bill Sawynok (InfoFish Services) 2013, pers comm., 16 May).

Barramundi Creek on the northern mouth of the Fitzroy River has been bunded to provide ponded wetland area for grazing activities occurring on marginal land (Figure 2.3.10). Being so close to the marine environment, Barramundi Creek is considered to be of high value as a nursery area for species such as barramundi (Bill Sawynok (InfoFish Services) 2013, pers comm., 25 March). At the Fitzroy basin assessment workshop it was discussed that appropriate modification of bund walls in collaboration with landholders and the implementation of effective fishways are seen as a proven mechanism for improving fish connectivity and general health of the system.

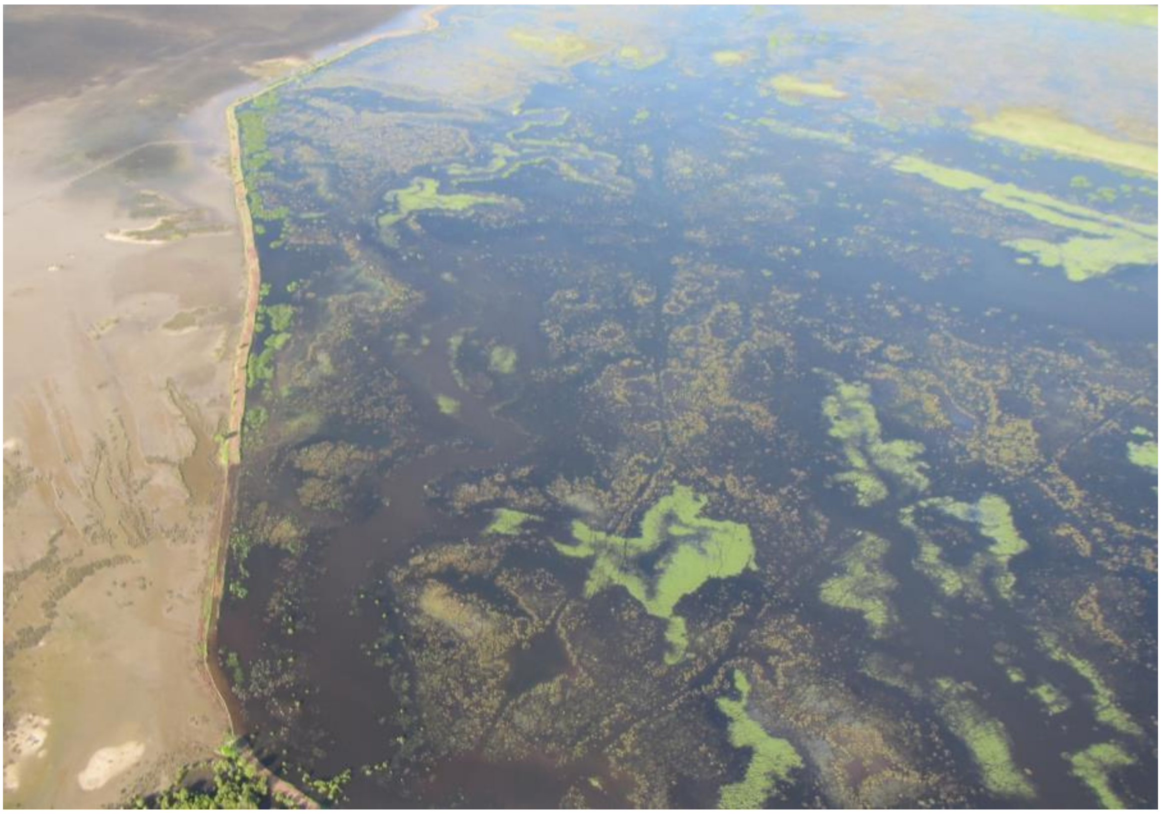

Figure 2.3.10: Barramundi Creek located north of Rockhampton, is a ponded pasture and a high value nursery area

Freshwater wetlands and associated floodplain coastal ecosystems

Freshwater wetlands and associated floodplain ecosystems provide physical, biogeochemical and biological processes, including the provision of major food and habitat resources for fish, birds and invertebrates as well as being a nursery ground for marine fish such as barramundi and invertebrates such as prawns.[30] They function as links between the terrestrial and marine ecosystems and provide pathways for the movement of nutrients as well as pollutants from the terrestrial environment to the World Heritage Area.[30]

Freshwater wetlands across the Fitzroy basin have been reduced to approximately 75 per cent of their pre-European extent. The mapped extent of freshwater wetlands often underestimates losses, especially in those wetlands that are periodically dry. As a result, these ephemeral wetlands are the ones that are most vulnerable to being lost or degraded. They are also often the ones that provide critical connections for fish species movement within catchments and connection to the World Heritage Area.[6]

Many otherwise intact wetlands are suffering a range of ecosystem health problems associated with loss of connectivity, sediment and nutrient overload, and weed infestations. The loss of functions therefore may be much greater than changes in extent might imply.

The Queensland and Australian governments, through the Queensland Wetlands Program, have mapped wetlands at a finer scale than the current regional ecosystems mapping. Through this mapping, approximately 6,539 lacustrine/palustrine wetlands were identified in the Fitzroy basin. The extent and classification types of wetlands within the Fitzroy basin are shown below at Table 2.3.3.

Table 2.3.3: Queensland Wetlands Program data for the freshwater and estuarine wetlands of the Fitzroy basin[9]

System as defined by Queensland Wetlands Program	Area (km²)	Wetlands area (%)	Total area of basin (%)
Artificial and highly modified	500.08	18.1	0.4
Estuarine	292.89	10.6	0.2
Lacustrine	52.12	1.9	0.0
Palustrine	368.89	13.4	0.3
Riverine	1,548.13	56.0	1.1
Total	**2762.12**	**100**	1.9

The Fitzroy basin contains a wide variety of streams and wetlands that provide habitat for numerous fish species, including endemic, vulnerable and threatened fish species (Study Site 1).[3] The streams, wetlands, floodplains, and lagoon systems in the Fitzroy basin are fertile nursery areas for fish species including barramundi and mangrove jack. Streams, wetlands, floodplains, and lagoon systems have suffered considerable degradation with few of these systems in good condition.[3]

Forested coastal ecosystems

The Fitzroy basin has been heavily impacted since European settlement from large scale alterations of natural river systems and clearing of vegetation for grazing. Rainforests, forests, woodlands, and forested floodplains have been subjected to the greatest losses within the Fitzroy basin (Table 2.3.1). Grazing dominates both the coastal and inland regions. Dryland production is the second biggest agricultural practice within the Fitzroy basin producing mostly grains (corn, wheat, chickpeas, and mung beans), cotton and horticulture. Land use impacts for the Fitzroy basin include changes in hydrology, landscape water balance, declining water quality, removal of riparian vegetation and installing barriers to fish passage (Figure 2.3.11).[3] Increased sediment and nutrient loads from land use practices have contributed to the degradation of freshwater, estuarine, and marine ecosystems in the World Heritage Area.[3,31,32]

Figure 2.3.11: Drains at Iwasaki Wetlands (Study Site 2) which act as a fish barrier (left) and loss of riparian vegetation due to clearing near Lake Mary (Study Site 1) (right)

The Queensland Government has assigned regional ecosystems a conservation status which is based on its current remnant extent (how much of it remains) in a bioregion (Figure 2.3.12). Regional ecosystems were originally defined by Sattler and Williams (1999)[33] as vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil. Vegetation that is classified as endangered is afforded most protection in Queensland; however some industries such as mining, transport, electricity and community infrastructure may be exempt. Lesser protection is afforded by the other categories. However regional ecosystem conservation classification is based on the remaining terrestrial extent of these ecosystems and does not take into account their intrinsic functional value or linkage to the World Heritage Area. For example, forested flood plains, that have been significantly lost already and play a limited role in trapping sediment, removing nutrient and recycling water, have protection limited to the riparian zone. Therefore regional ecosystem conservation classifications most likely do not protect coastal ecosystems most important to maintaining the health and resilience of the World Heritage Area.

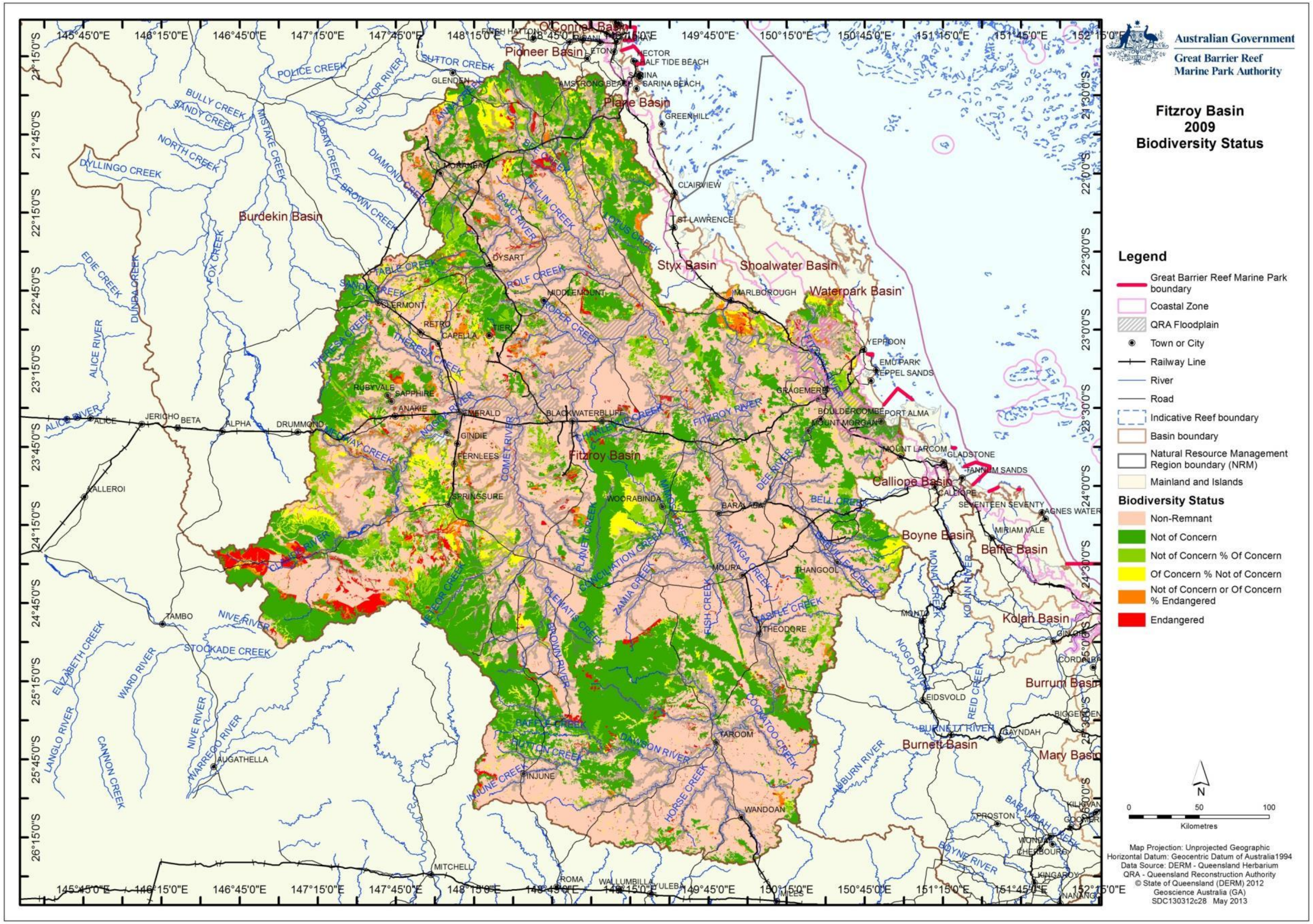

Figure 2.3.12: Regional ecosystem conservation status map for the Fitzroy basin

2.4 Ecosystem processes

The condition of ecosystem processes in the Fitzroy basin varies both spatially and temporally. Areas that have been highly modified from the natural coastal ecosystems that were once there show the greatest degree of change in processes. For example, rivers that have been modified into water distribution channels offer limited capacity for biological processes for fish species such as reproduction, dispersal recruitment and migration and are often nutrient enriched.

Appendix H contains a list of coastal ecosystems and some of the ecological processes they deliver for the health and resilience of the World Heritage Area. In a recently released Report Card developed by the Fitzroy Basin Association all rivers within the Fitzroy basin generally range from good to fair condition and are considered some of the healthiest in the catchment. They are considered to provide many of the same ecosystems services as they did before European settlement.[34]

Physical processes

Physical processes are those that transport and mobilise elements such as water, sediments and minerals. They include groundwater recharge/discharge, sedimentation/erosion of soils and deposition and mobilisation processes.[6] All coastal ecosystems provide these services, some more than others.

Changes in hydrology have occurred as a result of land use change (such as land clearing, grazing and urbanisation, leading to surface compaction and reducing soil porosity, and increased sediment loss to erosion in streams), barriers (such as dams, weirs and road/rail crossings), groundwater extraction, floodplain drainage networks and changing rainfall patterns as a result of climate change. These actions have altered run-off quality, quantity and seasonality of flows, and sediment build up in river beds. Storm intensity in recent years has delivered sudden large pulsed flows of freshwater into the World Heritage Area. These flows often have reduced residence times in the basin and the supporting coastal ecosystems sufficient for many ecological processes to occur. As a result, freshwater induced coral bleaching and smothering of corals and seagrass by sediments is occurring more frequently.[35] Water extraction has reduced flows and also resulted in increasing sedimentation of rivers. Reduced high velocity flows inhibit sediment movement along these watercourses. As these rivers fill with sediment (sand) they become shallower and wider. This changed hydrology results in scouring and erosion of banks during pulses from storm events, which impacts on World Heritage Area inshore ecosystems by increasing turbidity.

Physical processes such as sediment delivery have changed considerably in this basin as a result of land use change. The retention of heavier classes of sediments from the construction of dams and weirs, and water extraction (which reduces in-stream water quantity and hence velocity) can lead to reduced loads of heavier sediment material required to maintain estuarine habitat that is built on sedimentary inputs, and can increase the incidence of shoreline erosion as heavier sediments are reduced to point that is insufficient to replenish sediments eroded by coastal processes.[36]

Ecological processes from forested floodplains include detaining water, mitigating floods, connecting ecosystems, regulating water flow (groundwater, overland flow) and stabilising sediment from erosion. The loss of these ecosystem services results in loss of detention, increases in peak water flows, greater generation and transport of sediment and nutrients, and other contaminant loads.

Biogeochemical processes

Biogeochemical processes revolve around energy and nutrient dynamics. Biogeochemical processes include production, nutrient cycling, carbon cycling, decomposition, oxidation-reduction, regulation processes and chemical/heavy metal modification. Wetland and associated floodplain ecosystems offer the greatest capacity for maintaining biogeochemical processes as these ecosystems slow the flow of water and allow the processes to occur (Study Site 1) or in the case of groundwater, utilise the slow processes of water flow to recycle water and nutrients.

Study Site 1 - Hedlow Wetlands

The Hedlow Wetlands are located 30 km north of Rockhampton, and are an important cattle grazing resource for the local area. The wetland contains permanent water, along with a wide range of wetland habitats which provide important food resources and sheltered roosting and breeding sites for waterbirds. These wetlands were originally contained within open forests and woodlands (melaleuca and blue gum) however the vegetation has since been cleared from on and around these wetlands (Figure 2.4.1).

Hedlow Wetlands have been influenced through the development of roads and modification to provide ponded pasture for grazing (Figure 2.4.2). Although ponded pastures maintain some of the existing wetland values, the ponded pastures at Hedlow have caused dryland salinity problems which can be attributed to clearing vine scrubs, tree deaths, reduced ground cover, and conditions which promote the growth of exotic grass species (hymenachne and para grass) which are spreading into some natural wetlands.[37] There is concern regarding potential increases in ponded pastures in the area and if this occurs there is a greater risk of exotic grass encroachment and choking of native plants.[37]

Wetlands are vitally important for capturing freshwater flows and recycling of sediments and nutrients and even pesticides before they enter estuarine systems, inshore waters and the Reef. The also provide an important nursery area for many fish species (such as mangrove jack, sea mullet and barramundi), and other freshwater and marine life.[6] The Hedlow Creek area is part of the wetland network in the lower Fitzroy floodplain. During moderate and major flooding events, wetlands in the Hedlow area become connected through Fitzroy River breakouts from connecting rivers and streams, such as Alligator Creek. Moderate and major flood events allow many fish species to move through wetland and lagoon systems that bypass the Barrage, which normally acts as a significant barrier to fish movement and access to freshwater wetland systems. Wetlands such as in the Hedlow area provide important nursery grounds for fish species, where abundant food and few predators accelerate their growth before they re-enter the marine environment.[6]

Figure 2.4.1: Riparian vegetation nearly completely cleared due to land use (grazing) at Hedlow Creek, Lake Mary

Figure 2.4.2: Ponded pasture located at Hedlow Creek (Lake Mary) (photo: Jim Tait)

During large flood events biogeochemical processes in coastal ecosystems often do not occur as water flows at high speed directly into inshore coastal water. In more developed basins, the volume of nutrients is often higher as a result of fertiliser use and point source discharges. These processes are thus transferred to inshore coastal waters. Impacts of elevated nutrients on the marine environment are outlined in Table 2.4.1.

Elevated nutrients in inshore coastal waters indicate that the coastal ecosystems are not able to regulate the biogeochemical processes. This is likely due to increased run-off and elevated inorganic nutrients from agricultural and urban sources which often discharge directly into waterways.

Table 2.4.1: Forms of nutrients and their impact on the aquatic environment

Term	Description/source	Impact on aquatic environment
Particulate organic matter	Large particles of organic matter (e.g. dead plants and animals) that get broken down by decomposers into smaller dissolved organic matter.	Not immediately available for uptake by plants and animals.
Dissolved organic matter (DOM)	Large molecules of organic matter (nitrogen, carbon, phosphorus etc.) produced as a result of decomposition.	Not biologically available until broken down by bacteria.
Dissolved inorganic matter	By-product of bacterial decomposition of DOM or applied in this form as fertilisers.	Nutrients such as nitrogen and phosphorus are freely available in this form for uptake by cyanobacteria, plants and animals.

Biological processes

Biological processes are those that maintain animal and plant populations. These include survival/reproduction mechanisms, dispersal/migration/regeneration, pollination and recruitment. Wetland and associated floodplain ecosystems offer the greatest capacity for maintaining biological processes.

Pre-European development, riparian vegetation in the Fitzroy basin was dominated by forested floodplain, forest, and woodlands (Figure 2.3.1). Woodlands and forests provide a number of processes for coastal ecosystems including regulating water flow (groundwater, overland flow), trapping sediment, stabilising sediments from erosion and assimilating sediments (Appendix H).

The Fitzroy basin has some of the most diverse and largest extent of freshwater and estuarine wetlands in the Great Barrier Reef catchment. These provide for important biological processes such as the recruitment of animals like prawns, barramundi, mangrove jack, mullet and crabs. The health and resilience of these wetlands are important to the health and resilience of species using them.

Fish communities inhabiting the rivers and creeks of the Fitzroy basin are being impacted by poor water quality, hydrological changes and loss of connection to important catchment habitat[38] (Figure 2.4.3). The construction of ponded pastures for cattle grazing has caused disturbances to coastal wetland vegetation structure, changes in hydrology and salinity regimes, with subsequent changes to biological processes.[38] The location of pondage banks which are adjacent to fish nurseries will likely result in changes to fish population movement and increase the risk of entrapment under specific flow regimes.[39] An additional stress to fish is increased coastal erosion due to land use impacts, especially during periods of high rainfall. Erosion can result in the siltation of waterways and estuaries, altering water flow and environmental characteristics for fish communities and habitats.[39]

Figure 2.4.3: Bund walls and road crossings can affect fishes' life cycles by blocking their passage upstream. Bund wall at Iwasaki Wetlands (Study Site 2) (photo: Jim Tait)

2.5 Connectivity

Aquatic ecosystem connectivity refers to how ecosystem components are linked, whether through air, water or by land. Disruptions to connectivity between different areas where fish breed and grow can lead to a reduction in population resilience, or even localised extinctions of some species. Figure 2.5.1 shows the sub-basin waterways that were considered by this assessment. Figure 2.5.2 shows the stream orders (classification system where waterways are given an 'order' according to the number of additional tributaries associated with each waterway) combined with land zones and elevation. These tools were used to assess connectivity.

The hydrology and drainage of the Fitzroy basin has been highly modified with the construction of dams, weirs and the Fitzroy Barrage that provide water for agriculture, industrial and urban uses, but are also barriers to fish movement. The connectivity between marine, freshwater lagoons and wetland habitats are vitally important to life cycles and the productivity of natural populations.[3]

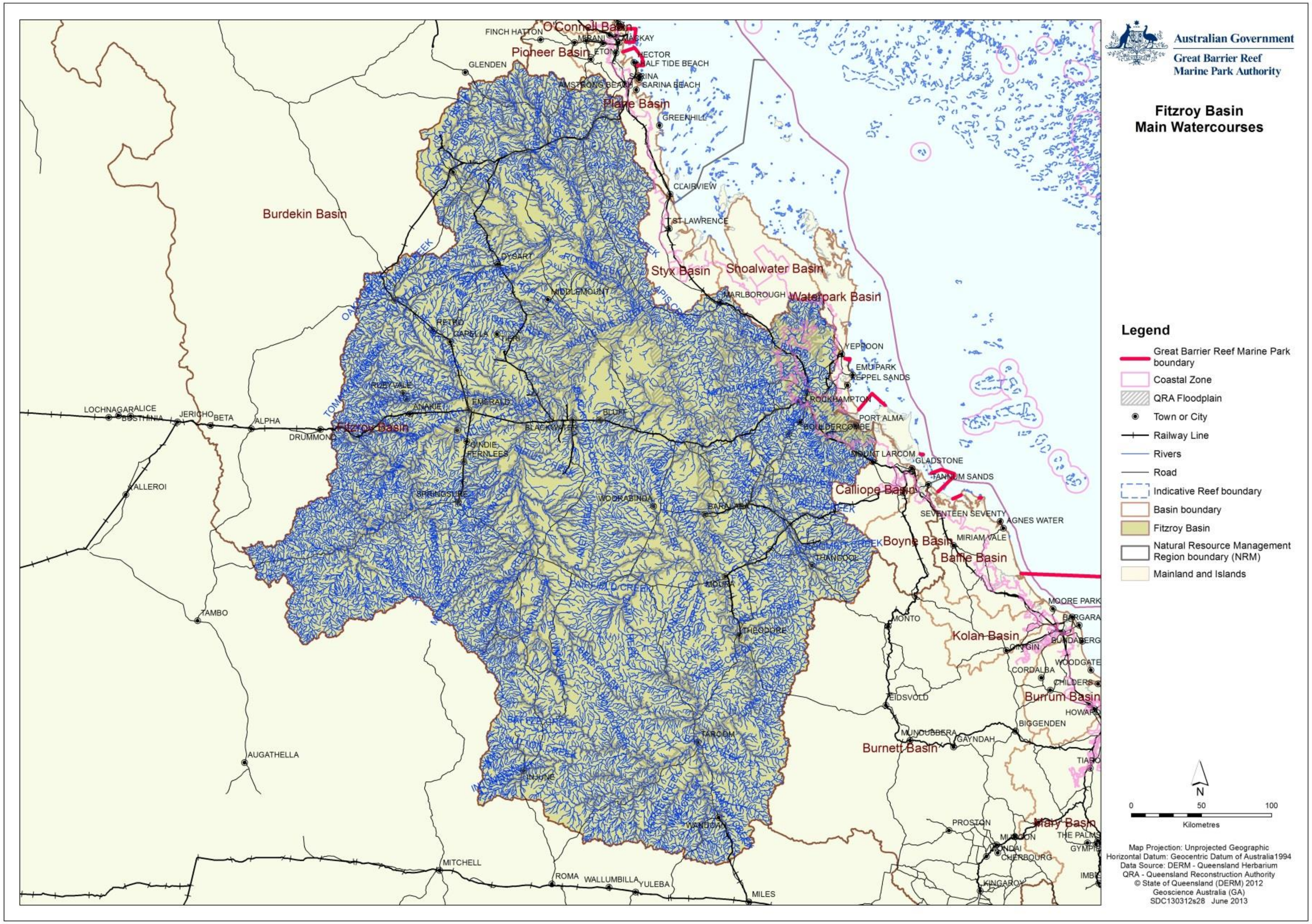

Figure 2.5.1: Major waterways in the Fitzroy basin considered in this assessment

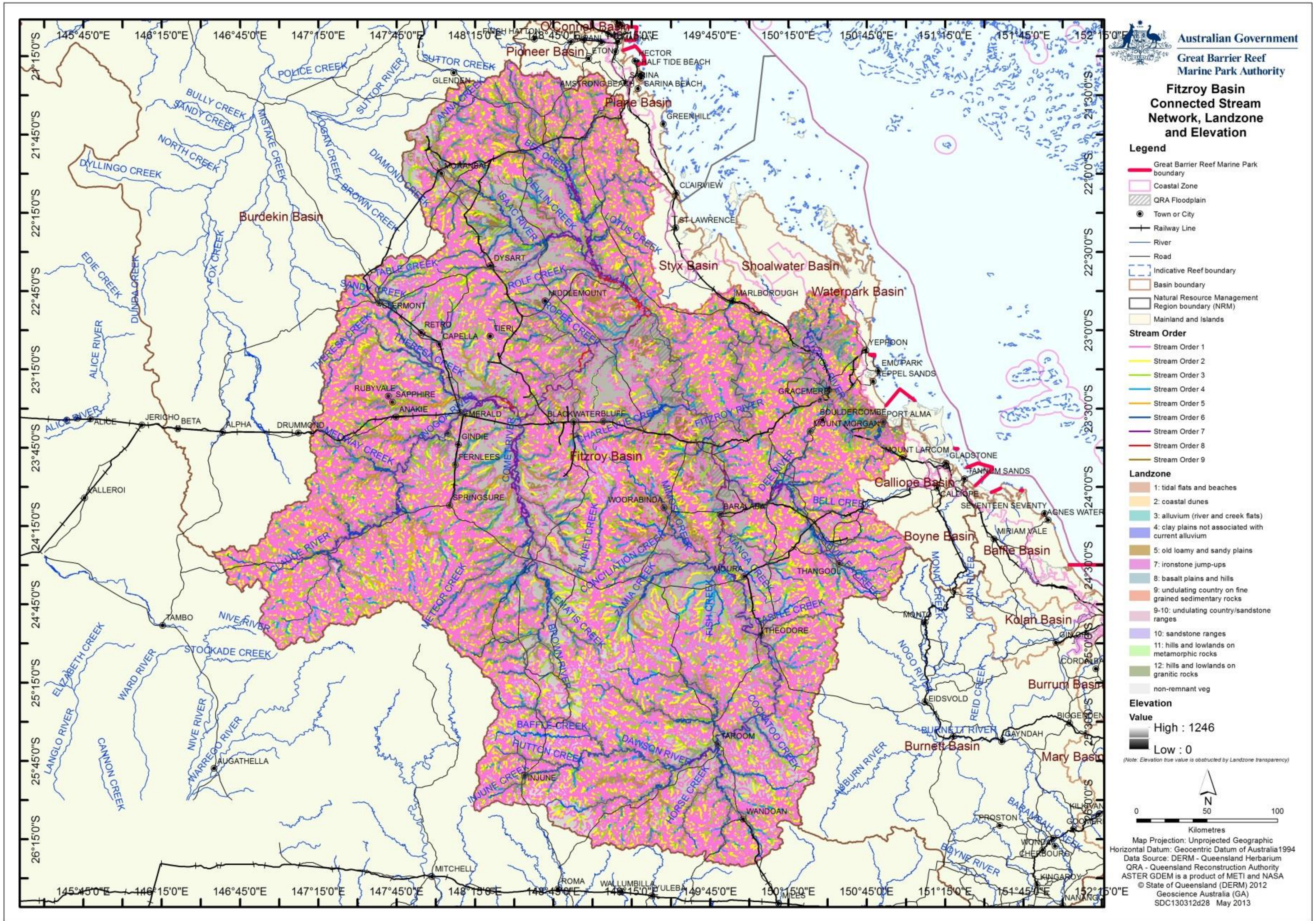

Figure 2.5.2: Stream order and elevation map showing the floodplain in the Fitzroy basin

Development within the Fitzroy region has been occurring for over 150 years. There has been extensive construction of coastal barrages to prevent the ingress of tidal waters to allow an expansion of cropping and grazing land, or through construction of roads accessing the coast Figure 2.5.3 and Figure 2.5.4).

Figure 2.5.3: Bund wall (left) and fish barrier (right) at Iwasaki Wetlands (source: Fitzroy Basin Association)

Figure 2.5.4: Ponded pasture on northern bank at the mouth of the Fitzroy River effectively acting as a barrage on tributaries of the river (photo: Jim Tait 2013)

Surface hydrology

Use of water within the Fitzroy basin underpins the entire social, environmental, and economic foundation of the area, and it is intrinsically linked to the day-to-day life of indigenous and non-indigenous communities.[3] Since European settlement, the Fitzroy basin has been heavily modified and large scale alterations have occurred to the natural river systems.[3] The hydrology and drainage of the Fitzroy basin has been highly modified through the construction of 29 dams and weirs that provide water for agriculture, mining, industrial and urban uses (Study Site 5).[11] The largest is Faribairn Dam which holds approximately 500,000ML. The majority of the dams and weirs found throughout the basin do not have adequate fishways to allow for natural fish migrations.[11]

Study Site 5 - Fitzroy River Barrage

The Fitzroy River Barrage (Study Site 5) at Rockhampton, located upstream of the estuary is a significant barrier to fish movement, and has modified tidal influence in the lower Fitzroy[28] (Figure 2.5.5). Environmental flow will be impacted to a lesser extent if effective fishways are constructed[11]. The general designs of existing Australian fishways have been based on northern hemisphere salmonoid fisheries, which have been shown to be inadequate for hydrology regimes and many fish species in Australia. The fishway associated with the Fitzroy River Barrage was initially ineffective; however several modifications have been made. The Barrage fishway still prevents passage by smaller fish of some specific species; however its effectiveness has generally increased. The few areas with no barriers are believed to be significant for maintaining many aquatic species populations. Fish barrier removal in the Fitzroy Basin Association region has become a priority, especially at the Tartus and Eden Bann weirs.[11]

Figure 2.5.5: Fitzroy River Barrage (Study Site 5) has not only modified tidal flows but also impacts fish passage (photo: Jim Tait)

As well as dams and weirs, fish barriers can include culverts, pipes, and road crossings. Dams and weirs are often used for irrigation supply, flow gauging, re-regulation, on-farm stock, and urban and industrial supply, flow management and flood control, or simply for urban beautification and recreation facilities.[3] Figure 2.5.6 (left) shows an old highway on Moores Creek (Study Site 6) which limits fish passage whereas the road crossing shown to the right shows good fish passage on Hedlow Creek (Study Site 7). The differences in these two fish passages are the heights of the structure. Smaller fish are more likely to be able to jump up the road crossing shown on the right.

Figure 2.5.6: Fish barrier at Moore's Creek (Study Site 6) (left) and passable fishway at Hedlow Creek (Study Site 7)

During the field work undertaken in March 2013, there were a number of cases where juvenile fish species were found congregating downstream of a fish barrier (Figure 2.5.7). These fish barriers increase chances of predation, reduce genetic transfer, and restrict access to preferred habitats and food resources.

Figure 2.5.7: Juvenile fish species congregated downstream of fish barriers at Iwasaki Wetlands (Study Site 2) (bottom photos: Jim Tait)

Constructed drains are found throughout the basin creating large water flows. These strong water flows create higher velocity and volume resulting in less residence time within natural systems such as mangroves and wetlands. This means that coastal ecosystems have insufficient time to treat water effectively before it is transported to the World Heritage Area. It also makes them largely impossible for many native fish to use.

Groundwater hydrology

The Fitzroy basin has access to three distinct sources of groundwater: alluvial soils, sedimentary rock and fractured rock aquifers.[40] The total groundwater resource use levels for the Fitzroy basin is approximately 943,200 mL per annum.[40] Irrigated agriculture occurs within the basin, and when direct access to river water supplies are not possible, irrigated agriculture is supported by groundwater supplies.[40] Groundwater supply is believed to be at risk of depletion and over-use among irrigators, accordingly this form of water supply is used mainly for small crops and pastures.[40]

Chapter 3: Impacts on the values

3.1 Drivers of change

The primary drivers of change for the Fitzroy basin are climate change, economic growth, population growth and technical development.

Climate change

The Queensland Government has carried out extensive mapping of coastal areas projected to be at risk based on climate change predictions up until the year 2070. The maps they produced factor in climate change impacts including sea-level rise of 30 centimetres and a 10 per cent increase in the maximum potential intensity of cyclones and associated storm surge at-risk areas and erosion prone areas.[41]

Information on climate change impacts is based on the most recent report from the Intergovernmental Panel on Climate Change (IPCC) – the international scientific authority on climate change. Property scale and area-based coastal hazard maps are available at http://www.ehp.gov.au/coastal/management/maps/index.html. Table 3.1.1 shows the regional climate change predictions for Central Queensland in relation to temperature, rainfall, evaporation and extreme events.

Woodlands and forests in the Fitzroy basin have been and will be most affected by invasive vegetation, changed fire regimes and extreme weather events that will become more commonplace as a result of climate change. Coastal wetland ecosystems will be impacted by sea-level rise, extreme weather events and changes in rainfall patterns, the water balance and hydrology as the demand for water increases.[42]

For a significant period prior to 2007, the Fitzroy basin experienced periods of extreme drought. From 2007-2013, the Fitzroy basin has experienced large flood events and good annual rainfall.

Table 3.1.1: The regional climate change predictions for the Central Queensland region for temperature, rainfall, evaporation and extreme events[43]

Element	Prediction
Temperature	Average annual temperature in Central Queensland has increased 0.5°C over the last decade (from 21.6°C to 22.1°C). Projections indicate an increase of up to 4.5°C by 2070, leading to annual temperatures well beyond those experienced over the last 50 years. By 2070, Rockhampton may have four times the number of days over 35°C (increasing from an average of 16 per year to an average of 64 per year by 2070), while Barcaldine may have nearly twice the number of hot days (increasing from an average of 87 per year to an average of 163 per year by 2070).
Rainfall	Average annual rainfall in the last decade fell by nearly 14 per cent compared with the previous 30 years. This is generally consistent with natural variability experienced over the last 110 years, which makes it difficult to detect any influence of climate change at this stage. Models have projected a range of rainfall changes from an annual increase of 17 per cent to a decrease of 35 per cent by 2070. The 'best estimate' of projected rainfall change shows a decrease under all emissions scenarios.
Evaporation	Projections indicate annual potential evaporation could increase 7–15 per

Element	Prediction
	cent by 2070.
Extreme events	The 1-in-100-year storm tide event is projected to increase by 51 cm in Gladstone and 32 cm at Cape Clinton if certain conditions eventuate. These conditions are a 30 cm sea-level rise, a 10 per cent increase in cyclone intensity and frequency, as well as a 130 km shift southwards in cyclone tracks.

Economic growth

Economic growth has been the major driver for the land use change that has occurred in the Fitzroy basin. The Fitzroy basin is resource rich (alluvial soils and mining) and many of the communities rely heavily on the resources and job opportunities that are created by mining and agricultural industries. The main commercial centres in the basin are Rockhampton, Emerald, Blackwater, Yeppoon and Biloela. To maintain long-term economic growth in the basin, communities must address issues of sustainable use of environmental assets.[40]

Currently, there are proposals for port expansion at Port Alma and the Fitzroy Terminal, which if approved are likely to generate more employment opportunities and promote expansion of some local industries including small business, fly in-fly out contractors, and heavy machinery maintenance and expansion of urban centres including in Rockhampton, Yeppoon and Emerald.

Population growth

The Fitzroy basin has low population densities, particularly in the northern and western parts.[3] Intensive urban residential development is mostly confined to the central and coastal portions of the basin and is linked to the city of Rockhampton. As of 30 June 2012, the estimated population of Rockhampton Regional Local Government Area was 115,399. By 2031 the population is expected to be 162,893.[44]

The Queensland Government expects the average annual population increase for the Fitzroy basin to be 2.1 per cent per annum. Population growth has been the driver for the expansion of the Rockhampton region.[45] It is expected that population growth will occur in the smaller townships, especially along or close to the coast within the Fitzroy basin, if new mining and irrigation projects continue to be developed.[40]

Technological development

Improved machinery and use of agricultural chemicals (herbicides and pesticides) have allowed for efficient management of vegetation and pests for increased productivity both in intensive and extensive agriculture. This has also led to increasing loss of sediment, nutrient and agricultural chemicals to the environment.

Technical development, primarily dams and weirs, have provided capacity to build extensive drainage networks and ponded pastures, transforming wetlands and a large part of the river floodplains into productive agriculture. This has resulted in significant modification of ecological functions these environments once provided. Small streams and seasonal creeks

have been developed and channelised, increasing flow rates and altering their ecological functions and the ecosystem services they once provided.
In more recent times improved land management practices within the grazing industry (such as cell and rotation grazing) have led to reductions in erosion and improvement in water quality.

3.2 Activities and impacts

Historically, the dominant land use in the Fitzroy basin has been grazing. Today the dominant land uses within the Fitzroy basin remain as grazing and dryland production. These industries support the urban centres of Rockhampton, Emerald, Blackwater, Clermont, and Dysart. Land use for 1999 and 2009 is shown in Table 3.2.1 and Figure 3.2.1. Note that the appearance of water - production ponded pastures is a result of the recognition of this land use in 2009.

Table 3.2.1: Major land use categories (hectares) for the Fitzroy basin in 1999 and 2009 based on Queensland Land Use Mapping Program data

	Land use area (ha) - Fitzroy	1999	2009
	Conservation, natural environments (inc. wetlands)	681,688	848,987
	Forestry - production	951,361	894,319
	Grazing natural vegetation	11,642,751	11,365,161
	Intensive animal production	532	1,172
	Intensive commercial	3,000	14,496
	Intensive mining	54,842	99,961
	Intensive urban residential	27,892	33,109
	Production - dryland	797,709	801,587
	Production - irrigated	73,377	124,992
	Water - production ponded pastures	494	17,703
	Water storage and transport	27,601	59,808
	Not Mapped	68	20

Figure 3.2.2 shows the extent of land use changes which have occurred from 1999 and 2009. Grazing occurs throughout the basin with the majority of dryland production occurring around central inland areas. Mines, gas fields, urban and industrial development, agricultural land use intensification, and water infrastructure construction have all expanded significantly in that period and are all likely future development activities which could result in further pressures on coastal ecosystems.[11] These need to be managed with innovative approaches and legislative controls to reduce further coastal ecosystem degradation.

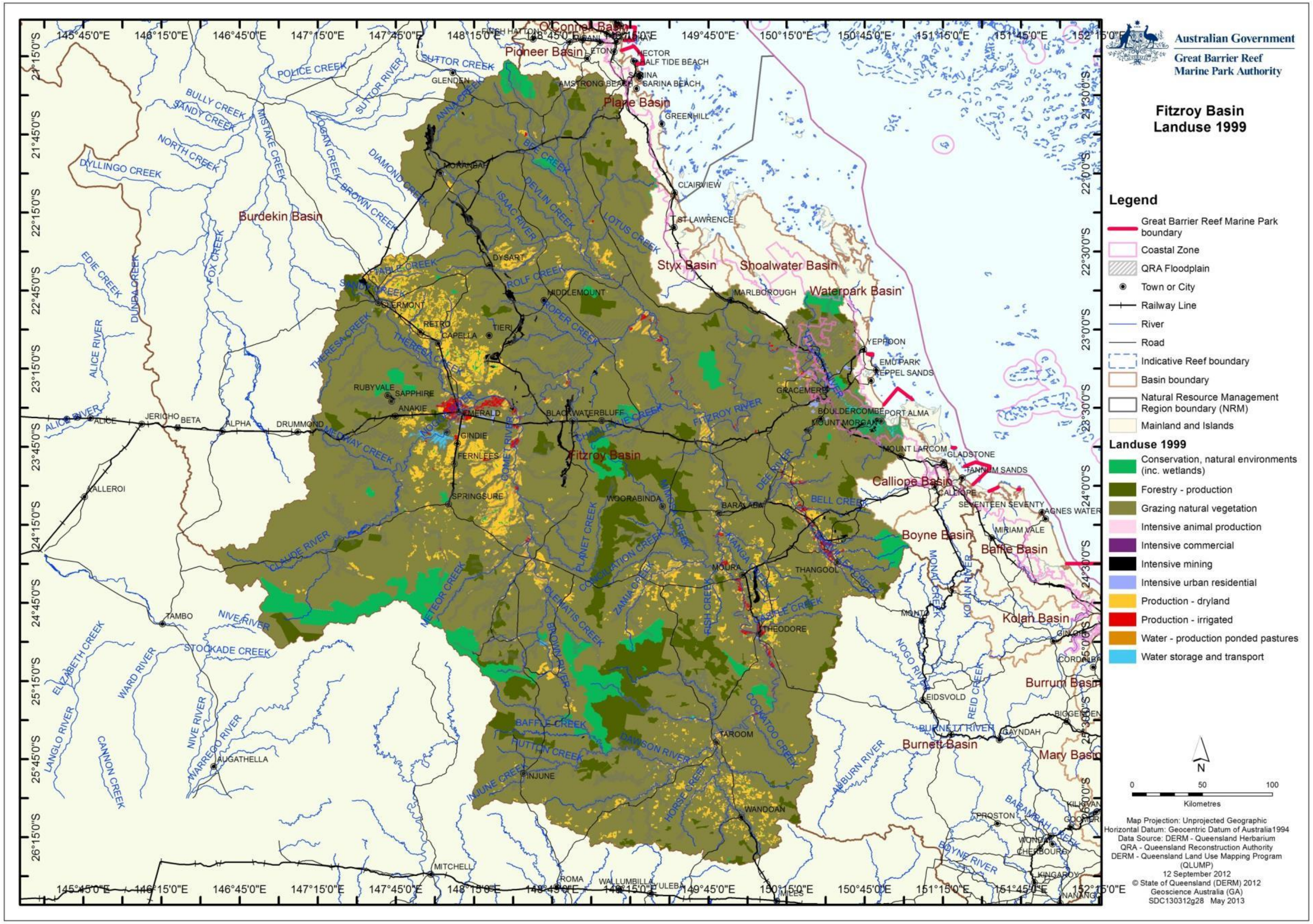

Figure 3.2.1: Map of land use for the Fitzroy basin based on 1999 QLUMP data

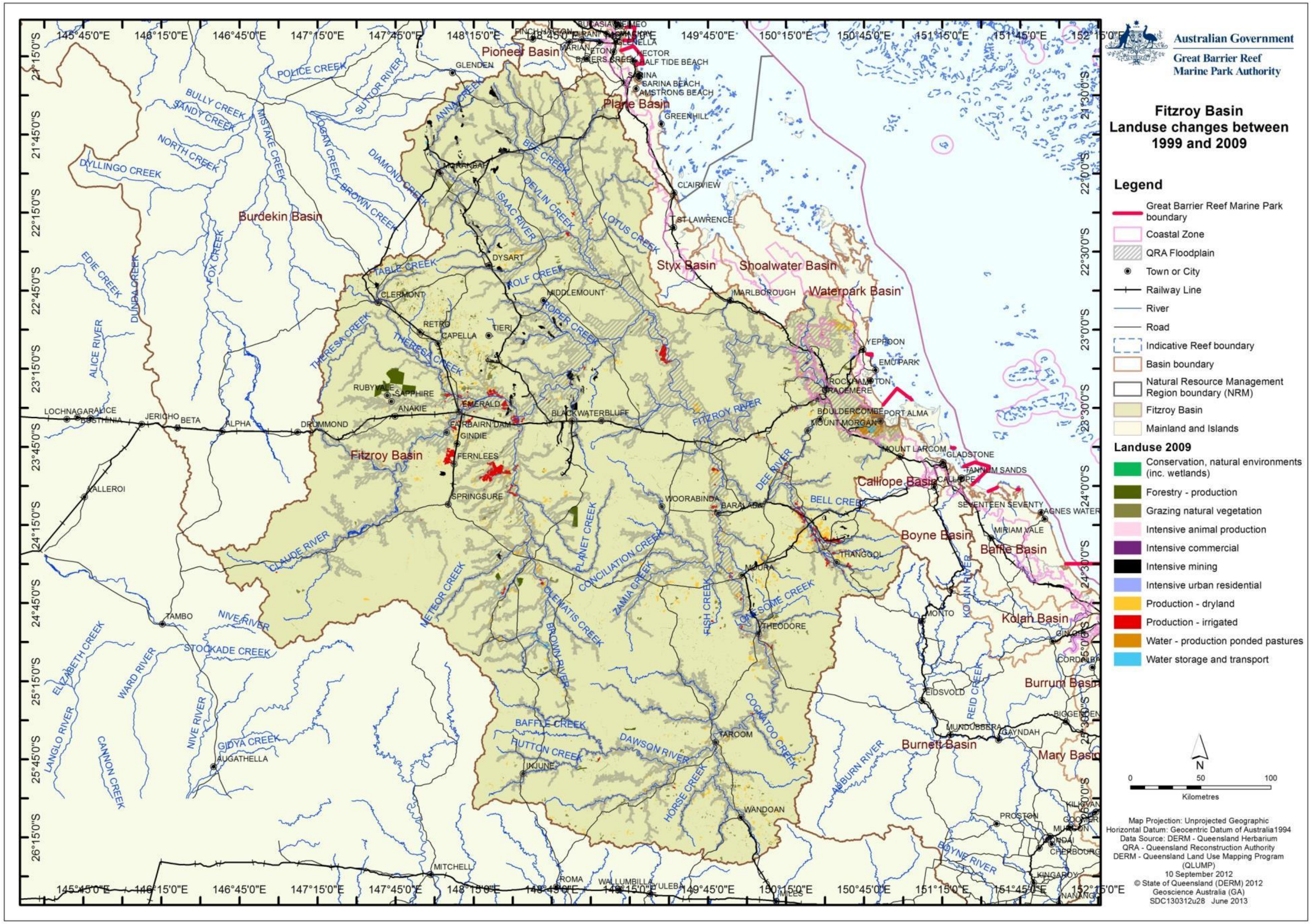

Figure 3.2.2: Map showing areas of changed land use in the Fitzroy basin based on 1999 and 2009 QLUMP data

Land use within the coastal zone

Land use adjacent to the coast (the coastal zone) can have the greatest impact on the World Heritage Area's inshore waters. The coastal zone includes Queensland's coastal waters (which extend three nautical miles out to sea), coastal islands and land below 10 meters Australian Height Datum or within five kilometers of the coastline, whichever is greater. The land use occurring within the coastal zone for 1999 and 2009 is shown in Table 3.2.2 and Figures 3.2.1 and 3.2.2. Approximately 15 per cent of the coastal zone is within protected areas and another 61 per cent is grazed natural areas. Only three per cent of the coastal zone is used intensively for mining, commercial use, animal production, or urban residential.

Table 3.2.2: Major land use categories (hectares) for the Fitzroy basin coastal zone in 1999 and 2009 based on Queensland Land Use Mapping Program data. Note the decline in Conservation, natural environments is due to greater resolution of mapping which has delineated the water-marsh/wetland production areas (ponded pastures)

	Land use area (ha) - Fitzroy Coastal Zone	**1999**	**2009**
	Conservation, natural environments (inc. wetlands)	37,194	24,810
	Forestry - production	116	99
	Grazing natural vegetation	108,160	98,580
	Intensive animal production	57	30
	Intensive commercial	804	2,395
	Intensive mining	2,506	717
	Intensive urban residential	2,505	3,161
	Production - dryland	1,486	2,705
	Production - irrigated	2,154	2,035
	Water - production ponded pastures	65	17,475
	Water storage and transport	5,995	9,102
	Not Mapped	68	0

3.3 Actual and potential impacts from key activities

The main impacts to the World Heritage Area from land use in the Fitzroy basin historically is primarily associated with land cleared for grazing and agricultural use.[11] Inappropriate management of grazing, particularly in response to climatic variability, has resulted in the decline of native grasses and land condition.[46]

Sediment, nutrient, and phosphorus loads delivered to the World Heritage Area from the Fitzroy basin were stated to be reduced from 2005 to 2008.[11] Prior to 2007, the Fitzroy basin experienced a period of extreme drought which has resulted in some areas in less than 30 per cent ground cover. From 2007-2013, the Fitzroy basin has experienced large flood events and good annual rainfall which has increased ground cover to over 80 per cent.[47] Improved agricultural management (such as maintaining high ground cover levels and the retention of appropriate riparian buffers) and annual rainfall is improving land condition generally and therefore improving water quality and reducing pressures on the Reef.[11] Other activities and developments in the basin may be relatively small in area, however may contribute significantly to cumulative impacts on the World Heritage Area (for example, increased intensity of land use).

Forestry

There is 946,502 hectares of forest and rainforest allocated as production forestry in the Fitzroy basin. Forestry areas only pose a risk to the World Heritage Area during harvest when clearing may lead to erosion and increased sediment run-off, however this is dependent on forestry practices and is not as substantive as the impacts from grazing and intensive agriculture.

Grazing natural vegetation

Localised land clearing occurred during the first 100 years of settlement in this region for cattle and sheep grazing, cultivation and mining activities.[11] From the 1960s to 1980s clearing rates intensified under the Brigalow Development Scheme, which resulted in some of the fastest rates of land clearing recorded in the world.[11] There is 12,148,650 hectares of dryland grazing in the Fitzroy basin making it the highest land use within the Great Barrier Reef catchment. There has been a decline in grazed area since 1999 (12,421,041 hectares) due to the increase in conservation areas, mining, and irrigated production.

Grazing can impact water quality by altering vegetation in catchments and, where cattle drink directly from natural waters, by increasing erosion turbidity and nutrient inputs. In the short term, grazing reduces ground cover and overgrazing can leave the soil disturbed, with minimal cover and vulnerable to erosion when it rains, resulting in increased movement of sediment into waterways. Longer term impacts of overgrazing are a decline of perennial grasses in pasture leaving it less resilient to dry periods (i.e. susceptible to greater decline in ground cover), vulnerable to invasion by weed species and reduced diversity and health of riparian vegetation.

Decline in pasture condition and ground cover has led to greater run-off and erosion, thus increasing sediment and nutrient loads and flow rates into streams within the catchment that discharge into the Reef.[11] Erosion rates from a range of land uses and land scales (plots to catchments) have been measured and are presented in Appendix I.

Sediment loads have significantly increased in the last 150 years due to extensive land clearing and subsequent land uses, and have been linked to the decline of freshwater, estuarine, and marine ecosystems including the World Heritage Area.[1,3] Coarse sediments alter river habitats by infilling beds and degrading benthic habitats.[11] Keppel Bay (adjacent to the Fitzroy basin) is home to reefs with some of the highest coral cover of any within the Marine Park, these inshore reefs are at risk from the impacts of sediments, nutrients, and pesticides.[11]

Nutrient loads have increased due to the use of fertilisers and accelerated erosion. When fertilisers are applied at a higher rate than needed, the excess fertiliser can leach from soil and make its way into river systems via run-off.[11] Nutrients can cause severe ecological effects and degrade water quality. Excess nutrients drive large algal blooms which restrict light penetration; they also favour macroalgae communities over coral communities.[11]

Stock access to riparian vegetation has been reported as the main contributor to poor riparian condition.[1] The small streams within the Fitzroy basin are relatively intact and in fair condition, with good riparian and in-stream habitat while many of the larger streams show signs of degradation from agriculture and grazing.[3] Good riparian management is necessary to reduce sediments, nutrients, and pesticides transported from the land into streams and potentially to offshore regions.[1]

Grazing has led to an increase in varying densities of weed infestation throughout the Fitzroy basin. Weeds reduce pasture productivity and can out-compete more desirable grasses and plants[48] and ultimately result in poorer ground cover and an increased risk of erosion. Significant weed threats include Lantana, hyacinth and hymenachne. The Fitzroy Basin Association has invested approximately $1.7 million on weed control from 2007 to 2013 (S. van Nunen, 2013 (Fitzroy Basin Association) per. comm., 4 June). Lantana is an ongoing concern for many landholders and can cost the Australian grazing sector in excess of $104 million per annum.[49] Lantana is highly toxic and can cause deaths in cattle, especially calves.[49] Another impact from grazing is the introduction of exotic grasses (para grass and hymenachne). Weed invasion in riparian vegetation results in loss of diversity and decline in function which leads to poor connectivity between coastal ecosystems. Aquatic weeds also have detrimental impact on stream health and can impede fish passage.

Fifty three per cent of graziers within the Fitzroy basin are now recorded as implementing Best Management Practices (BMP) under the Reef Water Quality Protection Plan. This involves using practices that are likely to maintain land in good to very good condition or to improve land in lesser condition. Good management practices in dryland grazing areas focus on controlling grazing distribution and pressure to maximise cover at the end of the dry season and for long-term good condition and resilience of the pasture. Fencing off riparian areas and watering infrastructure is also a desirable practice for preserving good water quality.[47] Healthy riparian vegetation assists in reducing sediment, run-off into creeks and streams, thus preserving functioning and healthy aquatic ecosystems and minimising the subsequent export of nutrients and sediments from the catchment to the World Heritage Area.[48]

Figure 3.3.1: Riparian fencing located at Mystery Park (Study Site 8) and good condition pastures providing excellent cover to protect the soil by reducing run-off and sediment loss into waterways

Study Site 9 - Melrose

Melrose, located northwest of Rockhampton, is a beef grazing station run by Jeff and Karen Mills and is a good example of best practice in grazing management. The station consists of riparian vegetation and remnant woodlands. Melrose has implemented a rotational grazing system which aims to optimise pasture utilisation and condition. Implementation of rotational grazing cells has increased ground cover and reduced sediment loss. They have established additional watering points and paddocks to achieve more even grazing which is important to maximise end of dry season cover and maintain and improve long-term land condition. They are protecting natural vegetation and reducing the impacts of grazing on their property by fencing riparian areas, allowing regrowth of native woodlands and pasture grasses (including Queensland bluegrass) and they no longer use chemicals on their cattle. Although this additional infrastructure increases maintenance requirements, this is more than compensated for by the benefits of better groundcover and land condition resulting in improved water quality and animal production, and enabling more effective weed management. They are recognised for promoting sustainable farming practices through the Great Barrier Reef Marine Park Authority Reef Guardian Farmers and Graziers Program.

Figure 3.3.2: Water infrastructure at Melrose, established away from riparian areas to protect them from the impact of the use by cattle

Figure 3.3.3: Good condition pastures at Melrose resulting from rotational grazing, provide excellent cover to protect the soil by reducing run-off and sediment loss

Intensive animal production

There is 1,172 hectares of intensive animal production scattered throughout the Fitzroy basin. There is also the possibility of increased coastal aquaculture, which could alter coastal foreshore, estuarine, mangrove, salt marsh and marine and other aquatic environments.[50] Environmental impacts associated with aquaculture includes water pollution, pest species, pressures on wild fish populations for feeding and brooding, and the culling of natural predators.[50]

Intensive commercial

The city of Rockhampton is the main centre for intensive commercial infrastructure and is located on the Fitzroy floodplain which was previously forested floodplain and woodlands.

Port Alma (Study Site 11) is the only port area in the Fitzroy basin, and is located approximately 60 kilometres from Rockhampton on the southern end of the Fitzroy River delta. This port has a small throughput (less than three million tonnes in 2011-12) and would be considered a minor port when compared to a larger port, for example Gladstone (>80 million tonnes in 2011-12). Port Alma specialises in the transport of explosives[28] including ammonium nitrate, bulk tallow and military equipment (Figure 3.3.4). Commercial salt mining is undertaken near Port Alma (Cheetham Salt and Pacific Salt) with approximately 2700 hectares of salt evaporation ponds.[28]

Figure 3.3.4: Port Alma (Study Site 11) specialises in the transport of explosives

Study Site 11 - Fitzroy Terminal Project (under assessment) and Balaclava Island Coal Export Terminal (application recently withdrawn)

With plans for 17 additional major coal mines in the area, coal terminal expansion has also been proposed for the region.[11] Eberhard (2012)[28] has reviewed the issues associated with proposed developments within the Fitzroy River estuary. Including the two independent proposals, the Balaclava Island Coal Export Terminal and the Fitzroy Terminal Project (Figure 3.3.5 and 3.3.6). The Balaclava Island Coal Export Terminal would have been larger than the Fitzroy Terminal Project and the facility planned to export 35 Mtpa at Balaclava Island, directly loading coal onto ships however, the Balaclava Island Coal Export Terminal proposal has currently been withdrawn. There are two stages to the proposed Fitzroy Terminal Project project; the first will handle approximately 10 Mtpa and the second stage will handle 22 Mtpa. The Fitzroy Terminal Project may require dredging. Additionally, two further developments have in the past been proposed by Gladstone Ports Corporation, a Queensland Government-owned port authority; however no formal applications have been prepared for assessment and approval of these proposals.[28] The first proposal involves the expansion of 3 additional berths to the Balaclava Island facility. The second proposal involves the development of a major port facility on north Curtis Island. These were identified in the port's 50 year strategic plan[51] which has since been revised.

Figure 3.3.5: Port Alma located at the mouth of the Fitzroy River

Figure 3.3.6: The proposed Fitzroy Terminal Project expansion project located at Balaclava Island

An independent report by Eberhard (2012)[28] outlined the potential implications of these port development proposals. If the projects were to proceed as planned and without considering potential mitigation measures and offsets, vegetation clearing may result in disturbance to wetlands and connectivity, soil exposure and erosion, benthic habitat removal and modification. Aquatic environments may be exposed to acid sulfate soils, turbidity and sedimentation. Noise and dust pollution, as well as boat traffic and contamination by oil and fuel may also increase. Additionally, marine debris, introduced species and greenhouse gas emissions are likely to increase (Appendix I).[28]

A major concern is the cumulative effects of many of these threats. Port expansion has the potential to have ecological impacts on the surrounding coastal zone. This coastal area is habitat for four species of turtles, all of which are listed as endangered under state and Commonwealth conservation legislation. A highly significant flatback turtle nesting site is situated at Peak Island, adjacent to the proposed Fitzroy Terminal Project ship mooring site. Additionally, three species of inshore dolphins (Australian snubfin dolphin, the Indo-Pacific humpback dolphin and the Indo-Pacific inshore bottlenose dolphin) inhabit areas around the Fitzroy estuary. The Australian snubfin dolphin is of particular concern as it is Australia's only endemic dolphin and the Fitzroy basin is known to have fewer than 90 individuals. This dolphin has a restricted home range and is only found in a small area of the Fitzroy estuary in the same location as the proposed port operations and shipping channel[28]. Fitzroy Terminal Project port expansions may involve dredging which will be located approximately 1 km away from important nursery and fish spawning areas for many fish species, in particular, barramundi.

Intensive mining

Large mineral deposits found throughout the basin support a large number of mines, particularly, coal production.[11] Coal mining covers less than one per cent of the Fitzroy basin area; however coal mining is the basins largest economic asset. In 2007-2008, Queensland exported approximately 152 million tonnes of coal.[11]

In regions where coal is too deep to mine, gas fields have been proposed that will cover a large area.[11] One of the implications of gas production is the release of salt laden groundwater to coastal waters.[11] Increases in salinity in water systems can have profound and measurable effects on ecosystems resulting in toxic effects on freshwater aquatic animals, loss of habitat, biodiversity, native vegetation and water resource value.[11]

Mine water discharge is an emerging issue with regards to saline releases, which impact freshwater ecosystems (Study Site 12). Mine discharges in 2007-2008 raised salinity levels dramatically in the Isaac, Mackenzie and Fitzroy rivers.[11] Mining procedures can also influence water quality due to water harvesting, stream diversions and unstable landforms from mining spoil and slumping.[11]

Study Site 12 - Mount Morgan Mine

Mount Morgan is an abandoned mine located 32 kilometres south west of Rockhampton. The mine began operations in 1882 and was closed in 1990. The mine extracted gold (250 tonnes) and copper (360,000 tonnes) as well 134 million tonnes of waste rock and tailings. The mine has left ongoing legacy issues including large waste rock and tailings dumps, and a water filled void which have been left over from mining and mineral processing.[52] These legacy issues create acid rock drainage and low quality seepage into the adjacent Dee River (Figure 3.3.7).[52] The characteristics of acid rock drainage include low pH, high levels of iron and sulphate, and heavy metals such as aluminium, copper, lead, zinc and cadmium. Monitoring of the Dee River shows that significant impacts to water quality occur within the first 20km downstream of the Dee River, from here the water quality substantially improves due to dilution from other freshwater catchments and continues to improve with further distance downstream.[52] Potential rehabilitation has occurred at the Mount Morgan mine since 2000 and focuses on reducing contaminated run-off, minimising risks of spills from the contaminates void and, where possible and resourced, progressively remediating the mine site.[52]

Figure 3.3.7: Mount Morgan mine site (Study Site 12) (left), acid rock drainage in the Dee River (Study Site 10) (middle and right) (photos: Jim Tait)

Intensive urban residential

The residents of the Fitzroy basin are located primarily within the town centres of Rockhampton (Figure 3.3.8) and Emerald. The urban footprint of Rockhampton is expected to increase north along the Bruce Highway.[53]

Run-off from urban areas will continue to impact on water quality entering the World Heritage Area. Water sensitive urban design is one method that can assist in maintaining or improving water quality outcomes from urban areas. Urban development should also be avoided in areas such as wetlands, riparian zones and flood prone areas.

Figure 3.3.8: Urban development in Rockhampton city

By 2031, the population of Rockhampton is expected to be 162,893[44] and no firm decisions have been made to upgrade the basin's largest Sewage Treatment Plants.[11] Sewage discharge in the Fitzroy basin includes the Capricorn Coast Service Network, Gracemere Sewerage Network, South Rockhampton Sewerage Treatment Plant and the West Rockhampton Sewerage Plant (Table 3.3.1). Other smaller settlements are currently not sewered and impacts on the World Heritage Area are unknown.

The Fitzroy estuary is a unique estuary with extensive wetlands that support fish and bird feeding, breeding and migration. Fish stocks within the estuary support recreational and commercial fisheries.[28] The upper end of the estuary passes through the Rockhampton urban area and receives treated effluent from three sewage treatment plants, as well as two abattoirs that have licenses to discharge further downstream. One abattoir discharges waste including organic and nutrient loads, the other abattoir no longer discharges into the Fitzroy River.[54] These discharges can result in nutrient enrichment of the estuary, resulting in increased algal growth[4] which can impact fisheries and ecosystems. The sewage treatment plants in Rockhampton would need to be upgraded to minimise the potential for eutrophication.[11]

Table 3.3.1: The status of wastewater treatment in the main urban centres in the Fitzroy basin[55]

Urban centre	Wastewater treatment
Rockhampton South	Comprises an inlet works for screening and grit removal, primary sedimentation, activated sludge treatment, secondary sedimentation and final effluent chlorination before discharge. It has a design capacity for a population of 12,000 plus commercial and industrial components. The final effluent is discharged into the Fitzroy River.
Rockhampton West	Is a conventional trickling filter system and operates by combining screened and de-gritted sewage with humus return that is treated through a trickling filter. Has a design capacity of 11,000 equivalent persons.
Rockhampton North	Currently serves a population of 37,300 persons plus commercial and industrial components. Comprises primary screening and grit removal. Effluent then passes into an extended aeration activated sludge plant with two oxidation ditches. The 'mixed liquor' produced in the oxidation ditches passes to the clarifiers to settle and the effluent drawn off, disinfected with chlorine and discharged into the Fitzroy River.
Gracemere	Is a conventional gravity reticulation network. Treated effluent is irrigated to pasture adjacent to the plant and also pumped onto Gracemere Golf Club.

Urban centre	Wastewater treatment
Yeppoon	Provides a service to Yeppoon, Pacific Heights, Meikleville Hill, Barlow's Hill, Cooee Bay, Taranganba, Lammermoor Beach, Statue Bay, Mulambin Waters and Rosslyn Bay.
Yeppoon West	Effluent is re-used for irrigation on parks, golf courses and other open space areas.
Emu Park	Provides a service to Tanby Point, Emu Park, Zilzie, and Great Barrier Reef Resort. Services a population of 3,000. The Emu Park sewerage system is based on a conventional sewerage reticulation system and includes gravity sewer mains, sewerage pump stations, sewerage rising mains, a sewerage treatment plant, treated effluent reuse and treated effluent disposal. There is no nutrient removal process. In dry weather conditions, all treated effluent is re-used by the Emu Park Golf Club.

Production – dryland

Dryland production represents the second largest land use in the Fitzroy basin (Figure 3.2.1) and has increased from 798,462 hectares in 1999 to 802,730 hectares in 2009.

Dryland production occurs predominantly in the west of the catchment and includes grains, cotton and horticulture. Dryland production can cause a number of land use impacts including declining water quality due to fertiliser application, erosion, low ground cover and poor riparian vegetation. Freshwater, coastal, and reef aquatic ecosystems that receive run-off from the Fitzroy basin are under threat due to deterioration of water quality brought about by changes in land use and continued use of some out-dated land management practice.[11] Fertilisers are used throughout the region to improve yield of crops and pastures. When fertiliser application is greater than that required by the crops, excess can be lost to river systems via run-off, affecting and placing pressure on water quality and the World Heritage Area.[11] Therefore, it is important for growers to optimise fertiliser application which in turn will reduce nutrient losses in run-off.[11] Wheel tracks from heavy machinery can also have water quality impacts by compacting soil and creating furrows for water to run down, which results in erosion.[56] Some growers are therefore introducing controlled traffic systems and modifying their machinery, for example increasing the width, allowing all machinery to repeatedly use the same tracks, minimising compacted areas and thus maximising infiltration.[56]

Currently in the Fitzroy basin there are three pesticides which have been recorded above water quality guidelines. These include Atrazine, diuron and tebuthiuron. Atrazine and diuron are used for weed control generally in intensive agriculture, and tebuthiuron is used for woody weed control on grazing lands. Recent studies have shown that pesticides can cause damage to marine organisms at relatively low concentrations, inhibiting the growth of aquatic plants, algae and seagrasses, as well as corals.[11] The impacts of these pesticides can be reduced by using best management practice including: maintaining riparian vegetation, avoiding application when rain is expected and avoiding application close to waterways.[11] Within the Fitzroy basin growers are implementing best management practices and improving the quality of water leaving their farms. Farmers are concentrating on improving water, nutrient and pesticide application through more efficient machinery and land management practices.[56]

Production – irrigated

In 1999, the Fitzroy basin had 75,586 hectares of irrigated agriculture. In 2009, irrigated agriculture had increased to 129,128 hectares. Irrigated agriculture mainly occurs in Emerald and Theodore. Other small areas of intensive agriculture occur along all major rivers and streams in association with weirs and water harvesting.[11]

Cotton is the main irrigated crop in the Fitzroy basin and predominantly occurs in the Dawson, Mackenzie and Nagoa rivers in the upper catchment areas. Farmers also grow a range of irrigated and dry land crops on their land including citrus and grapes.[11,40] Irrigated production can cause a number of impacts including accelerated delivery of sediments and associated nutrients, excess water quantity use including changed hydrology, water quality degradation, condition decline of riparian vegetation, incidence of foreign biota, loss of nutrients applied as fertilisers, pesticides over-applied and or applied during adverse conditions.[11] High levels of suspended solids, nutrients, and agrochemicals are exported to Keppel Bay and the Marine Park as a result of unsustainable land management and land use intensification.[11]

Irrigation generally relies heavily on water storages and they need to be sufficient to meet the losses associated with storage and delivery evaporation, as well as providing the need to meet crop requirements.[40] Around Mackenzie, Isaac and Dawson rivers, landholders are particularly interested in increases in water allocation for production of irrigated cropping.[1]

The cotton growing industries have developed best management practices that include the maintenance of riparian areas, reduction of fertiliser and pesticides used and the recycling of water.[56] Further information on best management practice for the cotton industry can be found at http://www.bmpcotton.com.au/.

Water – marsh/wetland production

In 1999 the Queensland Land Use Mapping Project identified the Fitzroy basin had 2,652 hectares of marsh wetland production (ponded pastures) however, in 2009 this increased to 84,703 hectares. This is largely due to changes in land use categories which provide more accurate representation of ponded pastures, which in 1999 were categorised as water storage areas.

Historically, Government sought to increase the extent of grazing land in many parts of the catchment and to expand dry land agriculture (Brigalow Scheme). Constant grazing often involved the bunding of coastal salt pan areas to prevent tidal ingress, allowing pasture grasses to become established. These areas, known generally as ponded pastures, are mapped as ‘wetland production’ under the Queensland Land Use Mapping Project (2009) classification. Areas of ponded pasture on or near the coast prevent the exchange of tidal waters into freshwater wetlands, a process which historically reduced the extent of grass and sedgelands seasonally. This in turn reduces the natural production in those salt marshes and inshore coastal waters, leading to unintended declines in inshore fish and invertebrate productivity.

There are a number of ponded pastures located around the Fitzroy River estuary. These ponded pastures have significant impacts on fish movement and their preferred habitat especially during juvenile life forms[1,48] (Figure 3.3.9). Generally, ponded pastures impact negatively on coastal ecosystems however; at Iwasaki Wetlands these bunds have in this instance created healthy freshwater marshes and ponds which provide a nursery, and feeding and breeding habitats for key recreational and commercial fish species for the Marine Park including barramundi, and for a range of wetland and migratory birds.

Figure 3.3.9: Ponded pasture used for grazing at Hedlow Creek (Study Site 1)

Water – intensive use and water-storage and treatment

Major land use changes are planned within the Fitzroy basin. In 2008, five dams and weirs were planned for construction or extension that would have the combined capacity to capture 1,200,000 ML of water.[11] To date, the Connors Dam project at Mount Budget has been discontinued and the Comet River Weir Dam is unlikely to proceed. The Nathan Dam on the upper Dawson River is still proposed. This dam proposes to hold half the volume of the Burdekin Falls Dam, which is approximately 888,000 ML.[57] This dam is a major initiative with the long-term goal of providing reliable water supplies to mining, power, urban and existing agricultural customers in the Surat Coal basin and the Dawson-Callide sub-region of central Queensland.[57] The proposed site of the dam is upstream of the Nathan Gorge on the Dawson River, approximately 70km downstream from Taroom, and 315km upstream from where the Dawson and Fitzroy rivers meet. Additionally, the Nathan pipeline has been proposed, which will run from the Nathan Dam through the Surat basin, potentially extending as far to the West as Dalby (a total of 260km).[57] If approved, this dam will result in flooding of grazing land, riparian habitat, and some areas of conservation value and open up land for further intensive agriculture. Water infrastructure has the potential to influence aquatic ecosystems by limiting fish migration and changes to the flow regimes and water quality. Impacts from barriers to fish migrations and movement can sometimes be minimised with the construction of effective fishways.[11]

Dams are a significant modification to the landscape and may result in consequential impacts, such as adjacent land use being changed from grazing to irrigated agriculture (cotton and grains) and further development of mining sites and commercial centers. In terms of changing the existing land used for grains, cotton and aquaculture, large changes will only occur if extra water is available, thus land use changes are highly dependent on availability of secure water supplies.

PART B: OUTCOMES OF BASIN ASSESSMENT

Chapter 4: Projected condition of Great Barrier Reef catchment values

4.1 Summary of current state of coastal ecosystems

Coastal ecosystems in the Fitzroy basin have been highly modified. From 1960 to the 1980s, the Brigalow Scheme promoted widespread clearing of woody vegetation and encouraged agricultural development. Coastal ecosystems that have been most affected are rainforests, forests, woodlands and forested floodplains (Table 4.1.1). In the coastal zone, estuaries (saltmarsh, saltpan) in many areas have been bunded for the purposes of ponded pastures, which has resulted in a small increase in freshwater wetlands in the coastal zone (Table 4.1.1). These changes have compromised the ability of many coastal ecosystems to provide ecological services to the World Heritage Area.

Table 4.1.1: Percentage of remaining coastal ecosystems in the Fitzroy basin. Orange cells indicate areas with 10-30 per cent remaining; yellow 31-50 per cent and green greater than 50 per cent. Note these figures provide no information about ecosystem condition or functionality. Pink cells denote an increase in area

Fitzroy basin % coastal ecosystems remaining	Rainforests	Forests	Woodlands	Forested floodplain	Grass and sedgelands	Heath and shrublands	Freshwater wetlands	Estuaries
Fitzroy basin	36	43	39	39	32	82	74	86
Floodplain	12	13	25	38	33	100	77	86
Coastal zone	42	41	12	19	N/A	100	103	86

The current state of coastal ecosystems in the Fitzroy basin is summarised in Table 4.1.2.

Table 4.1.2: Summary of the current state of coastal ecosystems in the Fitzroy basin

Coastal ecosystem	Current condition
Rainforests	64 per cent of rainforests in the basin have been lost with major losses in the floodplain.
Forests	Heavily impacted with 43 per cent remaining which is mostly used for grazing. Only 13 per cent of forests on the floodplain and 41 per cent of forests in the coastal zone remain.
Woodlands	Reduced in extent by 61 per cent with much of the remainder under grazing regimes.
Forested floodplain	Reduced in extent by 61 per cent. Areas surrounding remaining forested floodplains have been modified. Condition not assessed but generally significant invasive weed issues.
Grass and sedgelands	Extensively modified with only 32 per cent remaining. Remnant grass and sedgelands impacted by introduced species, irrigation and land modification.
Heath and shrublands	Reduced in extent by 18 per cent. Most remnant heath and shrublands are buffered by other remnant coastal ecosystems or protected areas.
Freshwater wetlands	Almost a quarter of the Fitzroy basin wetlands have been modified. Remaining wetlands assessed appear to be in a reasonable condition following a number of wet years. Increases in coastal zone freshwater wetlands can be attributed to ponded pastures.
Estuaries	Mangrove systems are mostly intact and in reasonable condition

	Coastal ecosystem	Current condition
		regarding extent. Much of the saltmarsh/saltpans have been modified with bund walls for ponded pastures.

4.2 Outline of key current and likely future pressures and impacts on coastal ecosystems in the Fitzroy basin

Table 4.2.1 provides a brief summary of the current pressures and future outlook for coastal ecosystems in the Fitzroy basin. Pressures include expansion of agriculture, urban areas, aquaculture and changes to hydrology. Indicators point to a rapid intensification of land use in the Fitzroy basin over the next two decades as mines, gas fields, urban and industrial development and water infrastructure are expanded.[11]

The Fitzroy basin is the largest catchment in the Great Barrier Reef Region and has undergone intensive and extensive land clearing over the last century. As a result, high amounts of sediments containing pesticides and nutrients are lost each year from the Fitzroy basin into the World Heritage Area, where these pollutants are widely dispersed. Coral reefs within the region are under threat from land-based pollution from Keppel Bay out to the Capricorn Islands group. After extreme flood events, flood plumes from the Fitzroy basin have been shown to cover hundreds of kilometres and reduce water quality for extended periods. There has been many changes to hydrological dynamics and drainage within the Fitzroy basin and many developments, mostly related to mining, are planned that may further impact the flow of waterways within the Fitzroy basin in the future. A major issue with modifications to the natural flow of waterways is that connectivity for aquatic species has been lost from upstream regions of the river, having potential downstream effects on the Marine Park.

Vegetation removal

The introduction of the *Vegetation Management Act 1999* and the *Sustainable Planning Act 2009* now regulates vegetation clearing on approximately 95 per cent of Queensland, by triggering assessment and applying penalties for non-approved clearing. The *Vegetation Management Act 1999* also provides mapping of areas of conservation significance through regional ecosystems. Regrowth vegetation (especially riparian) is provided some protection. However, this legislation does not provide protection to mangroves, grasses, non-woody vegetation or plants within some grassland ecosystems. Marine plants such as mangroves, saltmarsh and saltcouch are provided protection under the *Queensland Fisheries Act 1994*. Other legislation also applies depending on the location of the vegetation and the tenure of the land.

Hydrological changes

Changes in hydrology have occurred as a result of land use change (such as surface compaction/urbanisation reducing soil porosity), barriers (such as weirs and road/rail crossings), groundwater extraction, increased sedimentation in rivers as a result of land use practices, floodplain drainage networks, water harvesting and changing rainfall patterns as a result of climate change. These have in some cases forever changed run-off quality, quantity and seasonality of flows. Increasing storm intensity in recent years has delivered sudden large-pulsed flows of freshwater into the World Heritage Area. These flows now do not have sufficient residence times in coastal ecosystems to allow for ecological processes to occur. As a result freshwater induced coral bleaching and smothering of corals and seagrass by sediments and other contaminants is occurring more frequently and to a greater extent.[58]

Climate change

The impacts of climate change will vary across the basin, with the highest threats to low-lying coastal areas and the floodplain. Future development planning needs to map and consider the risks of sea-level rise, storm surge and flooding before allowing for further development in the coastal zone and floodplain. The interaction of rising sea temperatures and ocean acidification will exacerbate the impacts from catchment run-off on inshore coral reef ecosystems.

Future higher temperatures as a consequence of climate change will likely see a decline in intertidal, coastal and estuarine seagrass meadows in the World Heritage Area.[59] Ocean acidification as a result of increasing CO_2 on the other hand is expected to enhance seagrass production.[60]

Table 4.2.1: Summary of the current pressures and future outlook for coastal ecosystems in the Fitzroy basin

Pressure	Current status (1999-2009)	Description	Future outlook	Description
Urban development	Increase	Urban residential increased by 15 per cent (and by 21 per cent for the coastal zone) between 1999 and 2009.	Increase	Rockhampton, the major urban centre, is expected to increase in size from approximately 115,000 people in 2012 to 162,000 in 2031. There are no current plans to improve Rockhampton's Sewage Treatment Plants.[11]
Port development	No Change	Small ship port with specialist load e.g. explosives.	Increase	Expansion proposed for Port Alma, and the Fitzroy Terminal proposal would require new port facilities in Keppel Bay and in the Fitzroy estuary.
Agriculture	Increase	Agricultural production (dryland and irrigated) has increased by 6 per cent between 1999 and 2009. The majority of this increase is attributed to irrigated production.	Increase	Increases in irrigated agriculture are likely due to new dam and weir construction, especially along the Dawson and Fitzroy rivers.
Irrigation infrastructure	Increase	Water storage and transport has increased in extent by 54 per cent between 1999 and 2009.	Increase	Five dams and weirs are scheduled for expansion.[11]
Grazing	Decrease	Grazing has declined by 2 per cent between 1999 and 2009.	Likely to decrease	Some areas of grazing are expected to be replaced by irrigated production and mining operations.
Introduced species	Uncertain	Established throughout the basin.	Uncertain	Ongoing control programs for weed management in place however climate change impacts are uncertain and may encourage proliferation of some weed species.
Mining	Increase	Mining increased by 45 per cent between 1999 and 2009.	Increase	There are proposals for another 17 major coal mines[11] as well as new proposed gas fields covering a large area.[11]

Pressure	Current status (1999-2009)	Description	Future outlook	Description
Climate Change	Increase	Not assessed.	Increase	Increasing intensity of episodic events, droughts and changes in rainfall patterns all likely to impact on coastal ecosystems.
Vegetation removal	Minimal change	The introduction of the *Vegetation Management Act 1999* provided a regulatory framework for broad-scale land clearing across Queensland. Since its introduction, the rate of vegetation clearance in the basin has significantly declined.	Increase	Amendments proposed for the *Vegetation Management Act 1999.* Including the removal of present restrictions on clearing regrowth vegetation.

4.3 Current and likely future impacts on coastal ecosystems and likely resultant impacts on the World Heritage Area

The Fitzroy basin has changed, and any management actions to improve the condition of the adjacent World Heritage Area need to consider this system as a whole. The key current and likely future impacts on coastal ecosystems and likely resultant impacts on the World Heritage Area are summarised in Table 4.3.1.

The future prospects for the Fitzroy basin are largely dependent on the ability of natural resource managers to manage the balance between land and water use, and ecosystem health. If well managed, the potential to improve the health and resilience of wetland, estuarine and inshore coastal marine ecosystems (and the industries they support) are significant. Failure to address these problems will, however, continue to impact on coastal ecosystems and the species they support.

Actions are being taken to improve the condition of the Fitzroy basin. Natural Resource Management Group Fitzroy Basin Association has been working closely with local government and landholders to make improvements. One example of the initiatives introduced by the Fitzroy Basin Association is the Fitzroy Basin Fish Prioritisation Project.[3] This project identifies potential barriers to fish passage and prioritises barriers for remediation.[3] These works should improve fish productivity and improve water quality.

The Reef Water Quality Protection Plan (Reef Plan) is a collaborative program of coordinated projects and partnerships designed to improve the quality of water in the World Heritage Area though improved land management in Great Barrier Reef catchments. Reef Plan is a joint Australian and Queensland government initiative that specifically focuses on non-point-source pollution. This is where irrigation or rainfall carries pollutants such as sediments, nutrients and pesticides into waterways and the Reef lagoon. Reef Plan sets targets for water quality and land management improvement, and identifies actions to improve the quality of water entering the World Heritage Area. Initially established in 2003, Reef Plan was updated in 2009 and 2013.

Progress in the Fitzroy towards the Reef Plan targets has been encouraging such that there has been a reduction of nitrogen, sediment and pesticide loads between 2009 and 2011 of 2 per cent, 3 per cent and 4 per cent respectively.[47] Groundcover in the basin is around 90 per cent well above the original 50 per cent and still above the new 70 per cent target in Reef Plan 2013.[47]

Table 4.3.1: Key current impacts and likely future impacts in the Fitzroy basin and likely consequences for the World Heritage Area

Current impacts on Coastal Ecosystems	Trend 1999-2009	Impacts on the World Heritage Area	Future likely impacts on Coastal Ecosystems	Future likely impacts on the World Heritage Area
Broadscale clearing of coastal ecosystems for agriculture, urban or industry	Rates of clearing have declined as a result of the *Vegetation Management Act 1999.*	Loss of ecological process and connectivity, replacement of some ecological processes depending on the nature of the modified system.	Coastal ecosystems unlikely to be returned to their former state, and further losses expected with changes to existing legislation.	Ongoing loss of function will remain unless remedied.
Farm run-off	Improvements as a result of increasing rates of BMP uptake.	Improvements to water quality expected, although delayed due to lag effects. Changes in land use will not be obvious for a few years.	Dependant on extent of new intensive development and uptake of BMP.	Water quality expected to improve over time.
Groundwater changes	Used where river access is not possible.	Unknown.	Over extraction of groundwater may lead to increases in salinity and loss of dry season refugia in waterways.	Uncertain.
Drainage of the floodplain	Static.	Changes to fish passage and reduction in water residence time causing a reduced capacity for biogeochemical processes to occur.	May increase as a result of expected increase in irrigated cropping.	As for current impacts.
Introduced aquatic weeds and declining wetland health	Introduced aquatic weeds are well established in the basin.	Leads to lowered oxygen levels in aquatic ecosystems that render habitats unsuitable for most native fish species. Create black water pulses that cause downstream fish barriers and fish kills. Act as a barrier to fish movement.	If nutrient loads are reduced the weed growth could also decrease.	If weeds continue to proliferate a reduction in water quality, fish habitat and connectivity are likely to occur.
Stream/river bank erosion	Increasing as a result of extreme weather events and changed hydrology. Legacy issues from historical clearing and sedimentation.	Increase in suspended sediments and turbidity in coastal waters; increase in sediment build up in waterways.	Management actions (e.g. Reef Plan) underway to restore riparian areas. A reduction in sediment inputs could see	Likely to improve under uptake of best management practices and restoration projects but timelines expected to be long.

Current impacts on Coastal Ecosystems	Trend 1999-2009	Impacts on the World Heritage Area	Future likely impacts on Coastal Ecosystems	Future likely impacts on the World Heritage Area
			improvement in stream stability.	
Declining water quality	Improvements in recent years although still a major threat to the World Heritage Area.	Decline in inshore ecosystem health and resilience.	Likely to improve as a result of management actions targeted at improving water quality.	Improvements expected but will take time to take effect.
Barriers to fish migrations	Water security and proposed expansion of agriculture driving pressure to create dams and weirs.	Reduction/loss of connectivity and fish passage.	Projects planned to improve fish passage through lowering of smaller bund walls or installing fish ladders. New dams proposed may reduce fish passage.	Dependent upon effective works being implemented and connections restored and maintained.
Introduced species	Established throughout the basin (mostly in modified landscapes).	Introduced grasses generate hotter fires that can affect native species, destroy forest canopies and expose soil which can be eroded, especially when fires occur late in the dry season.	Eradication to date has been ineffective and many grasses are still used for pasture grass. Strategic basin scale management actions are needed to manage and control.	Likely to lead to increases in erosion and therefore more suspended sediments in the GBRWHA.
Mine release/tailwater	Releases regulated by the Queensland Government.	Heavy metals entering the river systems which flow into the World Heritage Area as part of authorised releases.	Dependent on content of mine release.	Likely to increase as a result of expansion in the mining industry.
Changed overland hydrology	Most development/modification has occurred on the floodplain and coastal zone.	Changes to connectivity and water retention which has impacted on all ecological processes.	Development continues to occur on the floodplain and coastal zone.	Likely decline in water quality and aquatic biodiversity in the GBRWHA.
Ponded pasture/wetland production	It became illegal to establish new ponded pastures in the coastal zone in 2001 (policy for development and use of ponded pasture).	Loss of connectivity and declines in fish productivity, blackwater, and the potential release of acid sulphate soils.	Plans to modify ponded pastures to improve ecosystem health.	Improved productivity, ecosystem health and resilience if significant restoration works undertaken.

Water quality

Water quality remains the greatest current and future risk to the World Heritage Area from the Fitzroy basin. The loss of coastal ecosystems and changes to connectivity has reduced the capacity to provide ecological functions to the World Heritage Area. In addition, the extent of habitat for species with connection to the World Heritage Area has been reduced and, if this continues, will affect natural productivity and may reduce the gross value of production of commercially and recreationally important fish species.

Figure 4.3.1 provides an example of the relationships between pressures, state and impact from increased pollutants being delivered to the Marine Park. Note that these sequential impacts are linked primarily to nutrient loading scenarios, and do not define the cumulative impacts from increasing temperature and nutrients, or from other pollutants such as suspended sediment and pesticides. Recent work[61,62,63] indicates that the combined impacts of rising temperatures and increasing nutrients, particularly dissolved inorganic nitrogen (DIN), will result in reduced resilience of coral reefs to recover from more frequent bleaching events.[64]

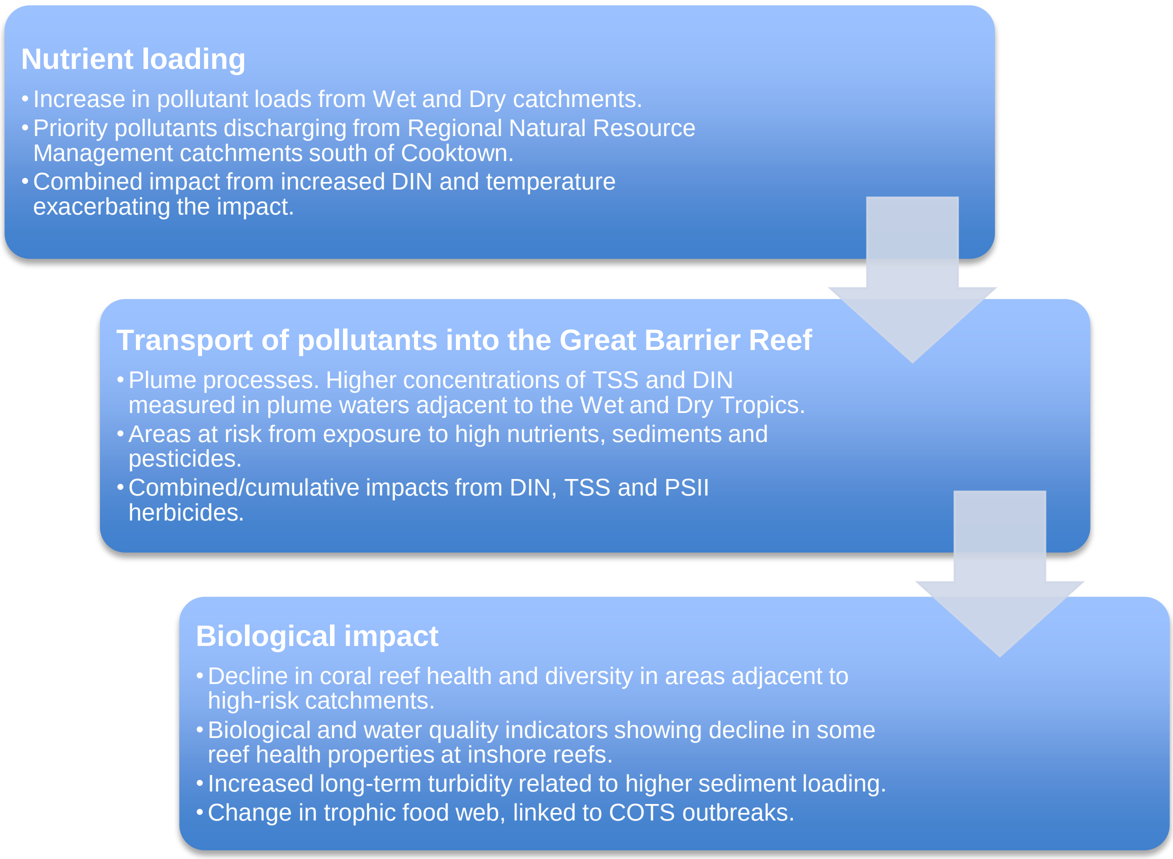

Figure 4.3.1: Pathway from nutrient enrichment to biological impact from total suspended solids (TSS); dissolved inorganic nitrogen (DIN); photosynthesis inhibiting herbicides (PSII); and crown-of-thorns starfish (COTS)[64]

The impacts of increasing sediments and nutrients on coral reefs (Figure 4.3.2) and seagrass (Figure 4.3.3) include shading, reduced resilience and reduced recruitment. Abundances of a range of other reef associated organisms have also been shown to change along the water quality gradient.[64]

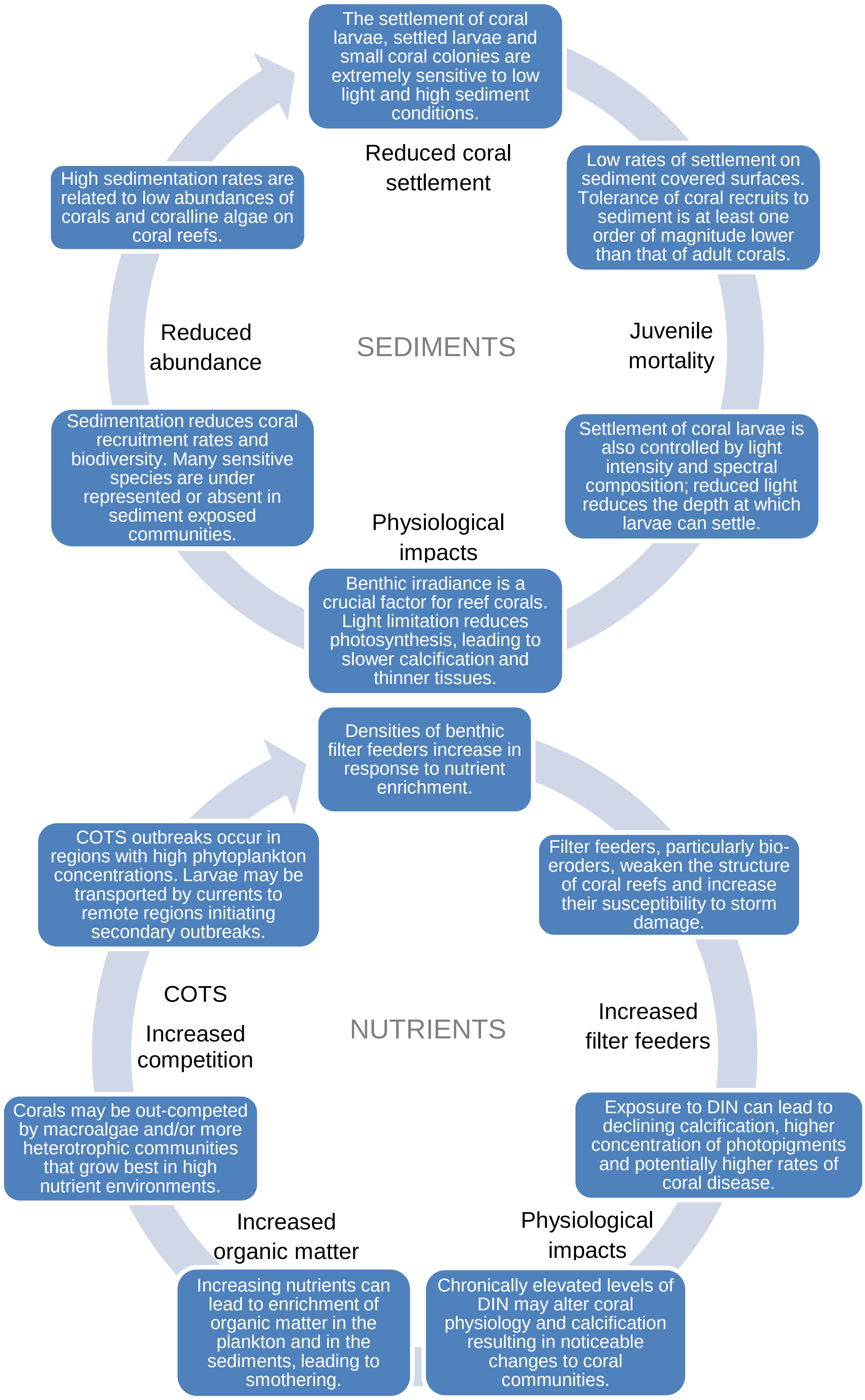

Figure 4.3.2: Potential and known impacts of increasing nutrients and sediments on coral reefs[64]

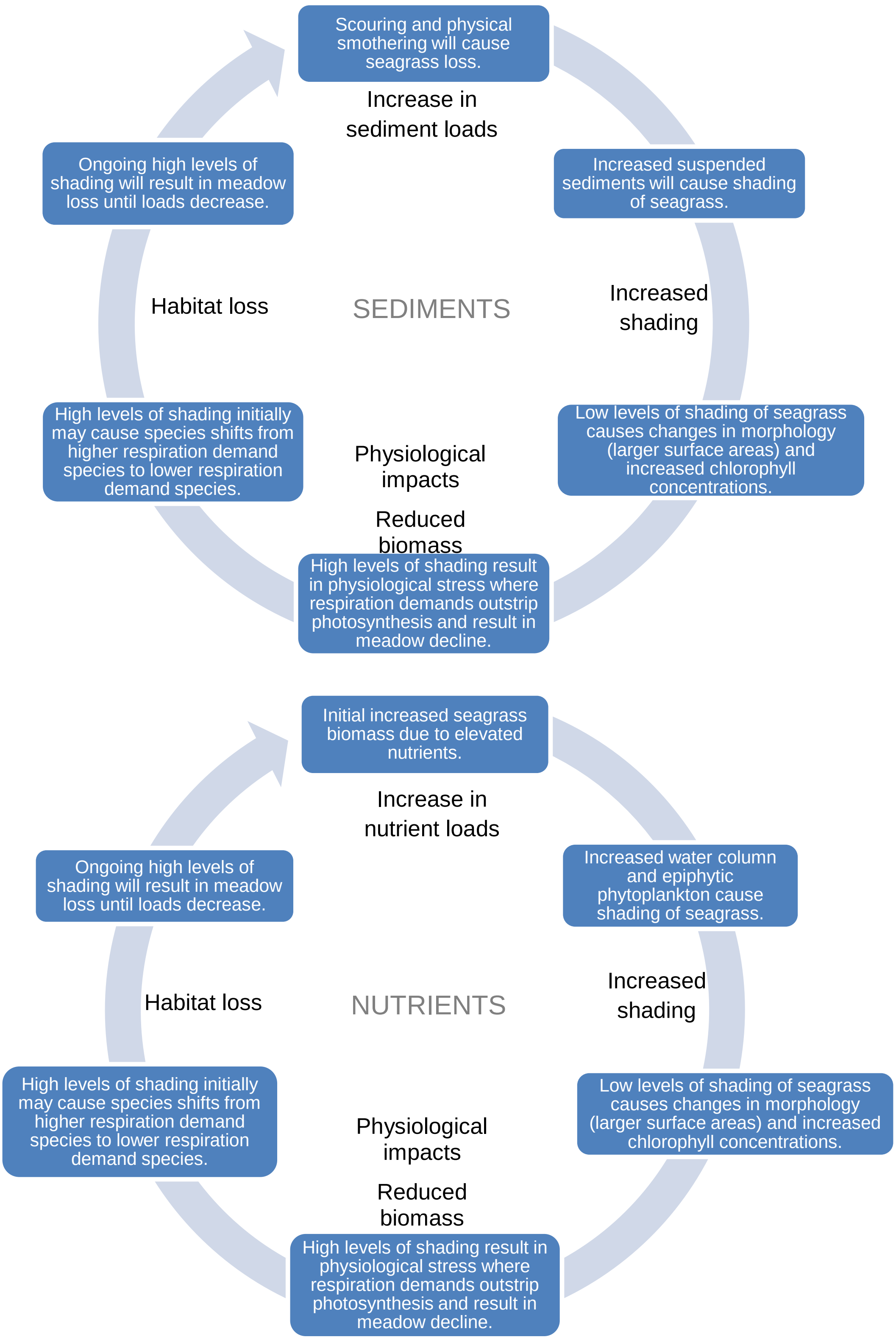

Figure 4.3.3: Potential and known impacts of increasing nutrients and sediments on seagrass beds[64]

The water quality discharged from the Fitzroy River varies spatially and over time. Most exceedances of water quality guideline values occur during episodic flood events and may last from a period of days to weeks, and in worse cases months. The impacts on the World Heritage Area will vary depending on the water quality, the size of the flood plumes, the flow duration, levels of mixing with coastal marine waters and the exposure time of organisms to the plume water. Total Suspended Solids (TSS), nitrogen, phosphorus and turbidity are expected to exceed guidelines during flood events. TSS is highly variable during Fitzroy floods, which is influenced based on the sediment source and where heavy rainfall has occurred (Appendix I). Sub-catchment pollutant concentrations were higher compared to whole of basin concentrations from the same flood events. Total phosphorus and total nitrogen were measured during flood events from 1994 to 2008 and were higher in concentration in sub-catchment areas compared to lower in the Fitzroy River. Highest nutrient concentrations often corresponded with run-off originating from cropping land (Appendix I).

Pesticides, diuron and tebuthiuron are detectable in the inshore waters of the Fitzroy basin. Diuron can be toxic to corals, seagrass, phytoplankton and mangroves while, tebuthiuron is a herbicide used to control weeds and can also be toxic to corals.[65] Highest tebuthiuron concentrations were measured in areas dominated by grazing. Grazing lands are a major contributor to the long-term average annual loads of most common pollutants and that maximum pollution concentrations measured at basin and sub-basin scales are related to the percentage of heavy rains received and status of ground cover. In 2008, atrazine, diuron, and tebuthiuron loads measured during flood events all had mean concentrations above guidelines trigger values set in the Water Quality Guidelines for the Marine Park (Appendix I).

Reef Plan (2013) identifies specific 'water quality' targets for the reduction of pollutant loads to the Reef lagoon across the adjacent catchment area. Pollutants were chosen based on their risk to receiving water environments (nitrate, herbicides, particulate nitrogen and phosphorus and sediment) and targets were based on a combination of previous targets, including those identified in 2001 for the Reef catchment area by the Great Barrier Reef Marine Park Authority.

Actions are being taken to improve the condition of the Fitzroy basin. The Fitzroy Basin Association along with Fitzroy River and Coastal Catchments has been working closely with local government and landholders to implement best management practice. Improved grazing management practices have been designed to benefit the Reef and water quality targets have been set for the export of pollutants from the Fitzroy basin. Since the implementation of the Reef Rescue program (2008/2009) some values have shown improvement, however the change is very small compared to other basins along the Queensland coast. For example, PSII herbicide values have decreased only slightly since Reef Rescue was initiated, respective to other regions: four per cent in the Fitzroy, compared to a Reef wide average of 15 per cent, and a high of 31 per cent in Mackay Whitsunday by June 2011. This is not considered a substantial change. It has been suggested that since nitrogen and phosphorus concentrations rarely fall below Queensland water quality guidelines, the current guidelines for nutrients may not be suitable for the Fitzroy basin during flood event conditions.

4.4 Priorities for conservation and restoration

Coastal ecosystems located in the floodplain and coastal zone are those that have experienced the greatest losses and those most at risk in the future. Future conservation measures should include protection these ecosystems from further loss and impacts, and restoration efforts should also focus on these areas. These areas are also at greatest risk from flooding, storm and climate change impacts. New high value infrastructure, such as residential and industrial development, should be avoided in these areas. Current infrastructure in these areas needs to be constructed and managed to current best practice for minimising impacts on the area's hydrological processes.

As with much of the catchment, many of the issues affecting the health and resilience of the Marine Park adjacent to this basin stem from legacy issues such as broadscale vegetation clearing. Current legislation should prevent recurrence of many of these issues however management actions to recognise and rectify these problems are rare. Riverbank erosion is still occurring due to upstream channelisation, clearing, loss of riparian vegetation and weed species all of which reduce habitat for native species with connections to the Reef. While the rate of loss has been reducing over the last decade, riparian vegetation continues to decrease.[47,66]

This Report demonstrates that the coastal ecosystem services provided by the Fitzroy basin cannot be further degraded if it is to maintain support for the Outstanding Universal Value and integrity of the Great Barrier Reef World Heritage Area. The coastal ecosystems in the floodplain are currently at greatest risk and require effective protection and restoration measures to ensure the long-term health of the Reef.

Coastal zone

Coastal ecosystems in the coastal zone generally have the closest connections to the World Heritage Area and generally have a higher capacity to provide physical, biological and biogeochemical processes for the World Heritage Area. Some coastal ecosystems in the coastal zone also fall within the World Heritage Area. The coastal zone is also the area at greatest risk from the impacts of climate change. Actions that could be taken to reduce pressure on the coastal zone in the Fitzroy basin include:

- Limit further loss of remaining coastal ecosystems.
- A basin scale landscape strategic study of land use and coastal ecosystems to enable a balance between sustainable agriculture and functional coastal ecosystem protection.
- Increase uptake of improved land management practices in broadscale grazing and pasture management, in particular restoring aquatic connectivity and the re-vegetation of critical coastal ecosystems.
- Limit further intensive development in the coastal zone, particularly in intact areas. This will not only reduce environmental impacts, but may also reduce the risk of economic impacts resulting from future climate change, as scenarios predict that the coastal zone will be at greatest risk from sea-level rise and storm surge.
- Consistent with Queensland planning provisions, future urban developments that cannot be sited outside of the coastal zone should be constructed to current best practice for easy removal, employing principles such as minimal impact on coastal

processes, water sensitive urban design, gross pollutant traps and tertiary sewage treatment.
- Manage modified coastal ecosystems to provide ecological functions and values that support the health of the World Heritage Area through the continued improvement in land management practices (grazing, dryland and irrigated production).
- Improve landscape connectivity through the use of finer scale coastal ecosystem mapping to identify required connections and actions that provide values and functions to support the World Heritage Area.
- Encourage community participation in identifying priorities for conservation and restoration and the agreed actions required to achieve these.

Floodplain

Floodplains support particularly rich coastal ecosystems, especially in terms of diversity and abundance. These areas are important for the physical, biological and biogeochemical processes they provide for the long-term health and resilience of the World Heritage Area. Actions that can be taken to reduce pressure on the floodplain include:

- Limit further loss of remaining coastal ecosystems.
- Increased protection afforded to remaining coastal ecosystems.
- Restore riparian corridors in this area to a standard that provides effective ecological functions. Any re-vegetation should consider the appropriateness of using species adapted for future climate scenarios.
- Improve connectivity between remnant coastal ecosystems within the floodplain to return and restore natural function where ever possible.
- Improve agricultural practices to current best practice standards and identify new practices where needed.
- Future urban developments that cannot be sited outside of the floodplain should be constructed to current best practice to minimise the impact of floodplain processes, employing principles such as water sensitive urban design, gross pollutant traps and tertiary sewage treatment.
- Limit further intensive development in the floodplain. This will not only reduce environmental impacts, but may also reduce the risk of economic impacts resulting from future climate change, as scenarios predict that the floodplain will be at increased risk from flooding.

Riparian areas

Riparian vegetation provides important physical, biological and biogeochemical processes essential for the long-term health and resilience of the World Heritage Area. Riparian vegetation slows water velocity and provides connectivity across the basin. Actions that can be taken to reduce pressure on the riparian zones include:

- Improving agricultural practices in areas where riparian vegetation is minimal or non-existent to restore their function.
- Restore riparian corridors to a standard that provides effective ecological functions. Any re-vegetation should consider the appropriateness of using species adapted for future climate scenarios.

- Seek to protect or reinstate in-stream habitats to provide improved flow regulation and fish habitat structure.
- Control exotic grasses, in particular hymenachne, as they choke waterways and remove oxygen which reduces water quality.
- Limit further construction of dams and weirs in this basin where they might impact on coastal ecosystems or the Marine Park.
- Protect riparian zones from future development, including urban and agricultural development.
- Further development adjacent to waterways should not increase point and non-point source pollutants entering waterways.
- Encourage strategic vegetation management, including planting of climate change adapted species and plants designed to address the modified landscape (e.g. deep rooted trees planted on floodplain to assist in managing rising groundwater and salinity).
- Encourage best practice management of grazing in riparian areas to reduce introduced pasture grasses and weeds.
- Encourage community participation in identifying priorities for conservation and restoration and the agreed actions required to achieve these outcomes.
- Restore riparian corridors and increase widths appropriate with stream order (i.e. the higher the stream order the wider the buffer) and landscape functions. This will provide better connections, in-stream habitat, reduce erosion, improve water quality and reconnect the basin.
- Restore and manage remnant floodplain and riparian vegetation to minimise bank erosion and filter nutrients and sediments.

Wetlands

Wetlands provide habitat for many species with connections to the World Heritage Area and are often referred to as the 'kidneys of the Reef'. Wetlands provide important physical, biological and biogeochemical processes that support the long-term health and resilience of the World Heritage Area. Actions that can be taken to reduce pressure on wetlands include:

- Improve connectivity between wetlands and the World Heritage Area, including maintaining or restoring environmental flows where appropriate.
- Control and manage introduced species that compromise wetland health.
- Restore and manage wetlands to maximise nutrient recycling, sediment deposition and nursery areas for fish species.

Hydrological Connectivity

The hydrological processes within catchments set the backbone of all ecological functions and water quality outcomes. These catchment ecosystems and water quality outcomes in turn provide the direct connection with the health of the marine environment to which they drain. Change to these processes is therefore of increasing concern for the long-term health of the Marine Park.[67] Actions that could be taken include:

- Accurately assess and where necessary modify dams, weirs and ponded pastures to promote hydrological connectivity and restore natural environmental flows.

- Appropriate modification of fish barriers (such as Barramundi Creek and Fitzroy Barrage) to improve fish populations through increased access and opportunity for species migration.
- Restore stream, river and waterway connectivity to achieve effective fish passage.

Other Areas

Areas outside of the coastal zone and floodplain still provide some physical, biological and biogeochemical processes to the World Heritage Area. Actions that could be taken to reduce pressure on these areas include:

- Appropriate restoration of riparian corridors to a standard that provides effective ecological functions.
- Encourage best practice management of agricultural activities, particularly in areas where riparian buffers are minimal or non-existent.
- Plan and manage new land use to have no net impact on the World Heritage Area values.

Potential mechanisms for achieving the conservation and restoration priorities outlined above include:

- Dedicated funding for coastal repair to rectify legacy issues and restore ecosystem health and resilience.
- Ongoing improvement in identifying and implementing best management practice for land use, especially with a focus on ecosystem health and function.
- Regional land management and catchment condition targets could be established in order to reduce Reef pollution to complement water quality targets. Additionally, regional management of pesticides could therefore make tebuthiuron, diuron and atrazine a priority.[11]
- Appropriate policy may be required by both State and Federal governments to ensure that future intensification of development does not negate the positive work being done by landholders across the basin.[11]
- Mining license conditions could be reviewed to account for new guidelines, environmental values and water quality objectives, and the cumulative impacts from point source releases within the Fitzroy basin.[11]
- Rehabilitation plans need to be designed into the life of a mining project and audited by management agencies to ensure compliance. Mount Morgan mine (Study Site 12) is a reminder that mining has the potential to have long-term ongoing issues if appropriate rehabilitation does not occur during the life of the mine and can cause major ongoing environmental impacts.

4.5 Potential management actions

This report has been developed as a baseline for the Fitzroy basin. In order to ensure that the basin is best represented, consideration of additional finer scale data, local knowledge and information will further enhance this assessment.

Ensuring the long-term health of the Reef requires greater protection and restoration of important ecological processes and functions provided by Fitzroy basin coastal ecosystems. Actions that would increase protection and restore processes and function include:

1. The inclusion of rehabilitation plans into the life of a mining project and audited by management agencies to ensure compliance.
2. Greater protection, restoration and management of remnant and riparian vegetation to reduce bank erosion and to filter nutrients and sediments.
3. Greater protection, restoration and management of wetlands and their floodplains that recycle and trap nutrients and sediments and provide important nursery areas for fish species.
4. Restore connectivity of streams, rivers and waterways to promote hydrological connectivity and improve fish passage.
5. Manage modified coastal ecosystems to provide ecological functions and values that support the health of the World Heritage Area through the continued improvement in land management practices (grazing, dryland and irrigated production).
6. Encourage strategic vegetation management, including planting of climate change adapted species and plants designed to address the modified landscape (e.g. deep rooted trees planted on floodplain to assist in managing rising groundwater and salinity).
7. Plan and manage new land use to have no net impact on the World Heritage Area.

4.6 Knowledge gaps

In assessing the Fitzroy basin, a number of knowledge gaps were identified, these include

- Reef Plan focuses on sediments, nutrients and pesticides, but further water quality research is required that relates to pollutants that are not covered by Reef Plan, such as microplastics, pharmaceuticals etc., and their effects on the World Heritage Area.
- Implications of many agricultural chemicals on the marine environment.
- Further fish community monitoring of the Fitzroy basin's waterways to better understand fish communities and their population dynamics and migration requirements.[3]
- Identify sources of dissolved nitrogen and phosphorus and actions to minimise their loss.[11]
- Research on the trigger value of Tebuthiuron (current values have low reliability).[11]
- Detailed groundwater mapping and understanding.
- The cumulative impacts of land use need to be investigated to comprehensively quantify the extent of pressure being placed on coastal ecosystems.[11]
- Collection and analysis of appropriate data to allow for locally relevant sediment guidelines to be set for lowland and upland waters.
- Impacts of coal dust on the marine environment.
- The impact that colliery waste water has on riverine ecosystems.
- The effects of mining water discharge on freshwater water and marine systems.

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Appendix A - Field Assessment Template

Date	**Basin Name**	**Latitude (-18.861499)**	**Camera No**	**Photo No**
Time	**Way Point**	**Longitude (145.865234)**	**Photo no.**	
Team Members				
Experts				
Site Name				
Site Description				
Site Condition (circle): Excellent Good Average Poor Very poor Unknown				
Coastal Ecosystems: Coral Reef Open Water Lagoon Floor Seagrass Coastline Estuaries Freshwater Wetlands Mangroves Saltmarshes Heath and Shrublands Grass and sedgelands Forested Floodplain Woodlands Forests Rainforests				
Condition: intact fragmented cleared other				
Landuse: **Conservation and natural environments** (inc wetlands), **Forestry:** dryland or irrigated plantation, **Grazing:** dryland, irrigates or natural vegetation **Intensive:** commercial, mining, animal production, urban residential **Production:** dryland or dryland sugar, Production forestry, **Water:** marsh wetland production or intensive use, water storage and treatment, uncertain				
Direct Impacts (threats):				
Direct Impacts (threats):				
Indirect Impacts / Threats:				
MNES or threatened species				
Other Information				

Appendix B - Key Terminology used in this report

Basins:	An extent or an area of land where surface water channels to a hydrological network and discharges at a single point i.e. river, stream, creek. Defined by Queensland Government and may include many sub-basins.
Coastal zone:	Area of coast as defined by the *Coastal Protection and Management Act 1995* (Queensland)
Coastal Ecosystem:	Marine, estuarine, freshwater and terrestrial ecosystems that connect the land and sea and have the potential to influence the health and resilience of the Great Barrier Reef. For this study, this includes the Great Barrier Reef catchment and 10% of the Reef waters seawards of the coastline.
Ecosystem:	A dynamic complex of plant, animal and micro-organism communities and the non-living environment interacting as a functional unit. Source: Millenium Ecosystem Assessment 2005.[68]
Ecosystem function:	The interactions between organisms and the physical environment, such as nutrient cycling, soil development and water budgeting.
Inshore marine areas:	Include (but not limited to) those areas extending up to 20 km offshore from the coast and which correspond to enclosed coastal and open coastal water bodies as described in the *Water Quality Guidelines for the Great Barrier Reef Marine Park (2010)*.[65]
Great Barrier Reef catchment (catchment):	The 35 river basins in Queensland which drain into the Great Barrier Reef (Table 1).
Natural Resource Management (NRM) regions:	A group of basins managed by non-government organisations (NRM bodies) within Queensland (Table 1).
Natural Resource Management (NRM) bodies:	Non-government organisations focused on environmental and sustainable agriculture programs and activities.
Non Remnant:	Vegetation that does not meet the criteria of remnant vegetation as defined under the Vegetation Management Act 1999.
Pre-clear:	Queensland Government reconstruction of regional ecosystems to represent vegetation pre-European settlement.
Post-clear:	Queensland Government mapping of the state of regional ecosystems that occurred in 1999 and 2009.
Remnant vegetation:	Vegetation that meets all of following criteria: • 50 per cent of the predominant canopy cover that would exist if the vegetation community were undisturbed. • 70 per cent of the height of the predominant canopy that would exist if the vegetation community were undisturbed. • Composed of the same floristic species that would exist if the vegetation community were undisturbed.
Regional ecosystem:	Regional ecosystems (REs) are vegetation communities that are consistently associated with a particular combination of geology, land form and soil in a bioregion. The Queensland Herbarium has mapped the remnant extent of regional ecosystems for much of the State using a combination of satellite imagery, aerial photography and on-ground studies. Each regional ecosystem has been assigned a conservation status which is based on its current remnant extent (how much of it remains) in a bioregion. Some areas of Cape York have not been mapped.
Sub-basin	Smaller catchment area situated within a basin.
Vulnerability:	The degree to which a system or species is susceptible to, or unable to cope with, adverse effects of pressures. Vulnerability is a function of the character, magnitude, and rate of variation or change to which a system or species is exposed, its sensitivity, and its adaptive capacity.

Appendix C - Values and their elements that underpin matters of national environmental significance

Values and their elements that underpin matters of environmental significance	Matters of national environmental significance: World Heritage Properties	National heritage places	Wetlands of international importance	Listed threatened species and ecological communities	Listed migratory species	Commonwealth marine areas	Great Barrier Reef Marine Park
Biodiversity - Habitats							
Islands	✓	✓				✓	✓
Beaches and coastlines	✓	✓				✓	✓
Mangroves	✓	✓				✓	✓
Seagrass meadows	✓	✓				✓	✓
Coral reefs (<30m)	✓	✓				✓	✓
Mesophotic (deep water) corals	✓	✓				✓	✓
Lagoon floor	✓	✓				✓	✓
Shoals	✓	✓				✓	✓
Halimeda banks	✓	✓				✓	✓
Continental slope	✓	✓				✓	✓
Open waters	✓	✓				✓	✓
Saltmarshes	✓	✓	✓			✓	✓
Freshwater wetlands	✓	✓	✓			✓	✓
Forest floodplain	✓	✓				✓	✓
Heath and shrublands	✓	✓				✓	✓
Grass and sedgelands	✓	✓	✓			✓	✓
Woodlands	✓	✓				✓	✓
Forests	✓	✓				✓	✓
Rainforests	✓	✓		✓		✓	✓
Biodiversity - Species							
Dune & saltmarsh plants	✓	✓					
Mangroves	✓	✓				✓	✓
Seagrasses	✓	✓				✓	✓
Macroalgae	✓	✓				✓	✓
Benthic microalgae	✓	✓				✓	✓
Corals	✓	✓				✓	✓
Seahorses and allies	✓	✓				✓	✓
Other invertebrates	✓	✓				✓	✓
Plankton and microbes	✓	✓				✓	✓
Bony fish	✓	✓				✓	✓
Sharks and rays	✓	✓		✓	✓	✓	✓
Sea snakes	✓	✓				✓	✓
Marine turtles	✓	✓		✓	✓	✓	✓
Estuarine crocodile	✓	✓			✓	✓	✓

Values and their elements that underpin matters of environmental significance	Matters of national environmental significance						
	World Heritage Properties	National heritage places	Wetlands of international importance	Listed threatened species and ecological communities	Listed migratory species	Commonwealth marine areas	Great Barrier Reef Marine Park
Seabirds	✓	✓		✓	✓	✓	✓
Shorebirds	✓	✓		✓	✓	✓	✓
Whales	✓	✓		✓	✓	✓	✓
Dolphins	✓	✓			✓	✓	✓
Dugongs	✓	✓				✓	✓
Ecosystem Processes – Physical processes							
Ocean currents	✓	✓				✓	✓
Cyclones & wind	✓	✓				✓	✓
Freshwater inflow	✓	✓				✓	✓
Sedimentation	✓	✓	✓			✓	✓
Sediment re-suspension	✓	✓				✓	✓
Sea level	✓	✓				✓	✓
Sea temperature	✓	✓				✓	✓
Light	✓	✓				✓	✓
Aquatic connectivity	✓	✓	✓				
Ecosystem Processes – Geomorphological processes							
To be determined (SEWPaC advice)							
Ecosystem Processes – Chemical processes							
Nutrient cycling	✓	✓	✓			✓	✓
Pesticide accumulation	✓	✓	✓			✓	✓
Ocean acidity	✓	✓				✓	✓
Ocean salinity	✓	✓				✓	✓
Ecosystem Processes – Ecological processes							
Microbial processes	✓	✓				✓	✓
Particle feeding	✓	✓				✓	✓
Primary production	✓	✓	✓			✓	✓
Herbivory	✓	✓				✓	✓
Predation	✓	✓				✓	✓
Symbiosis	✓	✓				✓	✓
Bioturbation	✓	✓				✓	✓
Reef building	✓	✓				✓	✓
Competition	✓	✓				✓	✓
Ecological connectivity	✓	✓	✓			✓	✓
Recruitment	✓	✓	✓			✓	✓
Heritage – Outstanding Universal Value							
Superlative natural phenomena, exceptional natural beauty and aesthetic importance (Criterion VII)	✓	✓					
Geological processes and geomorphic	✓	✓					

Values and their elements that underpin matters of environmental significance	Matters of national environmental significance						
	World Heritage Properties	National heritage places	Wetlands of international importance	Listed threatened species and ecological communities	Listed migratory species	Commonwealth marine areas	Great Barrier Reef Marine Park
features (Criterion VII)							
Ecological and biological processes (Criterion IX) See Ecosystem Processes	✓	✓					
Natural habitats for conservation of biodiversity (Criterion X) See Biodiversity - Habitats	✓	✓					
Integrity	✓	✓					
Heritage – Natural							
See Biodiversity and Ecosystem Processes above							
Heritage – Indigenous							
Cultural practices, observances and customs						✓	✓
Sacred sites, sites of significance, places for cultural tradition						✓	✓
Stories, song lines and marine totems	✓	✓				✓	✓
Indigenous structures, tools and archaeology	✓	✓				✓	✓
Places of historic significance - Indigenous						✓	✓
Places of aesthetic value - Indigenous						✓	✓
Heritage – Non-Indigenous							
Places of historic significance – historic shipwrecks						✓	✓
Places of historic significance - World War II features and sites						✓	✓
Places of historic significance - lighthouses						✓	✓
Places of historic significance – other						✓	✓
Places of scientific significance (research stations, expedition sites)						✓	✓
Places of aesthetic value See OUV - Criterion VII	✓	✓				✓	✓
Places of social significance – iconic sites						✓	✓
Community benefits derived from the Great Barrier Reef Region							
Income	✓	✓				✓	✓
Employment	✓	✓				✓	✓
Understanding and appreciation	✓	✓				✓	✓
Enjoyment						✓	✓
Access to Reef resources						✓	✓
Personal attachment						✓	✓
Social relationships						✓	✓

Values and their elements that underpin matters of environmental significance	Matters of national environmental significance						
	World Heritage Properties	National heritage places	Wetlands of international importance	Listed threatened species and ecological communities	Listed migratory species	Commonwealth marine areas	Great Barrier Reef Marine Park
Health benefits						✓	✓

Appendix D - Threatened species of the Fitzroy basin

Birds

- Australasian Bittern
  - *Botaurus poiciloptilus*
- Black-breasted Button-quail
  - *Turnix melanogaster*
- Black-throated Finch (southern)
  - *Poephila cincta cincta*
- Painted Snipe
  - *Rostratula benghalensis* (sensu lato)
- Red Goshawk
  - *Erythrotriorchis radiatus*
- Squatter Pigeon (southern)
  - *Geophaps scripta scripta*
- Star Finch (eastern), Star Finch (southern)
  - *Neochmia ruficauda ruficauda*
- White-bellied Storm-Petrel (Tasman Sea), White-bellied Storm-Petrel (Australasian)
  - *Fregetta grallaria grallaria*
- Yellow Chat (Dawson)
  - *Epthianura crocea macgregori*

Frogs

- Eungella Day Frog
  - *Taudactylus eungellensis*
- Kroombit Tinker Frog, Pleione's Torrent Frog
  - *Taudactylus pleione*

Mammals

- Bridled Nail-tail Wallaby
  - *Onychogalea fraenata*
- Brush-tailed Rock-wallaby
  - *Petrogale penicillata*
- Greater Large-eared Horseshoe Bat
  - *Rhinolophus philippinensis* (large form)
- Humpback Whale
  - *Megaptera novaeangliae*
- Koala
  - *Phascolarctos cinereus* (combined populations of QLD, NSW and the ACT)
- Northern Quoll
  - *Dasyurus hallucatus*
- Water Mouse, False Water Rat, Yirrkoo
  - *Xeromys myoides*

Other

- Boggomoss Snail, Dawson Valley Snail
  - *Adclarkia dawsonensis*

Plants

a shrub

Commersonia argentea

Homoranthus decumbens

Austral Cornflower, Native Thistle

Rhaponticum australe

Black Ironbox

Eucalyptus raveretiana

bluegrass

Dichanthium setosum

Cobar Greenhood Orchid

Pterostylis cobarensis

Cossinia

Cossinia australiana

Curly-bark Wattle

Acacia curranii

cycads

Macrozamia platyrhachis

Cycas megacarpa

Cycas ophiolitica

Macrozamia fearnsidei

Finger Panic Grass

Digitaria porrecta

Hairy-joint Grass

Arthraxon hispidus

Heart-leaved Bosistoa

Bosistoa selwynii

King Blue-grass

Dichanthium queenslandicum

Lesser Swamp-orchid

Phaius australis

Miniature Moss-orchid, Hoop Pine Orchid

Bulbophyllum globuliforme

Minute Orchid, Ribbon-root Orchid

Taeniophyllum muelleri

Mt Larcom Silk Pod

Parsonsia larcomensis

Ooline

Cadellia pentastylis

Salt Pipewort, Button Grass

Eriocaulon carsonii

Siah's Backbone, Sia's Backbone, Isaac Wood

Streblus pendulinus

Three-veined Hakea

Hakea trineura

Wedge-leaf Tuckeroo

Cupaniopsis shirleyana

Acacia grandifolia
Aristida annua
Calytrix gurulmundensis
Capparis thozetiana
Corymbia clandestina
Corymbia xanthope
Daviesia discolor
Decaspermum struckoilicum
Eucalyptus beaniana
Eucalyptus virens
Grevillea venusta
Leucopogon cuspidatus
Logania diffusa
Marsdenia brevifolia
Neoroepera buxifolia
Omphalea celata
Pimelea leptospermoides
Polianthion minutiflorum
Pultenaea setulosa
Samadera bidwillii
Sarcochilus roseus
Sophora fraseri
Tectaria devexa
Xerothamnella herbacea

Reptiles

Allan's Lerista, Retro Slider
Lerista allanae
Brigalow Scaly-foot
Paradelma orientalis
Collared Delma
Delma torquata
Dunmall's Snake
Furina dunmalli
Flatback Turtle
Natator depressus
Green Turtle
Chelonia mydas
Hawksbill Turtle
Eretmochelys imbricata
Leatherback Turtle, Leathery Turtle, Luth
Dermochelys coriacea
Loggerhead Turtle
Caretta caretta
Olive Ridley Turtle, Pacific Ridley Turtle

Lepidochelys olivacea
Ornamental Snake
Denisonia maculata
Yakka Skink
Egernia rugosa

Appendix E - Migratory species of the Fitzroy basin

Birds

Bar-tailed Godwit
Limosa lapponica
Black Noddy
Anous minutus
Black-naped Tern
Sterna sumatrana
Black-winged Petrel
Pterodroma nigripennis
Bridled Tern
Sterna anaethetus
Brown Booby
Sula leucogaster
Caspian Tern
Sterna caspia
Common Sandpiper
Actitis hypoleucos
Crested Tern
Sterna bergii
Eastern Curlew
Numenius madagascariensis
Flesh-footed Shearwater, Fleshy-footed Shearwater
Puffinus carneipes
Greater Sand Plover, Large Sand Plover
Charadrius leschenaultii
Grey-tailed Tattler
Heteroscelus brevipes
Lesser Crested Tern
Sterna bengalensis
Lesser Sand Plover, Mongolian Plover
Charadrius mongolus
Osprey
Pandion haliaetus
Pacific Golden Plover
Pluvialis fulva
Roseate Tern
Sterna dougallii
Ruddy Turnstone
Arenaria interpres
Sharp-tailed Sandpiper
Calidris acuminata
Silver Gull
Larus novaehollandiae
Wandering Tattler

Heteroscelus incanus
Wedge-tailed Shearwater
Puffinus pacificus
Whimbrel
Numenius phaeopus
White-bellied Sea-Eagle
Haliaeetus leucogaster

Mammals

Dugong
Dugong dugon
Humpback whale
Megaptera novaeangliae

Reptiles

Flatback Turtle
Natator depressus
Green Turtle
Chelonia mydas
Hawksbill Turtle
Eretmochelys imbricata
Leatherback Turtle, Leathery Turtle, Lute Turtle
Dermochelys coriacea
Loggerhead Turtle
Caretta caretta
Olive Ridley Turtle, Pacific Ridley Turtle
Lepidochelys olivacea
Salt-water Crocodile, Estuarine Crocodile
Crocodylus porosus

Appendix F - Conservation parks, national parks and forest reserves in the Fitzroy basin

- Albinia Conservation Park;
- Albinia National Park;
- Albinia Resources Reserve;
- Alligator Creek State Forest;
- Amaroo State Forest;
- Apsley State Forest;
- Aricia State Forest;
- Arthurs Bluff State Forest;
- Bandana State Forest;
- Barakula State Forest;
- Beilba State Forest;
- Belington Hut State Forest;
- Bell Creek Conservation Park;
- Belmont State Forest;
- Binkey State Forest 1;
- Binkey State Forest 2;
- Blackdown Tableland National Park;
- Blackwater Conservation Park;
- Blair Athol State Forest;
- Borania State Forest;
- Bouldercombe Gorge Resources Reserve;
- Bouldercombe State Forest;
- Boxvale State Forest;
- Bukkulla Conservation Park;
- Bundoora State Forest;
- Burn State Forest;
- Byfield State Forest;
- Cairdbeign State Forest;
- Callide Timber Reserve;
- Calliope Range State Forest;
- Camboon State Forest;
- Canal Creek State Forest;
- Carbine State Forest;
- Carminya Forest Reserve;
- Carminya State Forest;
- Carnarvon National Park;
- Carraba Conservation Park;
- Cherwondah State Forest;
- Collaroy State Forest;
- Combabula State Forest;
- Connors Forest Reserve;
- Cooaga State Forest;
- Copperfield State Forest;
- Crediton Forest Reserve;
- Crediton State Forest;
- Crystal Creek State Forest;
- Dawson Range State Forest;
- Dawson River Conservation Park;
- Develin State Forest;
- Devils Nest State Forest;
- Dinoun State Forest;
- Dipperu National Park (Scientific);
- Don River State Forest;
- Doonkuna State Forest;
- Duaringa State Forest;
- Emu State Forest;
- Epsom State Forest 1;
- Epsom State Forest 2;
- Epsom State Forest 3;
- Eugene State Forest;
- Expedition (Limited Depth) National Park;
- Expedition Resources Reserve;
- Expedition State Forest;
- Fairbairn State Forest;
- Flat Top Range Resources Reserve;
- Forrest State Forest;
- Gelobera State Forest;
- Ghungalu Conservation Park;
- Glencoe State Forest;
- Gogango Range State Forest;
- Goodedulla National Park;
- Grevillea State Forest;
- Gubberamunda State Forest 3;
- Gurulmundi State Forest;
- Gwambagwine State Forest;
- Hallett State Forest;
- Highworth Bend Conservation Park;
- Hinchley State Forest;
- Homevale Conservation Park;
- Homevale National Park;
- Homevale Resources Reserve;
- Howe State Forest;

- Humboldt National Park;
- Humboldt State Forest;
- Isla Gorge National Park;
- Juandah State Forest;
- Junee National Park;
- Junee State Forest;
- Keilambete State Forest;
- Kelvin Forest Reserve;
- Kelvin State Forest;
- Kettle State Forest;
- Kroombit Tops National Park;
- Lake Learmouth State Forest;
- Lake Murphy Conservation Park;
- Limestone Creek Conservation Park;
- Llandillo State Forest;
- Long Island Bend Conservation Park;
- Marlborough State Forest;
- Maxwelton State Forest;
- Mebir State Forest;
- Minerva Hills National Park;
- Montour State Forest;
- Morinish State Forest;
- Moultrie State Forest;
- Mount Archer National Park;
- Mount Archer State Forest;
- Mount Etna Caves National Park;
- Mount Hope State Forest;
- Mount Hopeful Conservation Park;
- Mount Jim Crow National Park;
- Mount Larcom State Forest;
- Mount Leura Conservation Park;
- Mount Nicholson State Forest;
- Mount Organ State Forest;
- Mount Pleasant State Forest;
- Mount Scoria Conservation Park;
- Mundell State Forest;
- Nandowrie State Forest;
- North Pointer Conservation Park;
- Nuga Nuga National Park;
- Overdeen State Forest;
- Palmgrove National Park (Scientific);
- Peak Range National Park;
- Pluto Timber Reserve;
- Porphyry Hill State Forest;
- Precipice National Park;
- Presho Forest Reserve;
- Presho State Forest;
- Princhester Conservation Park;
- Redcliffe State Forest;
- Redrock State Forest;
- Rockybar State Forest;
- Rosedale State Forest;
- Roundstone Conservation Park;
- Roundstone State Forest;
- Rundle Range National Park;
- Rundle Range Resources Reserve;
- Rundle State Forest;
- Serocold State Forest;
- Shotover State Forest;
- Snake Range National Park;
- Spencer Gap Forest Reserve;
- Spencer Gap State Forest;
- Squire State Forest;
- Stephenton State Forest;
- Stones Country Resources Reserve;
- Stuart Creek State Forest;
- Taunton National Park (Scientific);
- Theodore State Forest;
- Tierawoomba Forest Reserve;
- Tierawoomba State Forest;
- Trevethan State Forest;
- Tualka State Forest;
- Ulam Range State Forest;
- Vandyke Creek Conservation Park;
- Walton State Forest;
- Waterton State Forest 1;
- Waterton State Forest 2;
- Werribee Creek State Forest;
- West Hill State Forest;
- Withersfield State Forest;
- Woodduck State Forest;
- Zamia Creek Conservation Park; and
- Zamia State Forest.

Appendix G - Nature refuges in the Fitzroy basin

- Alectura Nature Refuge;
- Archontophoenix Grove Nature Refuge;
- Avocet Nature Refuge;
- Belgamba Nature Refuge;
- Bluegrass Nature Refuge;
- Boggomoss Nature Refuge;
- Boyle's Ridge Nature Refuge;
- Burwood Nature Refuge;
- Carnarvon Station Nature Refuge;
- Caroa Island Paddock Nature Refuge;
- Castlevale Nature Refuge;
- Cometside Nature Refuge;
- Coolibah Nature Refuge;
- Develin Nature Refuge;
- Dovecot Nature Refuge;
- Foggy Block Nature Refuge;
- German Creek Nature Refuge;
- Goonderoo Nature Refuge;
- Kemmis Creek Nature Refuge;
- Kenmare Nature Refuge;
- Lords Table Mountain Nature Refuge;
- Mimosa Park Nature Refuge;
- Moorabinda Nature Refuge;
- Mount Murchison Nature Refuge;
- Mount Rose Nature Refuge;
- Norwich Park Nature Refuge;
- Oxtrack Nature Refuge;
- Paddy's Lagoon Nature Refuge;
- Phiara Downs Nature Refuge;
- Pindari Nature Refuge;
- Rainbow Mountain Nature Refuge;
- Rainbow Nature Refuge;
- Rainmore Nature Refuge;
- Rifle Range Nature Refuge;
- Rivercal Nature Refuge;
- Rockhampton Pistol Club Nature Refuge;
- Shankeen Nature Refuge;
- Southernwood Nature Refuge;
- Stanwell Power Station Nature Refuge;
- Theresa Hut Nature Refuge;
- Trigona Nature Refuge;
- Wallaby Lane Nature Refuge;
- Willawa Nature Refuge;
- Wondekai Nature Refuge;
- Woodine Nature Refuge; and
- Yarrai Nature Refuge.

Appendix H - Ecological processes

Ecological processes of natural coastal ecosystems linked to the health and resilience of the Great Barrier Reef. Islands have been excluded as they vary considerably between island types.

Process	Ecological Service	Coral Reefs	Lagoon floor	Open water	Seagrass	Coastline	Estuaries	Freshwater wetlands	Forest floodplain	Heath and shrublands	Grass and sedgelands	Woodlands	Forests	Rainforests
	Physical processes- transport and mobilisation													
Recharge/discharge	Detains water						MH	H	✓					
	Flood mitigation						M	✓	H		L			
	Connects ecosystems						✓	H	H					
	Regulates water flow (groundwater, overland flows)	H	L		✓	✓	MH	H	✓		L	MH	MH	H
Sedimentation/ erosion	Traps sediment	M	MH	ML	M		H	H			L	MH	MH	MH
	Stabilises sediment from erosion		✓		M	H	✓	✓	✓	✓	L	MH	MH	M
	Assimilates sediment					✓	✓	H				MH	MH	H
	Is a source of sediment							M				MH	MH	
Deposition and mobilisation processes	Particulate deposition & transport (sed/nutr/chem. etc.)							H						
	Material deposition & transport (debris, DOM, rock etc.)							H						
	Transports material for coastal processes							H						
	Biogeochemical Processes – energy and nutrient dynamics													
Production	Primary production	✓	✓	H	H	✓	H	H				M	M	H
	Secondary production				H	✓	H	✓						
Nutrient cycling (N, P)	Detains water, regulates flow of nutrients							H						
	Source of (N,P)				M	L	H					M	M	H
	Cycles and uptakes nutrients	L	H	H	M	L	H	MH		✓	✓			
	Regulates nutrient supply to the reef				M	L	H	M	H			M	M	H
Carbon cycling	Carbon source				M	L	H	H						H
	Sequesters carbon	✓	H	L	M	L	H	H	✓					
	Cycles carbon	L	H	H	M	L	H					H	H	H

Decomposition	Source of Dissolved Organic Matter						H	H						H
Oxidation-reduction	Biochar source											H	H	
	Oxygenates water		H	H		L	✓							
	Oxygenates sediments		✓		M	L	✓							
Regulation processes	pH regulation				M			H						
	PASS management						H	H						
	Salinity regulation													
	Hardness regulation							H						
	Regulates temperature					✓	✓	✓	✓					ML
Chemicals/heavy metal modification	Biogeochemically modifies chemicals/heavy metals	L			M		✓	H						
	Flocculates heavy metals						✓	H						
Biological processes (processes that maintain animal/plant populations)														
Survival/reproduction	Habitat/refugia for aquatic species with reef connections	H	M	L	✓	H	H	H		✓				
	Habitat for terrestrial species with connections to the reef	H						H						
	Food source		✓		H	✓	✓	✓		H				
	Habitat for ecologically important animals	H	✓		H	L	H			✓	✓			
Dispersal/ migration/ regeneration	Replenishment of ecosystems – colonisation (source/sink)	H			H	M	H	H						
	Pathway for migratory fish							H						
Pollination														
Recruitment	Habitat contributes significantly to recruitment	H			H	H	H	H		H				

Capacity of natural coastal ecosystems to provide ecological services for the Great Barrier Reef[69]

H – high capacity for this system to provide this service, M – medium capacity for this system to provide this service, L – low capacity for this system to provide this service, N – no capacity for this system to provide this service, X – not applicable, ✓– service is provided but capacity unknown. Boxes with no data indicate a lack of information available. Note that the capacity shown for modified systems assumes periods of low hydrological flow.

Ecological processes of modified systems linked to the health and resilience of the Great Barrier Reef. Islands have been excluded as they vary considerably between island types.

Process	Ecological Service	Groundwater Ecosystems	Irrigated agriculture	Non-irrigated agriculture	Dams & Weirs	Urban	Mining – operational open cut	Forestry Plantation	Extensive agriculture	Ponded pastures
	Physical processes- transport & mobilisation									
Recharge/Discharge	Detains water	✓[1]	M			L	M		H	
	Flood mitigation	✓	N			L	X		X	
	Connects ecosystems	H	L			L	N		L	
	Regulates water flow (groundwater, overland flows)	H	M			L	L		M	
Sedimentation/ erosion	Traps sediment	N	M[4]			L	M		H	
	Stabilises sediment from erosion	✓	M[4]			H	N		H	
	Assimilates sediment		M			L	N		H	
	Is a source of sediment		L			L[11]	M		L	
Deposition & mobilisation processes	Particulate deposition & transport (sed/nutr/chem. etc.)	✓[2]	L			L	L		H	
	Material deposition & transport (debris, DOM, rock etc.)		L			L	L		L	
	Transports material for coastal processes		N			M	L			
	Biogeochemical Processes – energy & nutrient dynamics									
Production	Primary production	N							M	
	Secondary production	✓[3]							H	
Nutrient cycling (N, P)	Detains water, regulates flow of nutrients	✓							M[13]	
	Source of (N,P)	✓							M	
	Cycles and uptakes nutrients	✓							H	
	Regulates nutrient supply to the reef	✓							H	
Carbon cycling	Carbon source	✓							M	
	Sequesters carbon	✓							MH	
	Cycles carbon	✓							H	
Decomposition	Source of Dissolved Organic Matter	✓							L[14]	

Oxidation-reduction	Biochar source								X	
	Oxygenates water	N							L	
	Oxygenates sediments	N							✓[15]	
Regulation processes	pH regulation	✓							✓[15]	
	PASS management								L	
	Salinity regulation								✓[15]	
	Hardness regulation								✓[15]	
	Regulates temperature								L[16]	
Chemicals/heavy metal modification	Biogeochemically modifies chemicals/heavy metals	✓							X[17]	
	Flocculates heavy metals	✓							L	
	Biological processes (processes that maintain animal/plant populations)									
Survival/reproduction	Habitat/refugia for aquatic species with reef connections	N	L[5]	L[5]	L[8]	L[12]	N	N	L	M[18]
	Habitat for terrestrial species with connections to the reef	N	L	L	H[9]	L	N	N	L	L[19]
	Food source	N	N	N	M	L	N	L	M	L
	Habitat for ecologically important animals		N	N	L[10]	N	N	N	M	L[19]
Dispersal/ migration/ regeneration	Replenishment of ecosystems – colonisation (source/sink)	N	N	N	L	N	N	N	M	L[20]
	Pathway for migratory fish	-	N[6]	N[6]	L[8]	N	N	N	✓[15]	L[21]
Pollination		-	L[7]	L[7]	N		N			
Recruitment	Habitat contributes significantly to recruitment		N	N	L	N	N	N	M	N

Capacity of natural coastal ecosystems to provide ecological services for the Great Barrier Reef[69]

H – high capacity for this system to provide this service, M – medium capacity for this system to provide this service, L – low capacity for this system to provide this service, N – no capacity for this system to provide this service, X – not applicable, ✓– service is provided but capacity unknown. Boxes with no data indicate a lack of information available. Note that the capacity shown for modified systems assumes periods of low hydrological flow. End-notes 1 – capacity depends on hydraulic characteristics of the aquifer (porosity, permeability); 2 - particulate transport occurs sometimes in subterranean systems; 3 - secondary production is variable; 4 - dependent upon crop cycle; 5 - habitat for crocodiles and turtles; 6 - especially in channels, but is dependent on water quality; 7 - depends upon crop; 8 - only where fish passage mechanisms exist; 9 - especially water & shorebirds; 10 - particularly aquatic species (though may lack connectivity); 11 - refers to new developments; 12 - impoundments, ornamental lakes and stormwater channels; 13 - hoof compaction of soil increases run-off; 14 - particulate organic carbon is high, dissolved is low; 15 - unchanged from natural ecosystem capacity; 16 - relates more to extent of vegetation clearance of riparian zone; 17 - contaminant; 18 – in the dry season amongst Hymenachne; 19 - particularly for birds; 20 - sink biologically as species move into areas but reduced water quality can affect badly; 21 - subject to water quality and grazing regime.

Appendix I - Water quality report for the Fitzroy basin

1. Summary

The Fitzroy basin is the largest Great Barrier Reef catchment and has undergone intensive land clearing over the last century. As a result, high amounts of pesticide containing sediments are lost from the Fitzroy basin into the Great Barrier Reef lagoon, where these chemicals are widely distributed. Coral reefs within the region are under threat from land-based pollution from Keppel Bay out to the Capricorn Island group. After extreme flood events, flood plumes from the Fitzroy basin have been shown to cover hundreds of kilometres and reduce water quality for months. There has been many changes to hydrological dynamics and drainage within the Fitzroy basin and many developments, mostly related to mining, are planned that will further impact the flow of waterways within the Fitzroy basin in the future. A major issue with modifications to the natural flow of waterways is that aquatic species have been cut off from upstream regions of the river where they spawn. The Fitzroy River basin contains many resource management groups such as the Fitzroy Basin Association.

2. Hydrology and drainage

The Fitzroy basin has been highly modified by various processes over the last century. Localized land clearing occurred during the first 100 years of settlement in this region for cattle and sheep grazing, cultivation and mining activities.[1] Clearing rates intensified under the Brigalow Development Scheme (1960s to 1980s), which resulted in some of the fastest rates of land clearing recorded in the world.[1] Erosion reduces the productive potential of land, and transports sediments and nutrients, as well as increased flow rates to streams within the catchment that discharge into the Great Barrier Reef.[2] Erosion rates from a range of land uses and land scales (plots to catchments) have been measured and are presented in Table 1.

Table 1: Erosion rates for plot to small catchment scale areas in the Fitzroy basin. Source:[1]

Land Use	Location/Study	Land Type	Scale	Sediment Size	Period	Rate (t/ha/yr)
Mining	Carroll, C. 2000	Mines Rehab	Plot	Suspended and bedload	93-99	0.5-70
Irrigation	Carroll, C. 1995	Downs	Furrow	Integrated	<1 year	4-5
Cropping	Spottswood on farm (unpublished)	Brigalow with softwood scrub species	Small catchment	Integrated	00-01	5
Cropping	Carroll, C. 1997	Downs	Small catchment	Integrated	894-90	1-4
Cropping	Gordonstone on farm (unpublished)	Downs	Small catchment	Integrated	00-06	1
Cropping	Brigalow catchment study	Brigalow with	Small catchment	Suspended 00-50	00-05	1

	(unpublished)	softwood scrub species				
Grazing	Medway (Ciesiolka, C. 1987)	Narrow-leaved	Small catchment	Suspended	79-84	4
Grazing	Keilambete (Silcock, R.G. 2005)	Silver-leaved ironbark	Plot	Suspended + bedload	94-00	2-4
Grazing	Glentulloch (Silcock, R.G. 2005)	Poplar box flats	Plot	Suspended + bedload	94-00	0.3-1.3
Grazing	Springvale (Ciesiolka, C. 1987)	Silver-leaved ironbark	Small catchment	Suspended	79-84	0.7
Grazing	Spottswood catchment study (unpublished)	Brigalow with softwood scrub species	Small catchment	Suspended	00-06	0.5
Grazing	Brigalow catchment study (unpublished)	Brigalow with softwood scrub species	Small catchment	Suspended	00-05	0.27
Grazing	Gordonstone (unpublished)	Downs	Small catchment	Suspended	02-07	0
Remnant	Brigalow catchment study (unpublished)	Brigalow and softwood scrub species	Small catchment	Suspended	00-05	0.18

The hydrology and drainage of the Fitzroy basin has been highly modified with the construction of 29 dams and weirs that provide water security for agriculture, mining, industrial and urban uses.[1] The Fitzroy barrage is the last water structure before the mouth of the Fitzroy River and has effectively halved the length of the Fitzroy River estuary tidal extent to 56 km.

3. Basin water quality

a) Water quality

1) Status of monitoring in basin and rivers

The Fitzroy basin has been subject to intensive monitoring. For example, in 1992 the Fitzroy Catchment Symposium took place which addressed many different environmental aspects such as resources uses, impacts of agricultural land use on the Fitzroy River system, integrated catchment and river management, and much more. Water quality monitoring programs have been conducted by the Fitzroy Basin Association (2005-2009) and the Fitzroy Basin Water Quality Improvement Report was completed in 2008. This report focused on the Fitzroy basin and its receiving waters, agricultural land and surface water quality, diffuse sources of rural pollution and the adoption of best management practices.

Water quality is monitored by “Priority Neighbourhood Catchments”, which is a group associated with the Fitzroy Basin Association. They conducted event monitoring from 2005-2009 in priority catchments throughout the Fitzroy basin. Additionally, an 11 year study of source to sea pollutant delivery within the Fitzroy River basin was conducted by Packett et al. (2009).[3]

2) Water quality data

Packett et al. (2009) conducted a study on pollutant delivery from source to sea in run-off from the Fitzroy basin.[3] Floodwaters were sampled to determine concentrations and total loads of pollutants at various sites throughout the Fitzroy River basin during two sampling periods (1994-1998 and 2002-2008). The major tributaries included in the sampling were the Nogoa, Comet, Mackenzie, Isaac/Connors, Dawson and Fitzroy rivers and Theresa Creek. Annual discharge from the Fitzroy River basin was found to vary throughout the duration of the study. Very large floods (with approx. 16-20 million megalitres (ML) were recorded three times over the last 100 years, in 1918, 1954 and 1991. Medium to large volume floods (6-15 million megalitres) have a return period of approximately 10-15 years. Total annual discharge has exceeded five million ML on only 23 occasions over the last 80 years. Mean and median long-term annual discharge is 4.8-2.7 million ML yr^{-1} for the Fitzroy; however during the course of the eleven year study, small volume floods dominated the annual flow regime.

Total suspended solids (TSS) are highly variable during Fitzroy floods, which is indicative of differences in sediment source depending on where heavy rainfall has occurred. Sub-catchment pollutant concentrations were higher compared to whole of basin concentrations from the same flood events. Total phosphorus (TP) and total nitrogen (TN) were determined for 132 samples from 1994-2008. Concentrations ranged from 0.63-2.2 mg L^{-1} and the mean and median concentrations were 0.16 and 0.63 mg L^{-1}, respectively. TN ranged from 0.36-4.1 mg L^{-1}, while mean and median concentrations were 0.14 and 1.6 mg L^{-1}, respectively. Both TP and TN measured during flood events were higher in concentration in sub-catchment areas compared to lower in the Fitzroy River. Highest nutrient concentrations often corresponded with run-off originating from cropping land.

Pesticides were also measured by Packett et al. (2009), however less frequently.[3] Tebuthiuron and atrazine were the most commonly detected herbicides, with 90% of samples having detectable limits. Less frequently detected herbicides included hexazinone, prometryn, floumeturon and dieldrin. The highest maximum concentrations of atrazine and diuron were linked with run-off from regions with the highest percentage of cropping lands. During the Comet River (2002) and early Nogoa River (2004) flood events, maximum atrazine concentrations at a sub-catchment scale measured 2.20 and 4.26 µg L^{-1}, respectively, while at a basin scale, maximum concentrations were 0.80 and 0.95 µg L^{-1} respectively. Highest maximum tebuthiuron concentrations were measured in areas dominated by grazing during events in late 2004 and early 2005. Highest concentrations measured in 2004 and 2005 were 0.83 and 0.72 µg L^{-1}, respectively, compared to atrazine and diuron concentrations which were 0.30 and <0.01 µg L^{-1}, respectively. In 2008 atrazine, diuron and tebuthiuron loads measured during events all had mean concentrations above guideline trigger values set in the Draft Great Barrier Reef Marine Park Authority Water Quality Guidelines for at least one flood event at a basin scale. The authors concluded that grazing lands are a major contributor to the long-term average annual loads of most common pollutants and that maximum pollution concentrations measured at basin and sub-basin scales are related to the percentage of heavy rains received. The authors suggested that land management targets should be established in order to reduce Great Barrier Reef pollution rather than water quality targets. Additionally, management of pesticides should therefore make tebuthiuron, diuron and atrazine a priority.[1]

The Priority Neighbourhood Catchments Water Quality Monitoring Program collected data at 20 sites across 10 Priority catchment areas over four consecutive wet seasons from 2005-2009. Due to a lack of historical and local event-based data, comparisons of results could not be made and it was therefore difficult to draw conclusions, especially since most sites recorded concentrations of sediment and nutrients higher than levels outlined in national and state water quality guidelines.[2] Sampling was conducted during flow events that occurred almost entirely in third and further order streams. Results indicated that all pH and salinity averages were below the ANZECC trigger values for disturbed ecosystems[4], while turbidity and nutrient levels were well above ANZECC trigger values. However, the total average of most yearly averages was within the Fitzroy Association Interim Water Quality Guidelines.[2] It is expected that certain parameters will exhibit increased levels or concentrations during flood events, which was observed for TSS, nitrogen, phosphorus and turbidity. Turbidity was > 70 times the ANZECC trigger value for disturbed ecosystems, while TSS was 133 times the trigger value and nitrogen and phosphorus were over 4 times and 26 times the suggested upper limits, respectively.[2]

b) Ecological effects of water quality and hydrological changes in basin

The Fitzroy River Barrage at Rockhampton, located upstream of the estuary blocks fish passage and has modified tidal influence.[5] Environmental flow will be impacted to a lesser extent if effective fishways are constructed.[1] The designs of many Australian fishways were based on northern hemisphere salmonoid fisheries and are therefore not applicable in Australia. The fishway associated with the Fitzroy River Barrage was initially ineffective; however several modifications have been made. The Barrage fishway still prevents passage by smaller fish of some specific species; however its effectiveness has generally increased. There are a few areas with no barriers and these areas are believed to be significant for maintaining many aquatic species populations. Fish barrier removal in the FBA region has become a priority, especially in the Tartrus and Eden Bahn.[1]

4. Coastal water quality

a) Water quality

1) Status of monitoring in coastal areas

The Fitzroy Basin Water Quality Improvement Report was completed in 2008, which focused on the Fitzroy basin and its receiving waters, agricultural land surface water quality and Great Barrier Reef assets. Approaches to encourage best management practices were also developed. The Fitzroy Basin Association has conducted a lot of work to ensure sustainable development and natural resource management. In 2012, Rachel Eberhard of Eberhard Consulting completed the Fitzroy River Estuary Development Proposals – A Review of

Issues, which presented information that needed to be considered for sound ecosystem management in relation to the proposed developments within the Fitzroy basin.

2) Water quality data

Annual loads of sediments delivered to the Great Barrier Reef from the Fitzroy basin was 3,326,000 tonnes in 2008, which was 74,000 tonnes less than the 3 years prior.[1] The majority of suspended sediments released from the Fitzroy River into the Great Barrier Reef are deposited near the river mouth, while dissolved nutrients are transported with the plume into the Great Barrier Reef lagoon.[6] Annual average nitrogen and phosphorus loads have decreased by 193 and 56 tonnes, respectively since 2005. These improvements in water quality within Keppel Bay have been associated with improved management of agriculture. The Fitzroy Basin Association hopes to continue these gains in improved agricultural management over the next two decades.[1]

Flood plumes discharged from the Fitzroy River have extended more than 10,000 km^2, during large flood events, reaching the Capricorn Bunker Group to the east and north of Townsend Island.[1] Modelling and monitoring studies have shown that river plumes moving through the Fitzroy River Barrage transport contaminants into the GBR World Heritage Area including Keppel Bay and the Capricorn Channel. As a result, the reefs in these areas are at risk from exposure to sediment, nutrients and chemicals.[1] Dissolved matter is transported across and along the Great Barrier Reef lagoon, and contaminants are widely dispersed throughout the Great Barrier Reef. Wet season floods are a major delivery mechanism for land-derived pollutants and nutrients, as contaminant concentrations during flood events are much higher than during non-flood periods.[1] The storage, transformation and transport of contaminants reaching Keppel Bay determines the degree to which coral reefs and seagrass meadows are impacted. Initial flood pulses last several weeks, however the breakdown through bacterial action is a more long-term process and contaminants can become chronic through tidal re-suspension.[1] During acute flood events it has been estimated that almost all sediments and nutrients are delivered to the Fitzroy River estuary and Keppel Bay and that the majority of nutrient material transported down the river is in organic form attached to fine sediment particles. Nutrients and pesticides are carried further into the Capricorn Channel and Bunker Group of islands and impact the Great Barrier Reef.[1]

Discharge from the Fitzroy generally occurs as one or two small annual flows, however occasionally a very large flood event occurs that may last for several weeks and greatly exceeds discharge from other regional rivers.[7] The Marine Monitoring Program (MMP) sampled the 2011 flood plume in the Fitzroy River. Seven sampling trips occurred between January and April 2011, and 72 samples were taken at 14 fixed sites. The plume extent, frequency and duration were measured using remote sensing products, and passive samplers were deployed at several locations (Middle Reef, Miall, North Keppel Island, Halfway and Clam) in the Fitzroy region in order to monitor spatial variation in the concentrations of herbicides.[8] High water quality variables were measured over all transects and highest values were associated with the Fitzroy River.[8] Average TSS values ranged from 3-29 mg/L, average Chl-a values averaged between 0.5 to 2.6 µg/L, and average DIN values ranged from 2 to 5 µM along the 6 transects located at the Fitzroy River mouth to the southern end of the Whitsunday reefs. At every site, levels of suspended sediment, DIN, and

DIP were elevated above the long term mean.[9] PN was elevated at all but 3 sites and PP was elevated at all but 4 sites. Chl-*a* was only elevated above the long term mean at half of the sites. This data showed that 2010-2011 was one of the most extreme flooding events ever measured within the context of the Marine Monitoring Programs wet season flood plume sampling program. The water quality measured in 2010-2011 supports the conclusion that extreme weather events lead to unusually elevated levels of pollutants, particularly in the Fitzroy region.[9] Water quality changes driven by extreme weather events can reduce the resiliency of the Great Barrier Reef through sub-lethal and lethal effects on ecosystems that result in a lowered ability to recover.[10] he extent and duration of these conditions in the 2010-11 wet season also showed that the water quality conditions can be reduced over a period of months and cover a distance of hundreds of kilometres.[9]

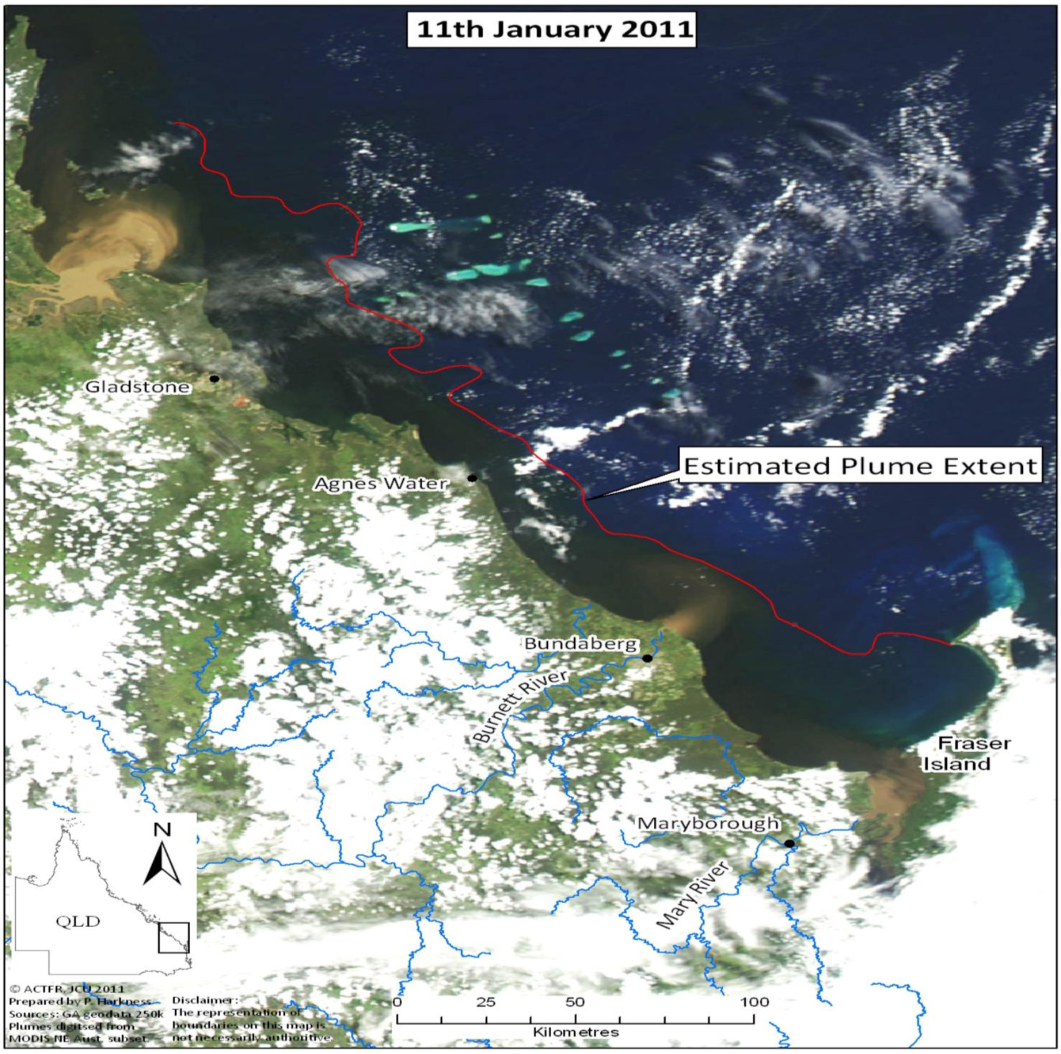

Figure 1: Image of the Fitzroy River plume (upper left corner) on January 11, 2011

Figure 2: Flood plume exiting the Fitzroy River January 29, 2013

The spatial distribution of various water quality variables were predicted and mapped across 6 regions and 3 cross-shelf (coastal, inner shelf and outer shelf) positions in the Great Barrier Reef using measurements from 1985-2006.[11] The values predicted for the Fitzroy are provided in Table 2. All variables generally decreased with increased distance from the coast with the exception of Secchi depth, which increased at more offshore sites. Compared to the other 5 analysed regions (Cape York, Burdekin, Mackay Whitsunday, Wet Tropics, Burnett Mary), the Fitzroy contained: the highest Secchi depth in the inner shelf region (14.3m), while Chl *a* values, particulate nitrogen (PN) and total dissolved phosphorus (TDP) were in the middle range of values measured between regions. All other values were low compared to the other regions.

Table 2: Mean annual values of water quality variables predicted in 3 cross-shelf regions of the Fitzroy region

Variable	Coastal	Inner Shelf	Outer Shelf	Across all zones
Secchi depth (m)	5.5 ± 0.9	14.3 ± 0.8	19.2 ± 1.0	16.7 ± 0.9
Chl a (µg L^{-1})	0.7 ± 0.05	0.5 ± 0.04	0.4 ± 0.04	0.4 ± 0.04
SS (mg L^{-1})	2.7 ± 0.4	1.6 ± 0.2	0.7 ± 0.1	1.1 ± 0.2
PN (µmol L^{-1})	2.0 ± 0.2	1.8 ± 0.2	1.1 ± 0.1	1.4 ± 0.1
PP (µmol L^{-1})	0.09 ± 0.01	0.08 ± 0.01	0.06 ± 0.01	0.06 ± 0.01
TDN (µmol L^{-1})	5.4 ± 0.5	5.1 ± 0.4	4.8 ± 0.3	5.0 ± 0.3
TDP (µmol L^{-1})	0.38 ± 0.06	0.31 ± 0.04	0.22 ± 0.03	0.26 ± 0.03
TN (µmol L^{-1})	6.9 ± 0.6	7.1 ± 0.5	6.8 ± 0.6	6.9 ± 0.6
TP (µmol L^{-1})	0.46 ± 0.07	0.42 ± 0.06	0.29 ± 0.05	0.34 ± 0.06

An assessment of in shore ecosystems exposed to different categories of surface pollutants within the Fitzroy region showed a total of 3,459.23 km^2 of coral reefs and 226.27 km^2 of seagrass beds are exposed to PSII, TSS and DIN.[8]

The current best estimates of modelled loads leaving the Fitzroy basin are provided in Table 4. Pre-development loads were substantially lower than current values for all parameters measured. TSS and TN have increased substantially since pre-development with overall increases of 1,362 kt/yr and 1,991 t/yr, respectively. Since the implementation of the Reef Rescue program (2009/2010) some values have shown improvement, however the per cent change is very small compared to other basins along the eastern coast of Queensland. For example, PSII herbicide values have not decreased since Reef Rescue was initiated and no values have shown an increase over 2%, which is not a substantial change.

Little information is currently available regarding the transport of nutrients in the basin. Best estimates of TN and TP exports from the Fitzroy were 3,702 and 1,022 t/yr, respectively. These values are approximately three times pre-development estimates of nitrogen and phosphorus. A strong relationship between Total Suspended Solids (TSS) and TP, as well as a moderate relationship for TN has been found at a basin and sub-basin scale, allowing the targeting of sediment hotspots to also target nutrient hotspots.[1] Mean concentrations for nutrients in event floodwaters were measured in 1994 and 2008. Event mean concentrations (EMCs) ranged from 1.09 mg/L in the Connors to 4.86 mg/L in the Nogoa for TN and 0.28 mg/L in the Connors and 1.87 mg/L in the Comet for TP.[1] Current ambient Queensland Water Quality Guidelines for TN and TP are currently 0.5 mg/L and 0.05 mg/L, respectively in lowland streams, thus measured mean values at the basin and sub-basin scales were above guideline values.[1] Mean event concentrations were also above guidelines for upland streams in 2005-2007 when nutrient concentrations were 2.9 mg/L for TN and 1.4 mg/L for TP in catchment floodwaters. The current guideline values are 0.25 mg/L and 0.03 mg/L. It has been suggested that since nitrogen and phosphorus concentrations rarely fall below Queensland water quality guidelines, the current guidelines for nutrients are not suitable for the Fitzroy basin during event conditions. Interim guidelines proposed for event based flows in the FBA region (based on the 80th percentile range of monitored data) are 3.7 mg/L for TN and 2.0 mg/L for TP and only related to event conditions.[1] Recent analyses have shown that past Great Barrier Reef load and risk exposure modelling for the Fitzroy basin have underrepresented dissolved phosphorus loads and risk exposure.[1]

Table 3: Best estimates of modelled total pre-development values, current values, and anthropogenic changes in water quality parameters. Reef Rescue values represent the values after the commencement of the Reef Rescue program and Reef Rescue change represents the improvement (%) after implementation

	Pre-development	Current (2008/2009)	Current (2009/2010)	Anthropogenic Increase	Reef Rescue (2009/2010)	Reef Rescue change (%)	Total change (%)
TSS (kt/yr)	442	1,805	1,789	1,362	1,792	0.9	1.2
DIN (t/yr)	631	1,106	1,106	475	1,106	0	0
DON	855	1,548	1,548	693	1,548	0	0

(kt/yr)							
PN (t/yr)	234	1,057	1,048	823	1,051	0.7	1.0
TN (t/yr)	1,719	3,710	3,702	1,991	3,704	0.3	0.4
PSII (kg/yr)	0	595	595	595	595	0	0
DIP (t/yr)	142	260	260	118	260	0.4	0.4
DOP (t/yr)	29	54	54	25	54	0.4	0.4
PP (t/yr)	146	718	709	572	710	1.4	1.7
TP (t/yr)	317	1,032	1,022	715	1,024	1.2	1.4

Source:[12]

b) Ecological effects of water quality and hydrological changes in coastal areas
Anecdotal evidence provided by local residents suggests that the Capricorn coastline was once rich in coral communities, however these mainland reefs have disappeared and coastal inland reefs within Keppel Bay are under threat.[1]

According to the First Report Card,[13] corals in the Fitzroy basin are in moderate condition, with moderate coral cover and good settlement of juvenile corals. However, the abundance of juvenile corals is poor and there is a high cover of macroalgae.[13] Although the reefs have recovered from significant disturbances over the last decade, their resilience to further disturbances is uncertain.[13]

Seagrass abundance in the Fitzroy region is good and has generally increased in coastal and estuarine locations. However, seagrass abundance has decreased in reef locations.[13] A reduction in resilience to disturbances has been indicated by the low numbers of reproductive structures. The coastal seagrasses in Shoalwater Bay are the least impacted meadows that occur along the urban coast of the Great Barrier Reef.

5. Additional pollutants
Coal mining covers less than 1% of the Fitzroy basin area; however coal mining is the basins largest asset. From 2007-2008, Queensland exported approximately 152 million tonnes of coal.[1] Mine water discharge is an emerging issue with regards to saline releases, which impact freshwater ecosystems. Mine discharges from 2007-2008 raised salinity levels dramatically in the Isaac, Mackenzie and Fitzroy rivers.[1] Mining procedures can also influence water quality due to water harvesting, stream diversions and unstable landforms from mining spoil and slumping.[1]

6. Management

a) In basin for basin
The Fitzroy Basin Association (FBA) is involved in the achievement of healthy catchments via strong independent leadership by an engaged community at a regional level. The

association is responsible for coordinating natural resource management across the Fitzroy basin. The areas of interest for the FBA are ecological integrity, water quality, land use management, cultural heritage and climate change action. Programs run by the FBA focus on: healthy waterways, rivers and wetlands, paddock to reef, sustainable landscapes, coastal and marine ecosystems. The FBA conducts long-term monitoring and strategic assessments.

The Central Queensland Strategy for Sustainability – 2004 and Beyond (CQSS2) is a multi-stakeholder, natural resource management plan that has outlined goals for the Fitzroy basin. A main target is to improve agricultural land management and run-off water quality.[2]

b) In basin for Great Barrier Reef

The Reef Water Quality Protection Plan (Reef Plan) was designed to accelerate the improvement of water quality in agricultural run-off that is released into the Great Barrier Reef and to ensure that the quality of water entering the reef is not negatively impacting the health and resilience of the Great Barrier Reef and by 2020.[12] Actions include engaging land managers in farm planning, risk assessment and training in nutrient and groundcover management, the protection of wetlands of high ecological significance, and partnership development between natural resource management groups and farmers to accelerate the voluntary adoption of best management practices that will benefit reef water quality.[12]

A 20 year intermediate target of a 44% reduction in sediment loads requires the implementation of best management practices (BMP) across all agricultural land by 2030.[1] Indicators point to a rapid intensification of land use in the Fitzroy basin over the next two decades as mines, gas fields and urban development, industrial development, land use intensification and water infrastructure are expected.

7. Future land use changes

Major land use changes are planned within the Fitzroy basin. In 2008, 5 dams and weirs were planned for construction or extension that would have the combined capacity to capture 1,200,000 ML of water.[1] To date, the Connors Dam at Mount Budget has been withdrawn and the Commet River Weir Dam is unlikely to proceed. However, the Nathan Dam proposal is still active. This dam would hold half the volume of the Burdekin Falls Dam, which is approximately 888,000 ML.[14] This dam is a major initiative with the long-term goal of providing reliable water supplies to mining, power, urban and existing agricultural customers in the Surat Coal basin and the Dawson-Callide sub-region of central Queensland.[14] The proposed site of the dam is on the Dawson River upstream of the Nathan Gorge, approximately 70km downstream from Taroom, and 315km upstream from where the Dawson and Fitzroy rivers meet. Additionally, the Nathan pipeline has been proposed, which will run from the Nathan Dam through Surat basin, potentially extending as far as Dalby, which is a total of 260km.[14]

If any of the proposed dams are built, it could be expected that land use would shift from grazing to irrigated agriculture (cotton and grains). In terms of changing the existing land used for grains, cotton and aquaculture, large changes will only occur if extra water is available, thus land use changes are highly dependent on the construction of dams.

With plans for 17 additional major coal mines in the area, coal terminal expansion has also been proposed.[1] Eberhard (2012) wrote a review on the issues associated with proposed developments within the Fitzroy River estuary.[5] The report discussed two independent proposals, the Balaclava Island Coal Export Terminal (BICET) and the Fitzroy Terminal Project (FTP), which are currently in State and Commonwealth Assessment Processes. The BICET will be larger than the FTP and the facility plans to export 35 Mtpa at Balaclava Island, directly loading coal onto ships. There are two stages to the proposed FTP project; the first will handle approximately 10 Mtpa and the second stage will handle 22 Mtpa. If the BICET is approved a third stage will be considered, which will entail an additional FTP berth. Barges with a loading capacity of 10,000 DWT will carry coal out to open waters where it will then be transferred to ships. Both the BICET and FTP will require dredging. Additionally, 2 developments have been flagged by Gladstone Ports Corporation (GPC), a Queensland Government-owned port authority; however no formal proposals have been prepared. The first proposal involves the expansion of 3 additional berths to the Balaclava Island facility. The second proposal involves the development of a major port facility north of Curtis Island.

Implications and associated threats of these port development proposals are outlined in the report by Eberhard (2012) and include the following: vegetation will need to be cleared which will result in disturbance to wetlands and connectivity, soil exposure and erosion, benthic habitat removal and modification. Aquatic environments will be exposed to acid sulfate soil, turbidity and sedimentation.[5] Noise and dust pollution, as well as boat traffic and contamination by oil and fuel will increase. Additionally, marine debris, introduced species and greenhouse gas emissions are likely to increase. A major concern is the cumulative effects of many of these threats. Coal port expansion could have immense ecological implications on the surrounding coastal zone. This coastal area is habitat for four species of turtles, all of which are listed under state and Commonwealth conservation legislation. A highly significant Flatback Turtle nesting site is situated at Peak Island, adjacent to the proposed ship mooring site. Additionally, three species of inshore dolphins (Australian Snubfin dolphin, the Indo-Pacific Humpback Dolphin and the Indo-Pacific inshore Bottlenose Dolphin) inhabit areas around the Fitzroy estuary.

In regions where coal is too deep to mine gas fields have been proposed that will cover a large area.[1] Three natural gas refineries have been proposed for the Port of Gladstone. One of the implications of gas production is salt laden.[1] Urban centers are expected to double in size and as of 2008 there was no concrete plan to improve the basin’s largest Sewage Treatment Plant (STP). There is also a possibility of increased coastal aquaculture, which could alter coastal foreshore, estuarine, mangrove, salt marsh and marine and other aquatic environments.[14] Environmental impacts associated with aquaculture are water pollution, pest species, strain placed on wild fish populations for feeding and brooding, as well as the culling of natural predators.[14]

8. Knowledge gaps

There is currently a large knowledge gap related to the impacts of coal dust on the marine environment, as well as riverine ecosystems that are impacted by colliery waste water. Considering that many new coal mines have been proposed and have been approved, increased research and monitoring is important to analyse the risks involved with coal processing and exportation.

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