Australian Government

Great Barrier Reef
Marine Park Authority

Mulgrave-Russell Basin Assessment

Wet Tropics Natural Resource Management Region

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

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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 Mulgrave-Russell 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 Mulgrave-Russell 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 Great Barrier Reef.
- 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 Mulgrave-Russell basin

The Mulgrave-Russell basin covers an area of 198,197 hectares and is situated in the Wet Tropics region. It has significant natural assets and is home to (and used by) many important marine, estuarine, freshwater, and terrestrial species with connections to the Great Barrier Reef. The basin is unique in that it lies between two World Heritage Areas – the Wet Tropics World Heritage Area and the Great Barrier Reef World Heritage Area (World Heritage Area). The stream and river systems that link these two world heritage areas house some of the highest fish diversity in Australia, with two thirds of the continent’s genera and 40 per cent of the species.[1] There has been recent discoveries of new species and at least nine endemic species occur here. Maintaining good in-stream water quality in this basin is therefore of utmost importance.

Key issues

Inshore coral reefs found within the Wet Tropics region of the Reef have been identified as supporting a relatively low biodiversity, which has been linked to poor water quality.[2,3,4] Progress has been made towards improving the water quality leaving the basin through Reef Plan, industry lead initiatives and programs initiated by local Landcare, catchment groups and the Cairns Regional Council.

Of particular concern in the inshore area surrounding the Mulgrave-Russell basin is the crown-of-thorns starfish (*Acanthaster planci*). Enhanced nutrient supplies are transported in Wet Tropics flood plumes (including plumes sourced from the Russell-Mulgrave River) and these travel around Cape Grafton and cover the outer shelf area from Green Island northwards.[5,6] Nitrate and orthophosphate in these plumes promote the formation of phytoplankton blooms and increased biomass of larger phytoplankton species (> 2 µm), which are the primary food source of crown-of-thorns starfish larvae.[7] Green Island and the surrounding area exposed to Wet Tropics flood plumes is believed to be an initiation area for crown-of-thorns starfish outbreaks, after which the larvae are transported southward by currents.[7,8]

The perennial stream flows in the Mulgrave-Russell basin, coupled with the fact that there are few man made barriers, allows generally good passage opportunities throughout the basin for migrating fish with connections to the Reef. However, proposals for groundwater extraction from the Mulgrave aquifer may result in a drawdown of dry season flows which may change this, especially in Behana Creek.

Whilst the rainforests of the mountain ranges that form the upper catchment of the basin are still relatively undisturbed, much of the former floodplain coastal ecosystems, namely rainforests, woodlands, grasslands and wetlands, have been heavily modified or removed. The changes to these ecosystems (and the ecological functions they provide) have occurred over the last century driven by the development of land for agriculture and growth of urban centres. These changes include removal of coastal ecosystems, significant changes to overland hydrology, introductions of feral species, drainage of wetland ecosystems, and exposure of potential acid sulphate soils. These changes are mostly irreversible and future management needs to be adaptive and innovative. Future urban development also needs to utilise water-sensitive urban design to ensure water quality and environmental values are maintained.

Potential Management Actions

This report has been developed as a baseline for the Mulgrave-Russell 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 of, 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:

- Greater protection, restoration and management of remnant and riparian vegetation in the floodplain.

- Greater protection, restoration and management of freshwater wetlands which have been reduced from 1854 hectares to 984 hectares.
- Restore connectivity of streams, rivers and waterways to improve fish passage through restoration of fish habitat (deep water pools, log jams).
- Improve connectivity between remnant coastal ecosystems, with preference to the freshwater wetlands and associated floodplain ecosystems.
- 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 such as Reef Plan best practice initiatives for agriculture.
- Limit the development of any further irrigated cropping in the basin to reduce the risk of nutrients causing further crown-of-thorns starfish outbreaks.

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 Mulgrave-Russell 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 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 Mulgrave-Russell basin, which includes ecosystems extending from the inshore areas of the Marine Park to the upper extent of the Mulgrave-Russell 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 thirty-five 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	
	MackayWhitsunday 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[9], 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*[10] 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[9] and have been used as a basis to assess the Mulgrave-Russell basin assessment. Figure 1 below describes the methodology used to rapidly assess the ecological functions and values to conduct the Mulgrave-Russell basin assessment.

Figure 1: Summary of the methodology for conducting a rapid 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*[10] 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 assessment 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.

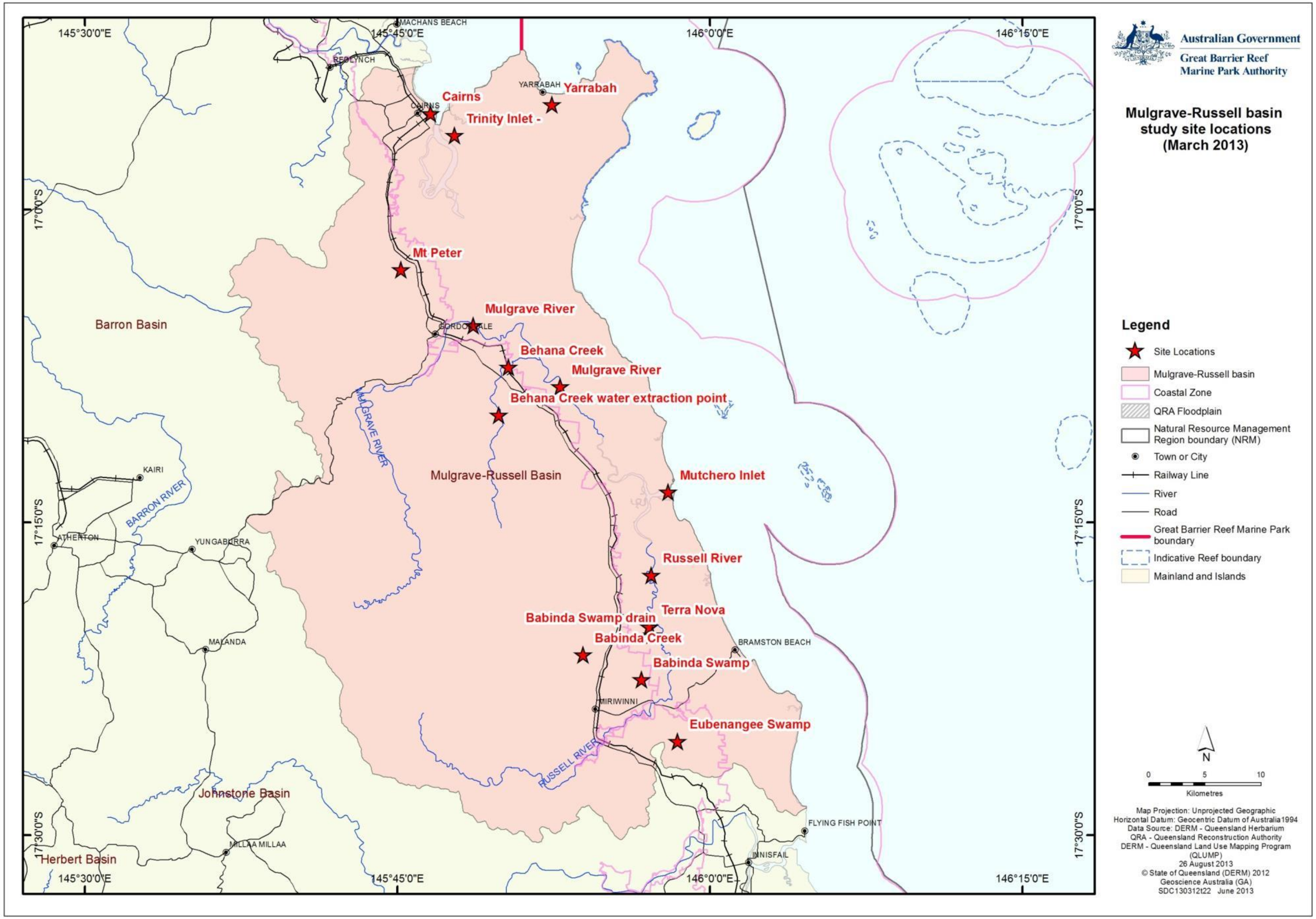


Figure 2: Study sites for the Mulgrave-Russell basin assessment

PART A: VALUES OF THE GREAT BARRIER REEF REGION – MULGRAVE-RUSSELL BASIN

Chapter 1: Mulgrave-Russell basin – background to changes affecting matters of national environmental significance

1.1 Background and history of the Mulgrave-Russell basin

The Mulgrave-Russell River basin (as mapped by the Queensland Government) (Figure 1.1.1) lies to the south of the city of Cairns between the latitudes of 16º55" and 17º25". The southern region of the Cairns Regional Council local government area covers the area of the basin between the eastern side of the Bellenden Ker Range to the coastline excluding the area occupied by the Shire of Yarrabah. The Shire of Yarrabah, a special local government area, lies to the South East of Cairns. Occupying the Yarrabah peninsula, this local government area is surrounded by the coastline that runs east from False Cape around Mission Bay, past Cape Grafton and Kings Point and then south to Palmer Point. The total coastline is in excess of 60 kilometres.[11] The eastern edge of the Tablelands Regional Council local government area covers the area of the basin to the West of the Bellenden Ker Range.[12]

The Mulgrave-Russell basin exists within the wet tropics region of North Queensland and is comprised of the catchments of the Mulgrave (1315km^2) and Russell (668km^2) rivers. The two rivers join together to form the Mutchero Inlet and enters the Marine Park adjacent to the Franklin Islands which includes Marine National Park Zone MNP-17-1063 and Conservation Park Zone CP-17-4041. The Franklin Islands include Russell Island, which is a Commonwealth island, and Normanby, Mable and Round Island National Parks.

The Mulgrave-Russell basin is home to the Wanyurr-Majay People and the Idinji people. The Idinji people used small heavy dug-out canoes cut from the wood of certain mangrove trees to move through the rivers, waterways and mangrove swamps of the Russell and Mulgrave River areas. Idinji had many traditional ways that were confronting to the Europeans, such as mummification.[13]

Figure 1.1.1: Mulgrave-Russell basin and proximity to the Great Barrier Reef

Mean annual rainfall varies from 400 to 2000 mm along the north south gradient of the basin while a rain monitoring station on the top of Mount Bellenden Ker in the Bellenden Ker Range that forms the catchments of both rivers receives an average annual rainfall of 8000 mm.

The area experiences occasional cyclones with Cyclone Larry (Category 4) crossing the basin in 2006 causing significant impact to the environment and communities of the area. In 2011 the eye of Cyclone Yasi (Category 5) passed within 100 km of the southern end of the basin resulting in moderate impacts to the environment and communities of the area.

The upper catchment of both rivers exists within the relatively undisturbed rainforest environments of the Bellenden Ker Range. This area includes the Wooroonooran National Park and the Bellenden State Forest both lying within the Wet Tropic World Heritage Area. After leaving the ranges the rivers flow through a narrow area of river floodplains which are bordered to the east by lower coastal ranges.

The Mulgrave-Russell basin has a long history of development (Table 1.1.1).[14] The river floodplains and the lower river valleys are dominated by intensive sugar cane agriculture. Here the environment has been significantly modified with the loss of much of the original lowland rainforest that inhabited this area prior to European colonisation. Minor streams in this area are often highly modified and lack riparian vegetation. Significant areas of wetlands have been reclaimed or exist as highly modified systems. The Eubanangee and Wyvuri swamps (Nationally Important Wetlands) are extensive wetlands that are largely intact although they have experienced encroachment around their margins and receive run-off from the surrounding agricultural and urban areas. All waterways within the Mulgrave-Russell basin (other than a few very short coastal streams/estuaries) are directly connected to either the Russell or Mulgrave rivers. High seasonal rainfall and over bank flooding have the potential to affect significant areas of agricultural lands. The resulting run-off carries sediment, nutrients and pesticides from these agricultural areas to the World Heritage Area via the rivers and streams of the basin.

To the south of the city of Cairns the coastal strip bordering the flood plain is lightly developed and includes the Russell River National Park, and the Greys Peak National Park. The Yarrabah community with a population of approximately 3000 people is located on the coast to the east of Cairns while the small beach side communities of Russell Heads and Bramston Beach are located to the east of Babinda.

At the northern end of the basin are the city of Cairns (population in excess of 170,000) and the Trinity Inlet. A Declared Fish Habitat Area (Plan Number FHA -003) covers Trinity Inlet which is a Nationally Important Wetland. This large estuary system incorporates extensive mangrove zones, seagrasses, salt marshes and tidal flats. The area supports recreational activities including fishing, traditional use and scientific research. The Port of Cairns occupies the lower end of Trinity Inlet and provides limited deep-water ship berthing. The berthing services allow the export of cane sugar, accommodates the region’s only tanker berth, and houses the Royal Australian Navy base, HMAS Cairns. Annual dredging of the entrance channel is required to maintain accessibility to the port.

The city of Cairns is the largest centre for Reef-based tourism in Queensland and has the only international airport outside of Brisbane. The Reef Fleet Terminal located at the mouth of the port accommodates tourism operators who cater for almost 50 per cent of the two million tourist visits to the Marine Park each year.

Table 1.1.1: Historical timeline for the Mulgrave-Russell basin

Year	Event
1873	Mulgrave and Russell rivers named by the explorer George Elphinstone Dalrymple.
1876	Hodgkinson goldfield proclaimed.
1878	Tinaroo tin field (Herberton) discovered by John Atherton.
1880s	Gordonvale used as a reprovisioning point for mule teams carrying goods over the range to Herberton.
1880	Mulgrave goldfield (Goldsborough) proclaimed.
1882	Sugar cane processing started with the Pyramid Mill on the Mulgrave River, about 6 km upstream from Gordonvale.
1882	Hambledon mill commences.
1884	With the demand for improved transport facilities, a railway from Cairns to Herberton was approved. Construction proceeded in stages with Kuranda (1891), Mareeba (1893) and Herberton (1910) which completed a line across the Atherton and Evelyn tablelands.

Year	Event
1885	Cairns Borough created. Status changed to a town in 1893 and a city in 1923.
1887-88	Cairns harbour channel dredged.
1898	Mulgrave sugar tramway opened to service the mill at Gordonvale.
1912	Cairns-Babinda-Pawngilly railway was extended through Miriwinni.
1915	Gordonvale and Babinda mills commenced.
1922	Gillies Highway linking Cairns with Atherton Tablelands begins construction. Completed in 1926.
1910-1924	The Cairns-Mulgrave tramway extended to Babinda in 1910. Linked to North Coast line at Innisfail in 1924 (actually a 3 feet 6 inch gauge railway).
1935	On 22 June 1935, 102 cane toads were released near Gordonvale.
1935	Barron hydroelectric scheme was switched on for Cairns and its suburbs.
1950s	The Harbour Board reclaimed mudflats and mangroves from the foreshores with minimal opposition but proposals to recover land off the Esplanade and develop Admiralty Island overturned by determined protest.
1988	Bellendan Ker was made a World Heritage site.
2006	Eighty per cent of Babinda’s buildings were severely damaged by Cyclone Larry. Cairns airport and harbour were closed, and all flights were suspended. Innisfail, where Larry made landfall, suffered severe damage. The region's banana industry, which employs up to 6000 people, suffered extreme losses of crops, accounting for more than 80 per cent of Australia's total banana crop.
2011	Cyclone Yasi (centred approximately 100 km south of Babinda) caused extensive damage to the sugar mill - the mill closed within two months.

The Cairns city industrial precinct, port service industries and a decommissioned and capped waste landfill site are located on areas of reclaimed land bounded by the lower end of the Smiths Creek arm of Trinity Inlet. The central and western urban areas of the city of Cairns occupy the western catchment of Trinity Inlet while a mix of agricultural and urban areas lie within the southern and eastern catchment of Trinity Inlet.

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 Great Barrier Reef 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 Mulgrave-Russell basin are outlined in section 2.1 below and the values and their elements that underpin matters of national environmental significance for the Mulgrave-Russell basin and adjacent waters are shown in Appendix C.

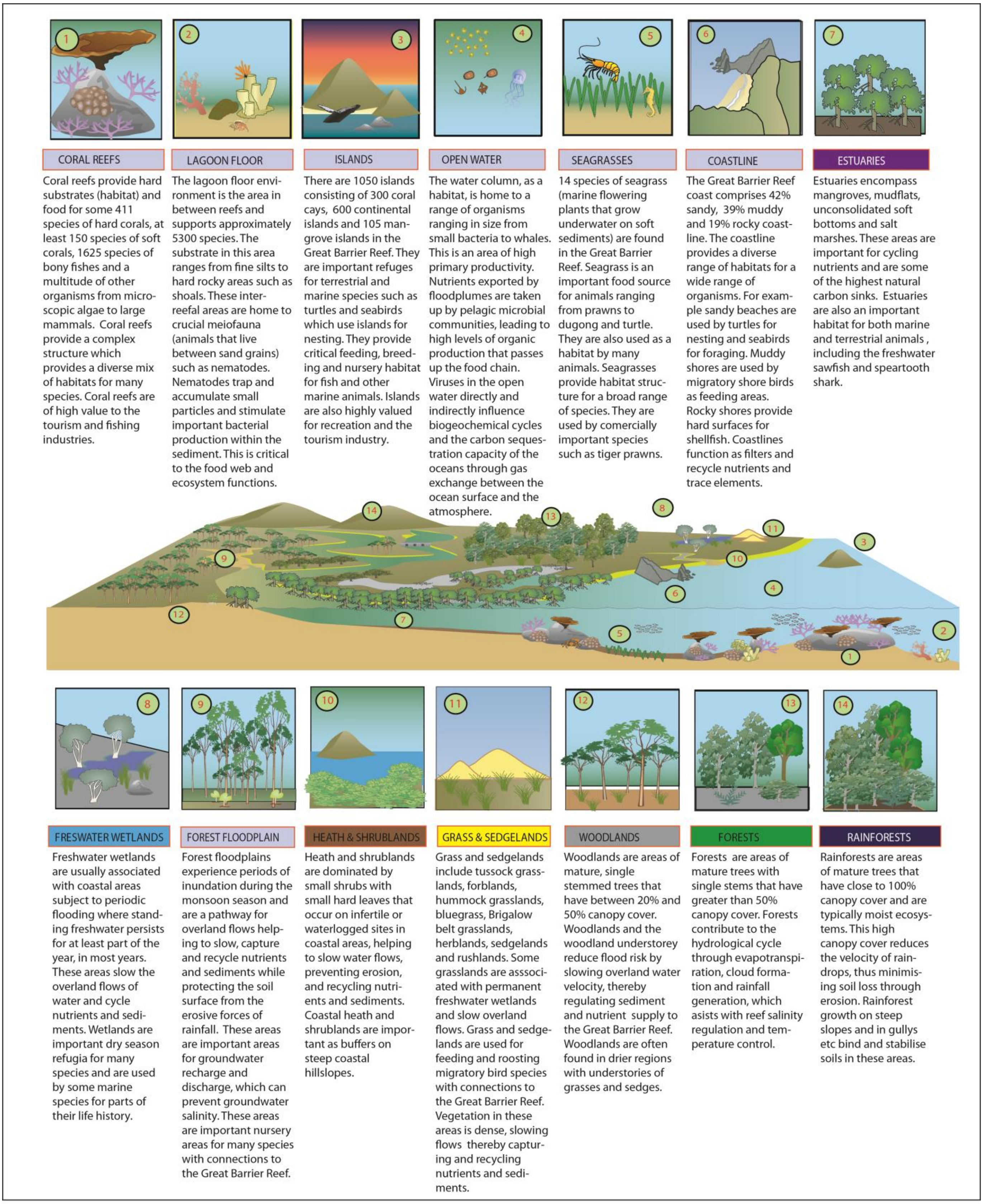


Figure 2.1: Conceptual model for categorizing the Great Barrier Reef coastal, catchment and inshore ecosystems and assessing the ecological functions and services of those ecosystems to the cumulative impacts of development

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 Mulgrave-Russell basin and all of the adjacent marine areas fall within the World Heritage Area.

The Wet Tropics World Heritage Area is also a declared World Heritage Property and occurs within parts of the Mulgrave-Russell basin.

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 Mulgrave-Russell basin only the Great Barrier Reef is listed as a National Heritage Property (for its natural values).

Wetlands of international importance (declared Ramsar wetlands)

There are no wetlands of international importance in the Mulgrave-Russell basin.

Listed threatened species

There are six bird species, one species of fish (that also uses the Marine Park), five species of frog, eight mammal species, 40 plant species (including some emergent aquatics), six reptile species (including marine turtle species) and one species of shark that have been identified as listed threatened species within the Mulgrave-Russell basin and adjacent waters (Appendix D).

Ecological communities

There are two Critically Endangered communities, and one Endangered Ecological community that occur within the Mulgrave-Russell basin. They are Littoral Rainforest and Coastal Vine Thickets of Eastern Australia (Critically Endangered), the Mabi Forest (Complex Notophyll Vine Forest 5b) (critically endangered) and the Broad leaf tea-tree (*Melaleuca viridiflora*) woodlands in high rainfall coastal north Queensland.

Listed migratory species

The EPBC Act lists migratory species which includes those species listed in the:

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

There are seven species of migratory marine birds, 16 species of migratory marine species, nine species of migratory terrestrial species and 28 species of migratory wetlands species occurring within the Wet Tropics NRM region (Appendix E).

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 Mulgrave-Russell basin that have intrinsic values and may also have significance for the long-term health and resilience of the World Heritage Area.

Nationally important wetlands (Directory of Important Wetlands in Australia)

Nationally Important Wetlands in the Mulgrave-Russell basin include:

- Alexandra Palm Forest
- Ella Bay Swamp
- Eubenangee – Alice River
- Great Barrier Reef Marine Park
- Lake Barrine
- Port of Cairns and Trinity Inlet
- Russell River
- Russell River Rapids
- West Mulgrave Falls

- Wyuri Swamp.

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

Conservation parks, national parks and forest reserves located within the Mulgrave-Russell basin include:

- Anderson Street Conservation Park
- Crater Lakes National Park
- Danbulla National Park
- Dinden National Park
- Dinden National Park (Recovery)
- Ella Bay National Park
- Eubenangee Swamp National Park
- Gadgarra Forest Reserve
- Gadgarra National Park
- Gillies Highway Forest Reserve
- Goldsborough Valley State Forest
- Grey Peaks National Park
- Little Mulgrave Forest Reserve
- Little Mulgrave National Park
- Malbon Thompson Conservation Park
- Malbon Thompson Forest Reserve
- Mount Peter Conservation Park
- Mount Whitfield Conservation Park
- Russell River National Park
- Trinity Forest Reserve
- Wooroonooran National Park.

These are shown in Figure 2.2.1.

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. There is one fish habitat area in this area – Trinity Inlet, Cairns which covers an area of 72km^2. This is shown in Figure 2.2.1 and is described in Table 2.2.1).

Table 2.2.1: Fish Habitat Areas located in the Mulgrave-Russell basin

FHA	Location	Habitat Values	Fisheries Values	Other benefits
Trinity Inlet	Trinity Inlet, Cairns	Extensive mangrove zones including *Rhizophora*, *Avicennia,* and *Ceriops*; seagrass beds off the esplanade; patchy areas of saltmarsh; and intertidal	Commercial, recreational, and Indigenous fishing; intense recreational crab fishery; important nursery area for several species of fish and penaeid prawns including barramundi, blue salmon, bream, estuary cod, flathead, garfish, grey mackerel, grunter,	One of only two areas on east coast of Queensland where chenopod (succulent shrub) species *Pachycomia tenuis*

FHA	Location	Habitat Values	Fisheries Values	Other benefits
		flats.	mangrove jack, queenfish, whiting, tiger prawns, and mud crabs.	has been reported.

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 recognised 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 10 nature refuges in the Mulgrave-Russell basin. These are listed below and shown in Figure 2.2.1.

- Barrine Park Nature Refuge
- Behana Creek Nature Refuge
- Danggaja Nature Refuge
- Donaghys Corridor Nature Refuge
- Garriya Nature Refuge
- Glen Idle Nature Refuge
- Rose Gums Nature Refuge
- Wairambar Creek Nature Refuge
- Wairambar Rainforest Nature Refuge
- Wait-A-While Nature Refuge
- Wooroonooran Nature Refuge.

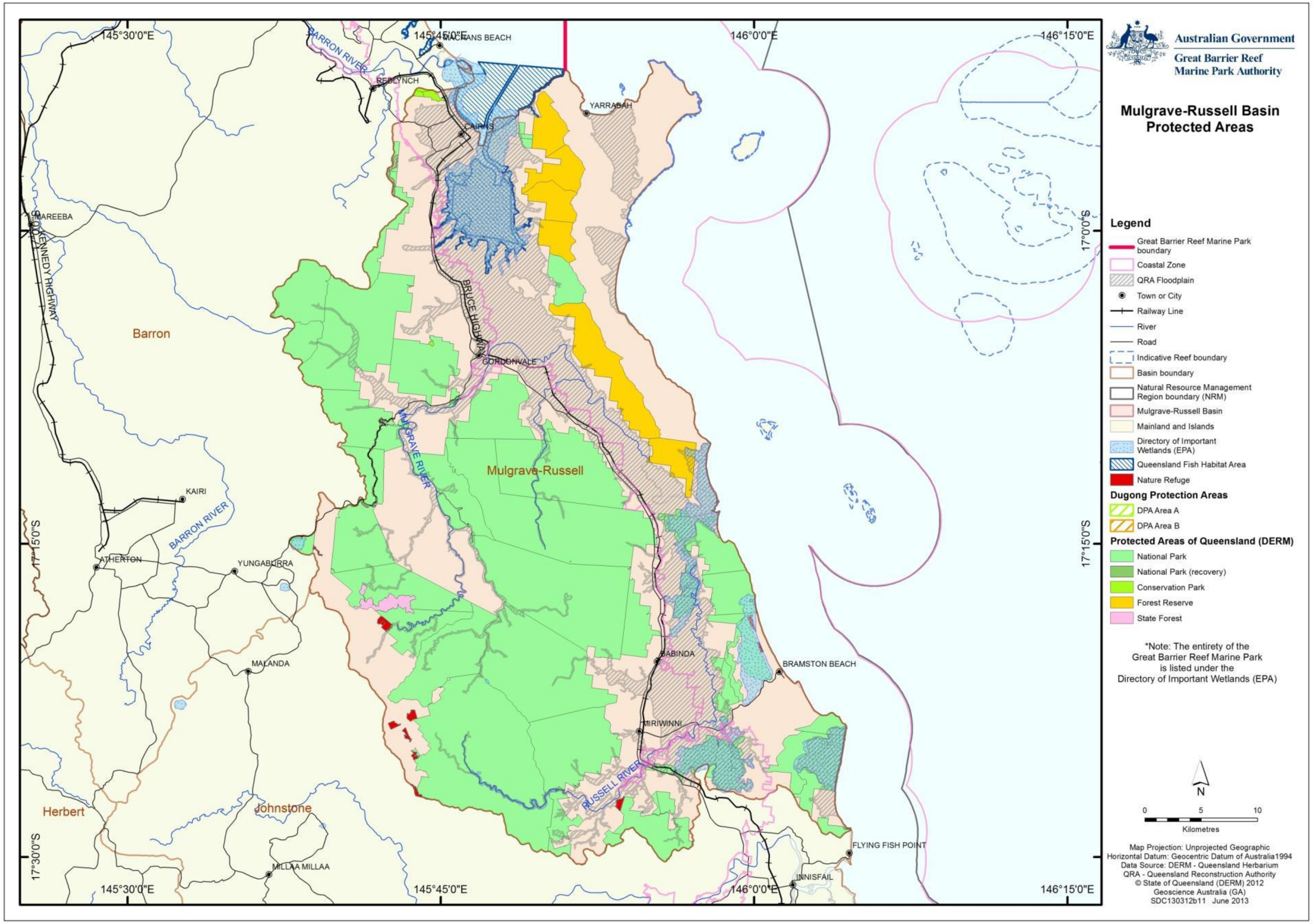


Figure 2.2.1: This map shows the spatial extent of some values that may underpin matters of national environmental significance are shown including Nationally Important wetlands, National Parks, Conservation Parks, forest reserves, Fish Habitat Areas, Dugong Protection Areas and Nature Refuges

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.

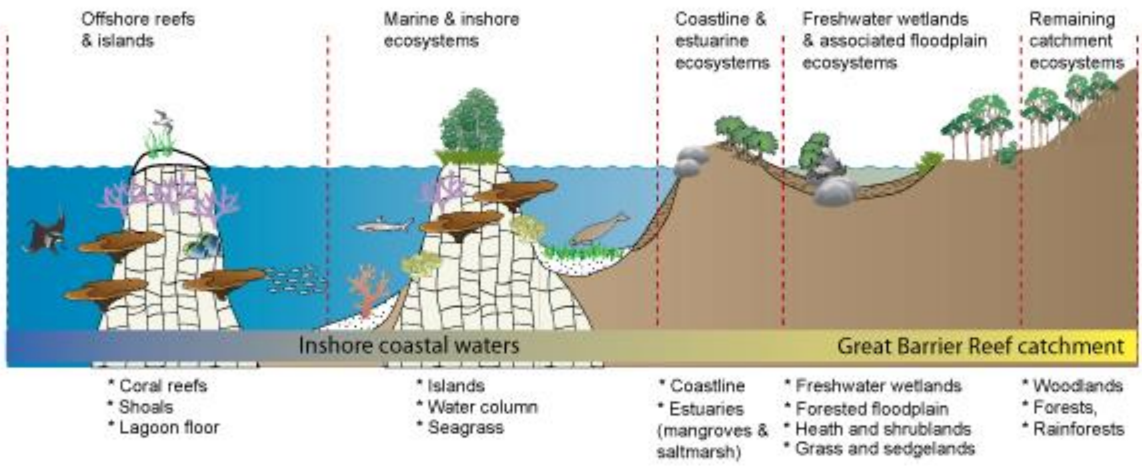


Figure 2.3.1: Broad groupings of coastal ecosystems illustrating the general level of importance for the ongoing health and resilience of the Great Barrier Reef

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 Mulgrave-Russell basin are home to a range of marine flora and fauna, many of which are of conservation concern. These include animals such as marine turtles, dugong, inshore coral reefs and seagrass meadows. Figure 2.3.2 shows the bioregions (regions of similar biological or biophysical diversity) that occur within the Great Barrier Reef adjacent to the Mulgrave Russell basin that were used as the basis for the Great Barrier Reef Marine Park Authority Zoning Plan. Figure 2.3.3 shows the Marine Park Zoning Plan used to conserve many marine values.

The Reef Water Quality Protection Plan Second Report Card 2010[15] found the overall marine condition for the Wet Tropics region was moderate and that inshore coral reef reefs and seagrasses were both in better condition in the north of the region compared to the south. The Mulgrave-Russell basin has its outflow approximately in the middle of the Wet Tropics region directly adjacent to two marine monitoring sites that inform the program.

The Reef Water Quality Protection Plan Second Report Card 2010[15] reported that for the Wet Tropics region:

- **Inshore water quality** was moderate with gradual improvement since 2005-6. Water quality was poorer nearer to the coast.
- **Inshore seagrass meadows** remained in poor condition and relatively stable since 2005-6. Sea grasses were found to be in moderate abundance in the northern part of the region and very poor in the southern parts. Reproductive effort was poor across the region in four out of the five years.
- **Inshore coral reefs** remained in moderate condition and have remained relatively stable since 2005-6. Reefs in the northern part were however found to be in good condition compared to those in the south of the region which were found to be poor. The density of juvenile corals was found to be good indicating that recovery from previous disturbances (for example Cyclone Larry) are underway.

The Reef Water Quality Protection Plan Second Report Card 2010[16] reported that the pollutant loads at the end of the Wet Tropics region's catchments had reduced since 2005-6 for all indicators modelled:

- Nitrogen loads reduced by 2 per cent or 111 tonnes
- Phosphorus loads reduced by 2 per cent or 20 tonnes
- Pesticide loads reduced by 4 per cent or 434 kilograms
- Sediment loads reduced by 1 per cent or 10 000 tonnes.

Following further extreme weather in 2011 the Third Report Card[17] now shows the coral communities are in poor condition.

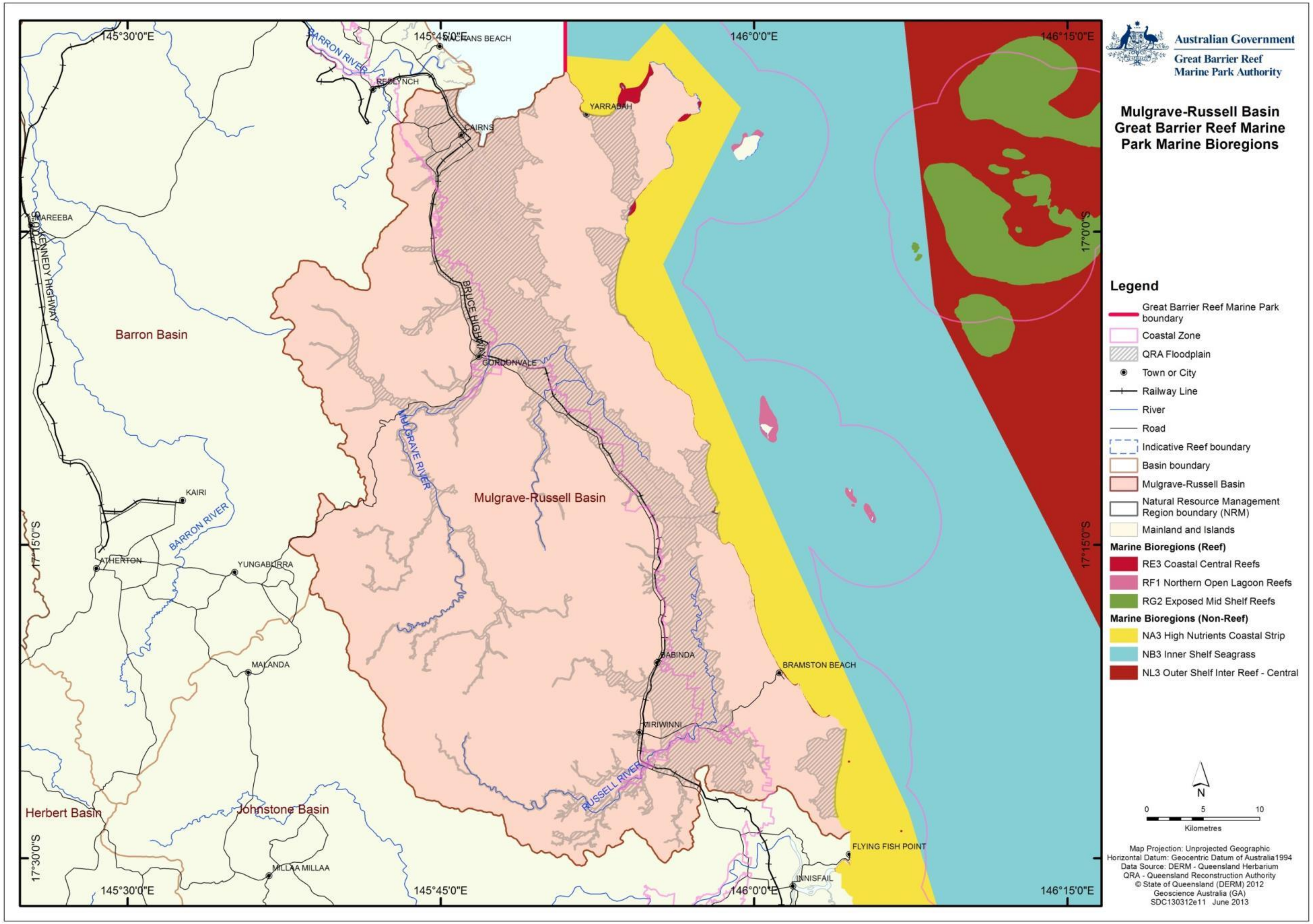


Figure 2.3.2: Marine bioregions adjacent to the Mulgrave-Russell basin

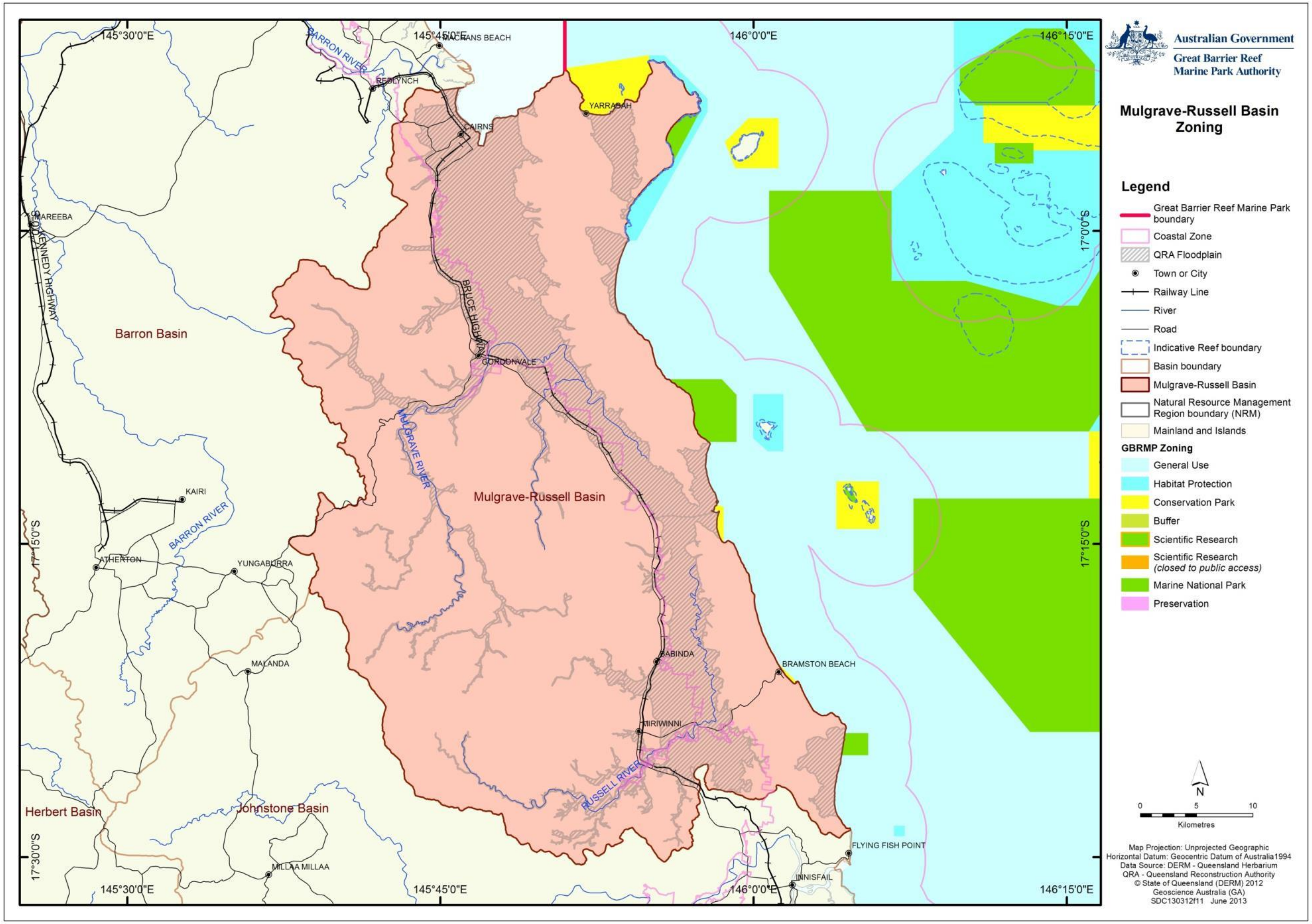


Figure 2.3.3: Great Barrier Reef Marine Park Zoning adjacent to the Mulgrave-Russell basin

Flood events generally take place annually during the wet season (November to April) and are enhanced during cyclonic events. Flood plumes from the Wet Tropics region (Figure 2.3.4) especially the Mulgrave-Russell River catchment, travel northwards around Cape Grafton and cover the outer shelf area north east of Green Island.[5,6,18] Within the Wet Tropics region, 218 coral reefs and 71 seagrass beds are located within the high to very high plume water exposure categories, covering a total area of 183,900 hectares.[19] An assessment of inshore ecosystems exposed to different categories of surface pollutants within the Wet Tropics region showed a total of 192,579 hectares of coral reefs and 18,685 hectares of seagrass beds are exposed to PSII (photosynthetic herbicides), TSS (total suspended solids) and DIN (dissolved inorganic nitrogen).[19,20]

Flood plumes from the Mulgrave and Russell rivers were monitored following catchment rainfall events associated with Tropical Cyclones Sadie (1994), Violet (1995), Justin (1997), Sid (1998), and Rona (1998). During most cyclone related rainfall events, the majority of particulate materials (sediments and particulate nutrients) were trapped within 10km of the coastline, while dissolved materials such as nitrate were dispersed in the plume waters up to hundreds of kilometres from the river mouths.

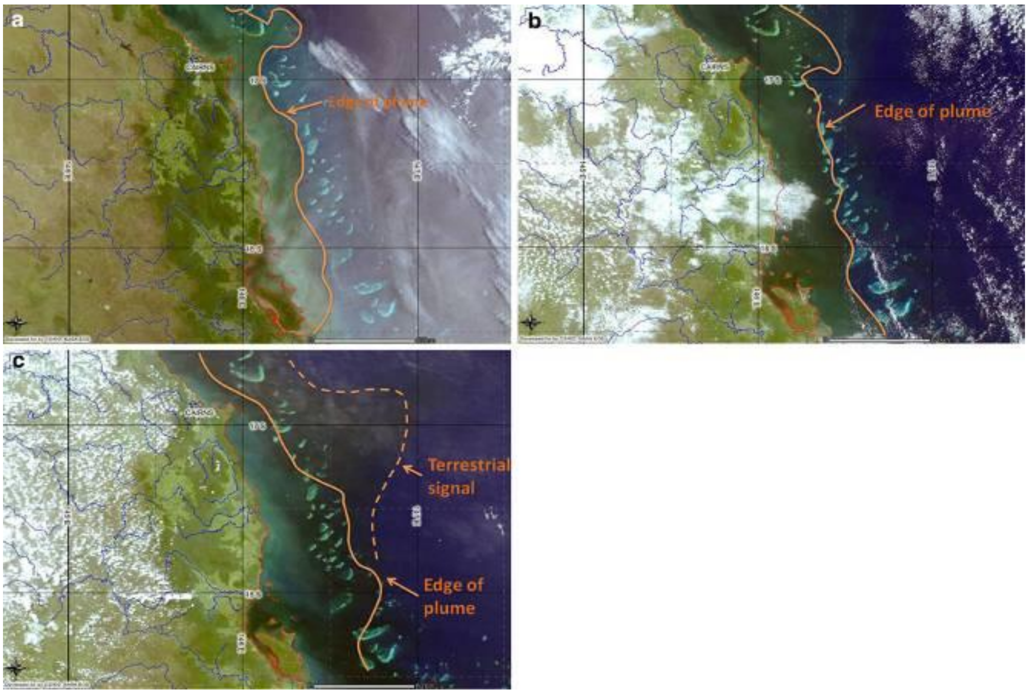


Figure 2.3.4: Satellite image of visible flood plume waters from the Wet Tropics rivers on the (a) 9th, (b) 11th and (c) 13th February, 2007. The plume moved from inner shelf waters on the 9th to the Coral Sea by the 13th February, 2007

For further information on inshore water quality, refer to Appendix F.

Changes to coastal ecosystems

Coastal ecosystems in the Mulgrave-Russell basin have been substantially modified or cleared (Table 2.3.1). Much species and ecosystem diversity has been reduced in the Mulgrave-Russell basin floodplain, which is due to changes in land use which modify or remove ecosystems, and the introduction of monoculture. Significant changes include:

- Modifications to river bank form including straightening, channelisation and removal of riparian vegetation and latter replacement with species (such as bamboo) to stabilise eroding banks.
- Replacement of floodplain ecosystems with sugar cane.
- Introduction of pasture grasses and cattle grazing to the floodplain.
- Construction of drains to remove water from floodplain wetlands and to aid drainage in urban areas.
- Introduction of weed species (such as Singapore daisy) to stabilise eroding banks which have become monospecific stands that inhibit the growth of other species that would otherwise provide habitat functions for in-stream species.

Ongoing legacy issues as a result of changed land use, such as river channelisation, 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) through habitat loss.

In pre-European times (pre-clear), the Mulgrave-Russell basin was dominated by rainforest and forests (Figure 2.3.5, Table 2.3.1). Since European settlement (post-clear), these forested areas have been cleared for intensive agriculture (Figure 2.3.6) and to accommodate the growth of the city of Cairns at the very northern end of the basin.

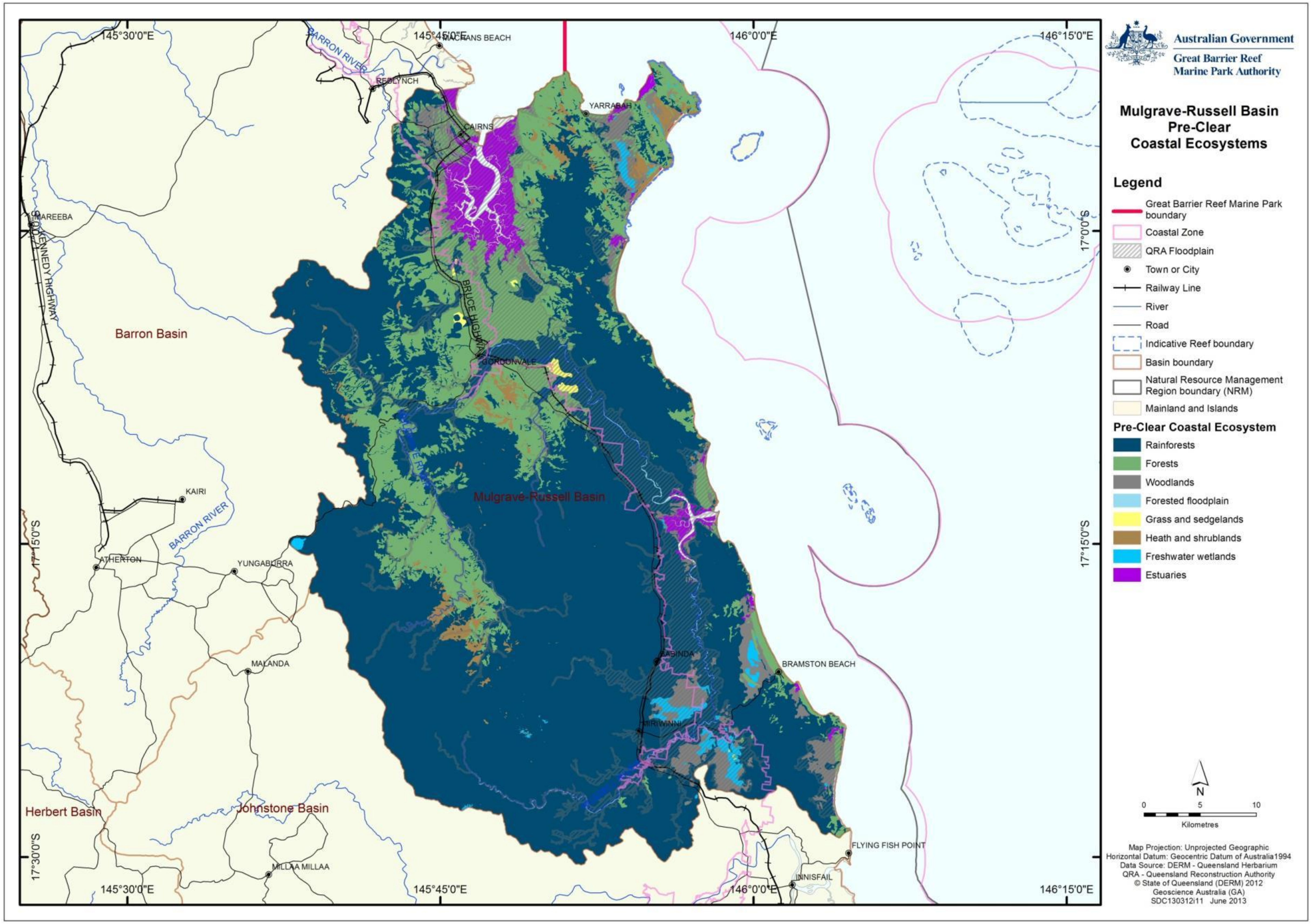


Figure 2.3.5: This map shows the pre-clear coastal ecosystem assemblages in the Mulgrave-Russell basin

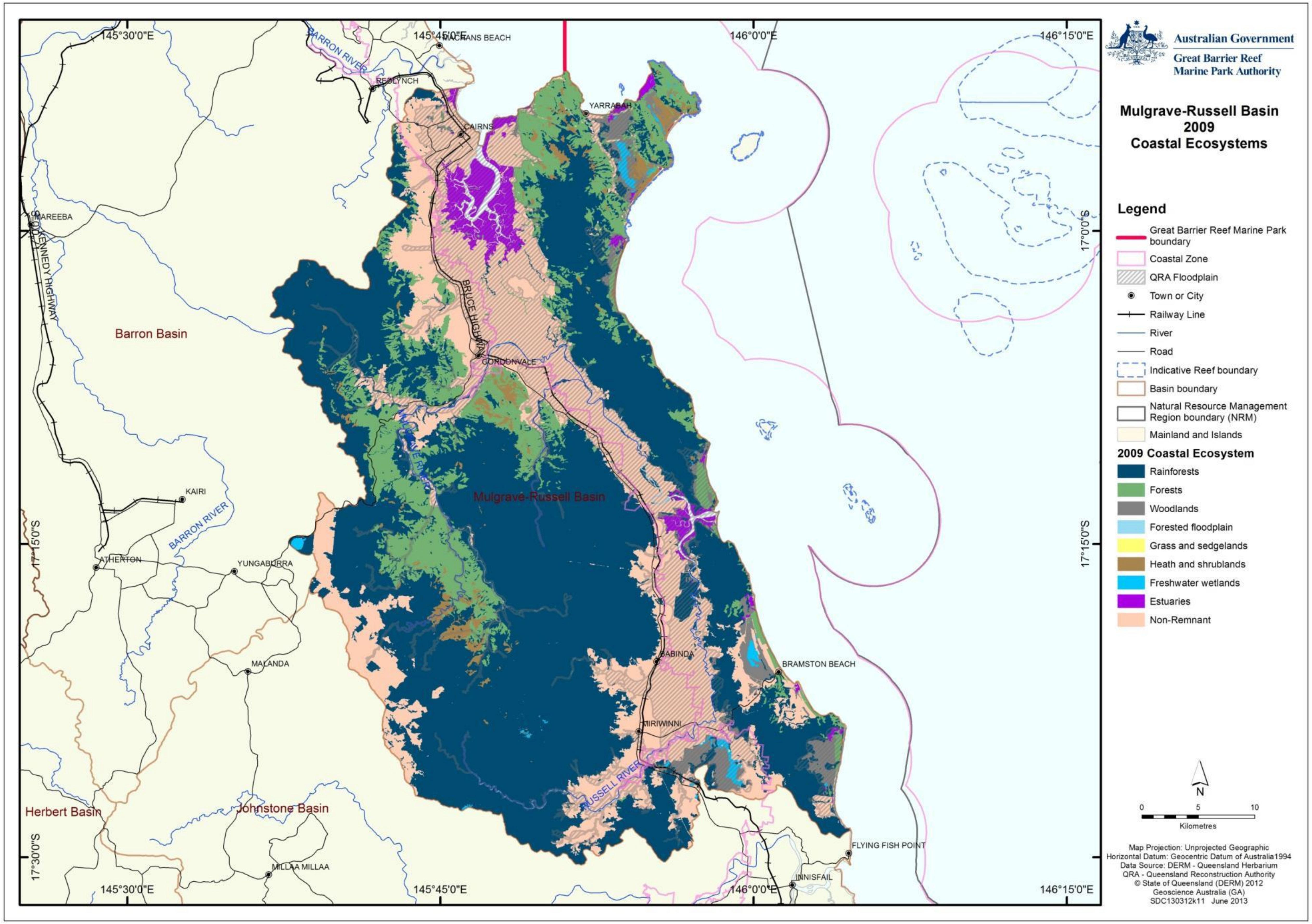


Figure 2.3.6: This map shows the post-clear coastal ecosystem assemblages in the Mulgrave-Russell basin (derived from 2009 Queensland government Regional Ecosystem data)

Changes to coastal ecosystems (Table 2.3.1) show that the greatest proportion of modification to terrestrial biodiversity has occurred to freshwater wetlands (loss of 47 per cent), woodlands (loss of 37 per cent) and forests (loss of 36 per cent). Rainforests have had the greatest area of loss (33,402 hectares).

Table 2.3.1: Area (ha) of pre-clear and post-clear coastal ecosystems based upon Queensland Government Regional Ecosystem mapping 2009

	Ecosystem	Pre clear	2006	2009	% remaining
	Rainforests	138,418	105,017	105,016	76
	Forests	38,134	24,606	24,588	64
	Woodlands	7,767	4,908	4,908	63
	Forested floodplain	610	599	599	98
	Grass and sedgelands	377	5	5	1
	Heath and shrublands	3,654	3,616	3,615	99
	Freshwater wetlands	1,854	984	984	53
	Estuaries	5,680	4,672	4,672	82
	Non Remnant	0	52,219	52,239	N/A
	Not Mapped	1,702	1,570	1,570	N/A

Coastline and estuarine coastal ecosystems

The extent of estuaries in the Mulgrave-Russell basin has declined by 18 per cent according to Queensland Government Regional Ecosystem mapping (Table 2.3.1). There are two estuarine ecosystems in the Mulgrave-Russell basin that experience a tidal range of around three metres (Table 2.3.2). These are Trinity Inlet in the north of the Mulgrave-Russell basin and Mutchero Inlet, at the mouth of the Mulgrave and Russell rivers.

Table 2.3.2: Australian Natural Resource Atlas (ANRA) classification of estuaries for the Mulgrave-Russell basin

Name of estuary	Class	Sub-class	Condition
Trinity Inlet	Tide dominated	Tidal flat/creek	Modified
Mutchero Inlet/Mulgrave	River dominated	Wave-dominated delta	Modified

Assessment of the condition of Trinity Inlet (Figure 2.3.7) and Mutchero Inlet (Figure 2.3.8) by the Australian Natural Resources Atlas in 2000 (Table 2.3.2)[21] identified them as modified (indicating modification of coastal ecosystems in the vicinity of the system).

Figure 2.3.7: Trinity Inlet showing Cairns to the right

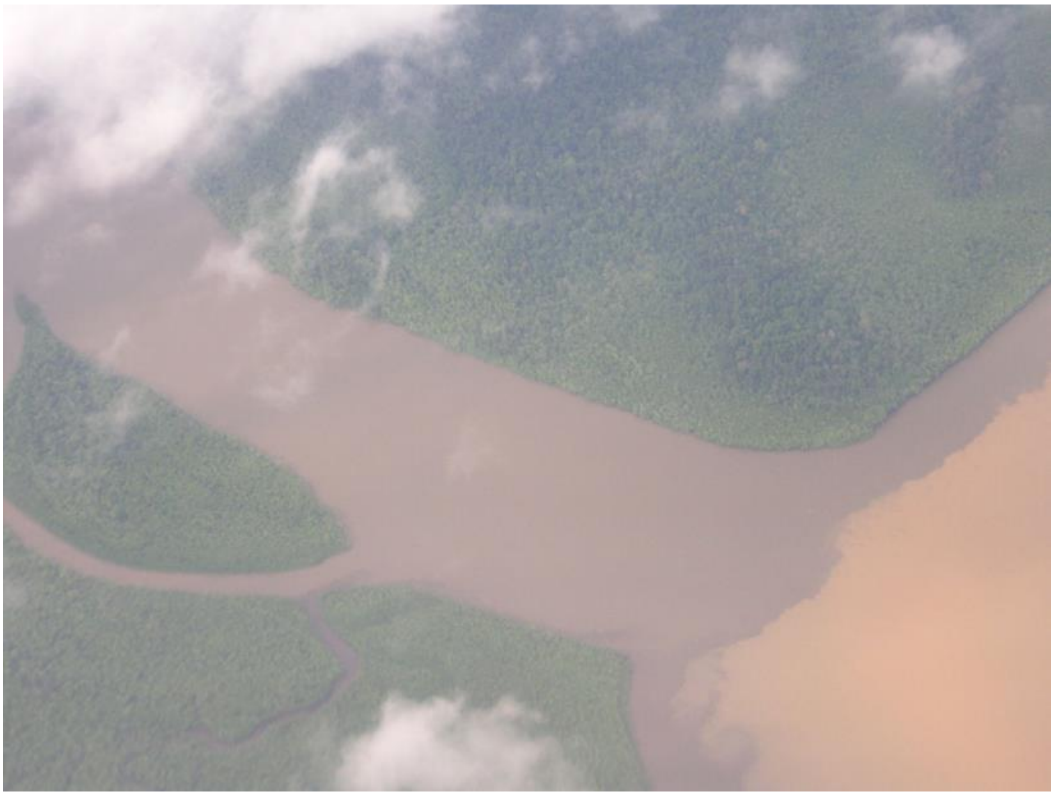


Figure 2.3.8: Mutchero Inlet in flood (photo Jason Hagen ABC)

Trinity Inlet has a high value for fisheries productivity (commercial and recreational) with extensive mangrove cover, patchy saltmarsh cover and sporadic seagrass occurring throughout the system. It also supports significant recreational values including recreational fishing opportunities and tourism opportunities supported by a high degree of visual amenity provided by the extensive mangrove forests with their backdrop of the undeveloped ranges of the Greys Peak National park to the south. The estuary is composed mostly of mangroves (61.9 per cent) patchy areas of salt marsh (24.1 per cent) with the remainder consisting of flood ebb and tide delta and intertidal flats.[22]

The surrounding margins of the Trinity Inlet ecosystem are moderately developed, posing a real threat to its long-term health and resilience. The city of Cairns and its associated urban and industrial areas occupy the Trinity Inlet's northern and western catchments. The waterways and drainage of the catchment are highly modified to accommodate high rainfall events that have the potential to flood urban areas (Figure 2.3.9). Management in the form of regular dredging of creeks, such as Moody's Creek, that form part of the catchment of the Trinity Inlet results in impacts to mangrove communities. As well as adopting offsets for the loss of mangroves in this process, the Cairns Regional Council uses alternative methods such as hedging mangroves to maintain access for dredging while retaining the mangroves' contribution to the waterways function (Figure 2.3.10).

Figure 2.3.9: The city of Cairns and its associated urban and industrial areas occupies the Trinity Inlet's western catchments. The waterways and drainage of the catchment are highly modified to accommodate high rainfall events that may otherwise threaten the flooding of urban areas. Riparian condition is generally best at the upper end of the catchment. Ecological functions provided to Trinity Inlet by the waterways and wetlands in the urban areas have been significantly impacted. This is most significant between the suburb of Earlville and the city centre

Figure 2.3.10: Top left – The Cairns Central Swamp protects 80 hectares of remnant wetland. These wetlands were once extensive, occupying the areas between the sand ridges that formed the original coastal environment on which the city of Cairns was built. The filling and draining of these lands allowed saltwater to intrude into areas once occupied by freshwater habitats (above right) significantly modifying their biodiversity. In recent years tidal gates have been installed on major creeks and drainage channels to reverse these impacts. Bottom left – Where creeks and man-made drains that are connected to Trinity Inlet pass through the urban and industrial areas of Cairns they typically have mangroves occupying only one bank. This is maintained by the Cairns Regional Council to allow for machinery access when dredging these waterways as part of the urban flood management strategy. The Council has a Marine Plant Management strategy that addresses the issue of offsets to compensate for losses of mangroves. Bottom right – The Cairns Regional Council has installed litter booms in the lower sections of a number of waterways. These aim to capture litter carried by these waterways and preventing it from entering Trinity Inlet

On the eastern side of the mouth of the Trinity Inlet is the East Trinity Reserve which was formerly a natural wetland of mangroves and salt marsh. The site was drained and tidal gates installed in an unsuccessful attempt to grow sugar cane during the 1970s (Figure 2.3.11). The soil became heavy with acid sulphate which created impacts to the Trinity Inlet. In May 2000, the Queensland Government purchased the 9.4 km^2 site and has implemented pest control programs and devised an acid sulphate remediation plan involving controlled lime-assisted tidal exchange. The remediation program has been successful and the natural functions are beginning to return to this area.

Figure 2.3.11: Mangrove dieback as a result of the bund wall and the release of sulphuric acid from acid sulphate soils in the 1980s (photo DEHP)

The coastline to the west of the Trinity Inlet fronts the central Cairns urban area where it is highly modified along the city esplanade. At the north western end of the esplanade an extensive mangrove shoreline completes the western shoreline of Trinity Bay. The Cairns International Airport occupies reclaimed lands behind this extensive mangrove forest buffer. To the east of the mouth of the Trinity Inlet the coastline extends towards False Cape and then Cape Grafton backed by the Malbon Thompson Range. The narrow coastal strip includes some residential areas with the Yarrabah Township occupying the lower lands between Mission Bay and Wide Bay bordered by Cape Grafton and Kings Point to the north east and the Greys Peak range to the south west.

The Mutchero Inlet arises at the junction of the Russell and Mulgrave rivers and connects these rivers to the World Heritage Area and the Marine Park. Mutchero Inlet has extensive mangrove cover (72.5 per cent) while the remainder of this estuary consists of flood and ebb tidal delta, intertidal flats, saltmarsh/saltflats and tidal sand banks.[21]

The Mutchero Inlet estuarine area has only minimal coastal development within its mangrove and linked wetland area. A small residential community exists on the vegetated sand dune system that forms the southern coastline at the mouth of the inlet. Various attempts including the use of sandbag groins have been made to stop the movement of sand in this area that has resulted in the loss of some dwellings. To the north the coastline is quite natural with areas of Melaleuca wetlands situated between Malbon Thompson Range and the coastal dune. This undeveloped strip continues to the eastern beaches of the Yarrabah Community located inshore of Fitzroy Island.

Freshwater wetlands and associated floodplain coastal ecosystems

According to the regional ecosystem mapping, the Mulgrave-Russell basin has lost 47 per cent (870 hectares) of its freshwater wetlands, 99 per cent of grass and sedge lands (372 hectares) and 1 per cent of heath and shrub lands (39 hectares). Approximately 98 per cent of forested floodplain (599 hectares) remains intact (Table 2.3.1).

The Queensland and Australian governments, through the Queensland wetlands program have mapped wetlands within the Mulgrave-Russell basin at a finer scale than the current regional ecosystem mapping. The extent and classification types of wetlands within the Mulgrave-Russell basin are shown in Table 2.3.3.[23] This mapping identified approximately 214 lacustrine/palustrine wetlands in the basin.

Table 2.3.3: Queensland Wetlands Program data for the freshwater and estuarine wetlands of the Mulgrave-Russell basin

System as defined by Queensland Wetlands Program	Area (km²)	Wetlands area (%)	Total area of basin (%)
Artificial and highly modified	11.56	7.2	0.6
Estuarine	49.49	30.7	2.5
Lacustrine	1.17	0.7	0.1
Palustrine	80.66	50.0	4.1
Riverine	18.32	11.4	0.9
Total	161.20	100	8.1

In the Mulgrave sub-basin, palustrine wetlands are mostly small in area with Alexandra Palm (*Archontophoenix alexandrae*) forests most common. Levelling and drainage to create land for agriculture has resulted in the loss of many of these wetlands. These agricultural areas are often low in agricultural productivity and experience regular and extensive flooding. This low productivity results in poor or negative economic returns for the farmer. Acid sulphate leachate is an issue in some of these areas. To the east of the Mulgrave River downstream from Barbagallo Bridge is the Lower Mulgrave wetland aggregation consisting of Tanner and Galletts lagoons. These Alexander Palm dominated ecosystems are the last examples remaining in the Mulgrave catchment. Issues such as agriculture encroachment and Pond Apple (weed of national significance) have contributed to some loss of function. Mulgrave Landcare has a strategic program targeting these wetlands, which involve the revegetation of the margins of the wetlands and the control of Pond Apple.

In the Russell sub-basin a similar situation exists as found in the Mulgrave sub-basin with levelling and drainage for the development of agricultural lands resulting in the loss of many of the smaller wetlands. Unlike the Mulgrave catchment, large wetlands such as Eubenangee Swamp, Wyuri Swamp and Ella Bay Swamp still occur in the area. These wetlands fall within National Parks and appear to maintain good health and representative biodiversity. Both Eubenangee (Figure 2.3.12) and Wyuri have experienced encroachment by urban development and agricultural lands resulting in losses to their historical areas and the associated function of these areas. During the field assessment observations of acid sulphate exposure were made on grazing lands forming the boundary of the Wyuri Swamp National Park, while there was some evidence of tree dieback within the Eubenangee Swamp wetland ecosystem at its border with a cleared easement. These wetlands are also vulnerable to colonisation by Pond Apple which has the potential to impact on their function and the ecological processes they provide if let unmanaged.

Figure 2.3.12: Above – The Eubenangee Swamp National Park is a large functionally intact wetland system in the Russell River catchment. Agriculture and urban encroachment has resulted in the loss of some of the wetlands original area and function. Below left – The Eubenangee wetlands receive sediment and nutrient run-off from agricultural lands. Below right – There is some evidence of dieback in areas of the Eubenangee wetland

East of the town of Babinda, the Babinda Swamp Drain project reclaimed the Babinda Swamp for agricultural lands during the 1950s (Figure 2.3.13). The area is now dominated by sugar cane production with some grazing occurring. Field observations noted that acid sulphate soils may be an issue in this area. The lands serviced by the drain experience regular overbank flooding from the Russell River and Babinda Creek impacting on production outputs from the sugar cane lands.

The main drain joins Babinda Creek approximately 200 meters from its junction with the Russell River. The owner of a 40 hectare property at the junction of the drain and Babinda Creek has indicated a willingness to work with the appropriate partners to rehabilitate the land and return it to a functioning wetland environment. This area of land is occupied by several Alexandra Palm forest remnants. There are several grant applications to the Biodiversity Fund and Caring for our Country funds to support projects aimed at restoring the wetland connectivity and ecological functions of this area. The location of this area at the end of the Babinda Swamp drain sub catchment would see these projects have a positive effect on improving water quality leaving this area and the ecological functions provided to the World Heritage Area by the existing wetland remnants.

Figure 2.3.13: Above – The main Babinda Swamp Drain channel. A network of smaller drains connects with the main channel to form the Babinda Swamp Drain program. Note the oxidised stain to the water. The drainage program is managed by the Babinda Swamp Drainage Board. Below left – The main drainage channel joins Babinda Creek approximately 200m from its junction with the Russell River. Below right – Water exiting the Babinda Swamp Drain (top of picture) has a significantly different appearance to the very clear water of Babinda Creek (bottom of picture)

In the Mulgrave-Russell basin, the riparian condition of the rivers and streams is poor where they flow through the urban and agriculture lands of the flood plain. Remnant riparian vegetation is more common in this area of the Mulgrave River sub-basin (Figure 2.3.14) than in the Russell River sub-basin (Figure 2.3.15). Where the Mulgrave River and its larger tributaries flow across the flood plain, the remnant riparian vegetation present is generally restricted to the steep bank of the river channel with land cleared for sugar cane production to the top of the bank.

In the Russell River sub-basin, there is very little remnant riparian vegetation present where the Russell River or its largest tributary, Babinda Creek, pass through developed lands of the flood plain. Bank erosion is a significant issue in this part of the Russell River sub-basin.

Figure 2.3.14: In the Mulgrave River sub-basin along the Mulgrave River and larger tributaries, the riparian vegetation that is present is generally restricted to the steep bank of the river channel with land cleared for sugar cane production to the top of the bank. Collaboration between farmers and the Mulgrave Landcare group are focusing on repairing gaps in the riparian zone and addressing the remaining erosion hot spots

Figure 2.3.15: In the Russell River sub-basin there is very little riparian vegetation present where the Russell River or its largest tributary, Babinda Creek, passes through developed lands. Bank erosion is a significant issue. The middle photo above shows a large rock revetment and riparian planting on Babinda Creek. Such projects are very expensive with this example costing $140 000 for this 180m section of creek. The top right photo shows the Russell River where the Miriwinni – Bramston Beach Road crosses the river. Bamboo and "cane grasses" have been used historically to stabilise cleared river banks. This has generally been unsuccessful

In general, smaller streams (stream order 1 and 2) flowing through the agricultural lands of the Mulgrave-Russell basin have poor riparian condition with little remnant riparian vegetation. These systems are often highly modified and channelised and are generally dominated by grasses and weeds. Erosion is prominent where the grasses and weeds are controlled by herbicide spraying (Figure 2.3.16).

Figure 2.3.16: Camp Creek is an example of a highly modified minor stream with evidence of a loss of connectivity with upstream habitats important for a number of fish species with life cycle linkages to estuarine and coastal environments. Modifications to the stream course and profile to achieve desired drainage outcomes impact on the ecological functions these streams provide. Herbicide spray management of weeds and the consequential erosion have impacts on water quality entering the Great Barrier Reef

Indicators of in-stream health such as water quality, hydrology, geomorphology, riparian vegetation, aquatic macrophytes, macro-invertebrates and freshwater fish were investigated and compared between the Russell River sub-basin (Woopen Creek and Babinda Creek) and the Mulgrave River sub-basin (Little Mulgrave River and Behana Creek).[24] The study indicated the importance of intact riparian zones with an adequate buffer for in-stream health in areas adjacent to agricultural lands (Figure 2.3.17). Woopen and Babinda creeks had relatively poor bank structure resulting from low riparian vegetation and were considered in poorer condition than the waterways studied in the Mulgrave River sub-basin. Riparian vegetation was particularly poor in Babinda Creek, which was infested with invasive weeds (Singapore daisy and Para grass) that caused channelised flows, increased flow velocity, and stream incision. Macro-invertebrate taxa (~20 per cent) and fish species were lower in Babinda Creek compared to Behana Creek.

Figure 2.3.17: Vegetating narrow corridors along the riparian areas of even highly modified streams and farm drains will provide positive water quality outcomes and improve connectivity and stream function

The freshwater wetlands and streams of the Wet Tropics are home to 78 of Australia's 190 species of freshwater fish.[25] The Mulgrave-Russell system is home to many unique freshwater fishes, some with a limited range such as Allen's Stiphodon, *Stiphodon semoni,* which has only been found in a few tropical streams in Australia including Harvey Creek, a tributary of the Russell River (Figure 2.3.18).[26] This fish is listed as Critically Endangered under the EPBC Act. Other unique freshwater species found in the Mulgrave-Russell basin include freshwater moray eels and freshwater pipefish.[27,28] Although freshwater, evidence suggests that these species use the waters of the Reef for part of their life cycle.

Figure 2.3.18: Top – Allen's Stiphodon, *Stiphodon semoni* (copyright: Gerald Allen). Bottom – Freshwater moray eel (Photo Brendan Ebner)

Forested coastal ecosystems

Rainforests are the most prevalent coastal ecosystem in the Mulgrave-Russell basin, with a post-clear extent of 105,016 hectares. Rainforests, forests, and woodlands have been subjected to the greatest losses within the Mulgrave-Russell basin. Although the loss as measured by percentage is lowest for rainforest (24 per cent) when compared with forests (36 per cent/13,546 hectares) and woodlands (37 per cent/2,859 hectares), the actual area of land lost from rainforest is greatest at 33,402 hectares (Table 2.3.1). Much of this loss has been from the river floodplains where the vegetation has been completely removed and replaced by agriculture. Only small areas of remnant vegetation remain in these areas. Sugar cane production dominates the land use with dry land grazing and banana plantations (irrigated) being the other significant agriculture practices to be found in the basin. The Cairns city urban footprint has replaced much of the pre-clear forested and woodland areas at the northern end of the basin.

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. Regional ecosystems were originally defined by Sattler & Williams (1999)[29] 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. These have been mapped for the Mulgrave-Russell basin (Figure 2.3.19).

Regional ecosystem information provides the basis for the development of coastal ecosystem functional groups identified in the Coastal Ecosystem Assessment Framework.[9] However regional ecosystem conservation classification is based on terrestrial distribution, and do not assess their functional linkage to the World Heritage Area. Regional ecosystem conservation classifications most likely do not protect coastal ecosystems most important to maintaining the health and resilience of the World Heritage Area.

Many of the endangered regional ecosystem assemblages located on the floodplain are experiencing encroachment and subject to impacts from adjacent land uses such as agriculture.

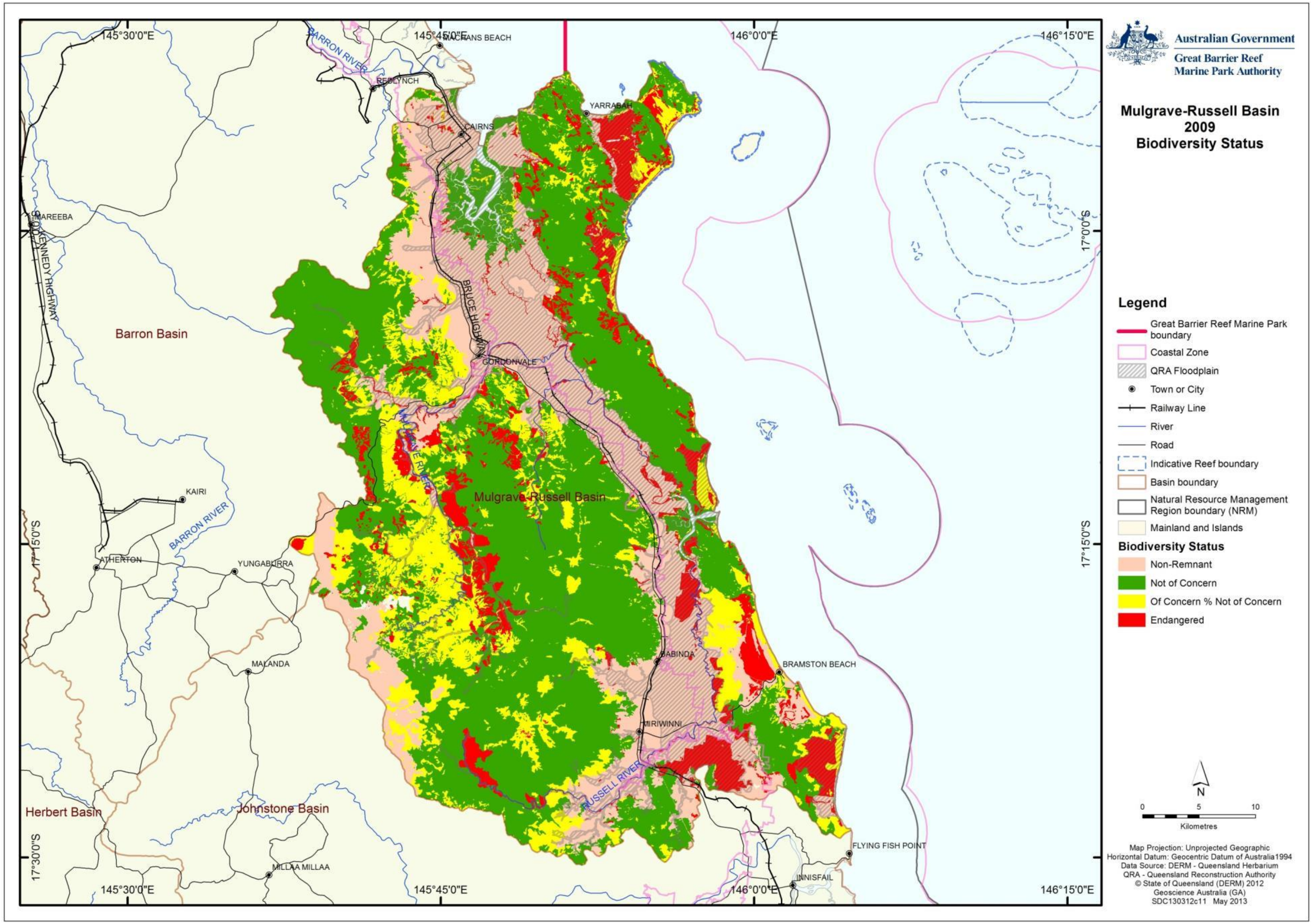


Figure 2.3.19: Regional ecosystem conservation status for the Mulgrave-Russell basin

2.4 Ecosystem processes

The condition of ecosystem processes in the Mulgrave-Russell 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 F contains a list of coastal ecosystems and some of the ecological processes they deliver for the health and resilience of the World Heritage Area.

The Mulgrave-Russell basin has some of the largest extent of rainforest in the Great Barrier Reef catchment. Year round rainfall provides seasonal flows to the basin river systems that support dense rainforest riparian areas and the highest fish diversity of any basin in the catchment. These flows provide clean, high quality water for coastal wetlands, the estuaries and coastal ecosystems. While the upper catchments of the basin are relatively undisturbed the clearing of the flood plain for intensive agriculture has significantly altered the sediment and nutrient inputs provided by this area.

Introduced weed species have the potential to impact on the capacity that established and restored riparian and wetland areas have to provide ecological functions. Weed management needs to be recognised as an integral and ongoing component of riparian and wetland maintenance and rehabilitation projects, to ensure desired outcomes are achieved.

Physical processes

Physical processes are the processes 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. All coastal ecosystems provide these services, some more than others.

Since European settlement in the Great Barrier Reef Region, water quality discharged from the catchment to the Reef lagoon has declined. Flood plumes from the Wet Tropics basins have been shown to reach beyond the Reef, exposing reef systems to poor water quality in the form of sediments, nutrients and pesticides.[30]

The freshwater systems in this basin are free of dams or weirs and water extraction is limited. This is allowing physical, biogeochemical and biological processes dependent on water flow to continue.

Trinity Inlet (Cairns) is a tidally driven estuary. This means that it has naturally low sediment trapping efficiency and therefore, a naturally high level of turbidity.[22] Therefore, modifications to the estuary are unlikely to alter physical processes in the system.

Mutchero Inlet at the mouth of the Mulgrave-Russell is driven primarily by river energy. This means the estuary would have low sediment trapping efficiency, naturally low turbidity, and a low risk of habitat loss due to sedimentation.[21]

Across the flood plains of the basin, changes in hydrology have occurred as a result of the clearing of the area for agriculture, the reclamation of wetlands and the establishment of flood plain drainage networks. Physical processes such as sediment delivery and flow rates have changed considerably in this basin as a result of these changes. The clearing of the flood plain and soil disturbance from historical logging in some parts of the rainforest catchments has resulted in increasing sedimentation of rivers.

Within Babinda Creek and the Russell and Mulgrave rivers the accumulation of sand deposits both in the midstream and inside bends of these waterways has been identified as a contributing factor to bank erosion issues.[31] High historical sediment inputs from the erosion of the floodplain and river banks following the broadscale clearing of vegetation has overwhelmed the rivers natural ability to transport these heavier sediments downstream. This coupled with the trapping effect created by rapid colonisation of sand bars by weeds such as Singapore Daisy and Hymenachne (*Hymenachne amplexicalis),* that further limit the movement of these sand deposits through the system, is creating unnatural channelisation and narrowing at the bends of the rivers. Both of these create increased flow rates and changed flow dynamics that have an impact on the extent and severity of bankside erosion.

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. During large flood events biogeochemical processes in coastal ecosystems often do not occur as water flows at high speed directly into inshore coastal waters. In more developed basins such as the Mulgrave-Russell basin, the volume of nutrients is often higher as a result of fertiliser use and point source discharges. These nutrients are therefore transported rapidly into the World Heritage Area where they are cycled within the marine environment. Table 2.4.1 outlines the nutrient forms and their availability for biogeochemical processes.

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 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.

Changing rainfall patterns as a result of climate change also have the potential to affect the hydrology of the basin. These changes have been shown to affect the run-off quality and quantity in particular. Increasing storm intensity in recent years has delivered sudden large pulsed flows of freshwater into the World Heritage Area. As a result freshwater induced coral bleaching and smothering of corals and seagrass by sediments is occurring.[32] Inshore reefs found within the Wet Tropics region of the Reef have been identified as containing coral reefs with relatively low diversity, which has been linked to poor water quality.[3,4,33]

There is emerging evidence that poor water quality resulting from floods and extreme weather events in the summers of 2009 to 2011 have created conditions for crown-of-thorns starfish numbers to increase at some locations on the Great Barrier Reef. The crown-of-thorns starfish (*Acanthaster planci*) is a coral eating starfish, or sea star, native to coral reefs in the Indo-Pacific region. Predation by crown-of-thorns starfish poses an extreme risk to coral reefs and was found to account for 42 per cent of the estimated loss in coral cover between 1985 and 2012.[34]

Nitrate and orthophosphate promote the formation of phytoplankton blooms and increased biomass of larger phytoplankton species (> 2 µm), which are the primary food source of crown-of-thorns starfish larvae.[7] (Figure 2.4.1) Enhanced nutrient supplies are transported in plumes northward from the Wet Tropics, in particular from the Mulgrave-Russell basin. The Wet Tropics flood plumes (including plumes sourced from the Mulgrave-Russell River) travel around Cape Grafton and cover the outer shelf area from Green Island northwards.[5,6] Chlorophyll *a* concentrations within these plumes have been measured above 2 µg l^{-1}, which is over double the range measured within other areas of the Reef (0.2 – 0.8 µg l^{-1}).[35] These high chlorophyll *a* values are of particular concern since an experiment conducted by Fabricius et al. (2010) showed that the odds of crown-of-thorns starfish larvae finishing development increases approximately eight-fold with every doubling of chlorophyll *a* concentrations up to 3 µg l^{-1}. Green Island and the surrounding area exposed to Wet Tropics flood plumes is believed to be an initiation area for crown-of-thorns starfish outbreaks, after which the larvae are transported southward by currents.[7,8]

Ten estuarine sites in the Mulgrave-Russell basin were found to contain elevated levels of nutrients (when compared with other waterways in North Queensland). Further information on water quality in the Mulgrave-Russell basin can be found in Appendix F.

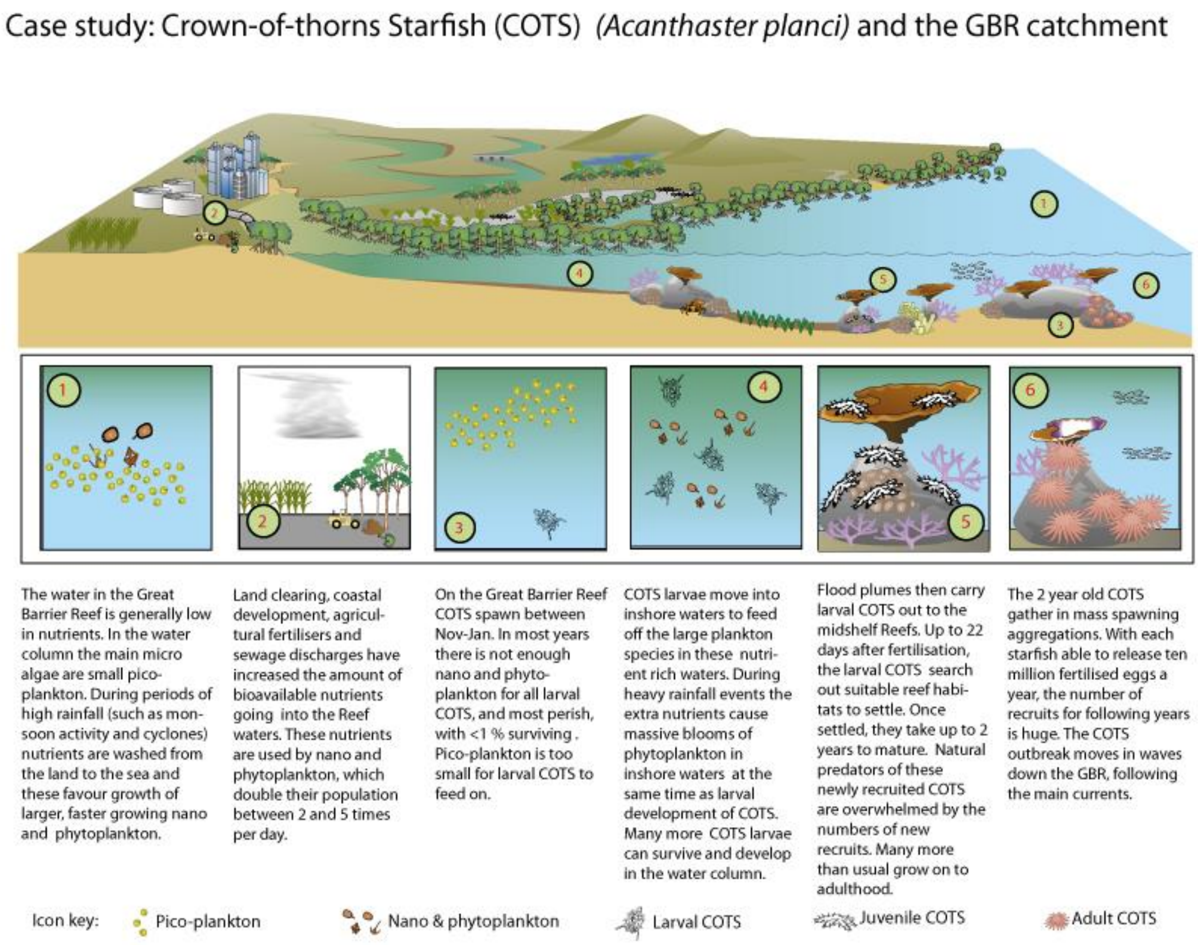


Figure 2.4.1: Crown-of-thorns starfish life cycle is dependent on the abundance of food (phytoplankton) which can be linked to water quality and exposure to flood plumes

Biological processes

Biological processes are the processes 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.

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 so that they shed water faster, offer limited capacity for biological processes such as reproduction, dispersal, recruitment and migration. Similar impacts can occur as the result of the loss or modification of wetlands, while weeds that choke freshwater systems can also affect their capacity to support these processes. Weeds such as Pond Apple (*Annona glabra) and* Hymenachne (*Hymenachne amplexicalis)* are established in the Mulgrave-Russell basin and have been identified as contributing to such problems. Glush weed (*Hydrophila costata*) is an emerging threat in the basin to the biological services provided by the stream margins.

In this basin, man-made barriers to fish movements and flows (for example dams and weirs) are very few, which allows physical processes to occur. However, poor design used in the construction of culverts and stream crossings on both public and private lands have the potential to impact on upstream fish migration. Poor design of culverts at road crossings, particularly on streams of lower orders, can have significant implications for the capacity of these streams to continue to support biological processes such as upstream fish migrations. This is likely to be a widespread issue throughout the basin where round pipes are common in the construction of crossings and are often associated with scoured pools on their downstream sides. Flow dynamics of round pipes can be a significant impediment to upstream fish migrations while the vertical drops associated with scoured pools on the downstream side of crossings can prevent upstream passage in moderate flow regimes.

2.5 Connectivity

Connectivity is a mechanism that supports ecological processes.[36] Disruptions to connectivity between different areas where fish breed and grow can lead to degraded populations, reduced resilience to change and possible localised extinctions of species. Figure 2.5.1 shows the sub-basin waterways that were considered in this assessment.

Both the Mulgrave and Russell river systems experience overbank flows during most wet seasons. These flows provide overland aquatic connectivity however also remove topsoil from agricultural and grazing lands and deliver them to inshore coastal waters.

Surface hydrology

The Mulgrave and Russell rivers both converge into Mutchero Inlet. The only dam in this basin is a low weir in the upland area of Behana Creek, a tributary of the Mulgrave River. The high volume of rainfall and lack of dams and weirs has resulted in a good state of aquatic connectivity across the basin. Year round stream flows prevent weed chokes and black water from occurring in all but the smaller creek systems.

Throughout the Mulgrave-Russell basin, linear drainage channels that have been constructed for draining water from the agricultural lands that now cover the flood plain. They are designed to rapidly remove water from these areas following high rainfall events or flooding of the flood plain and as such generate high velocity flows that cause bank erosion, soil loss and can deliver excessive nutrients and sediments to downstream rivers and wetlands, and to the World Heritage Area.

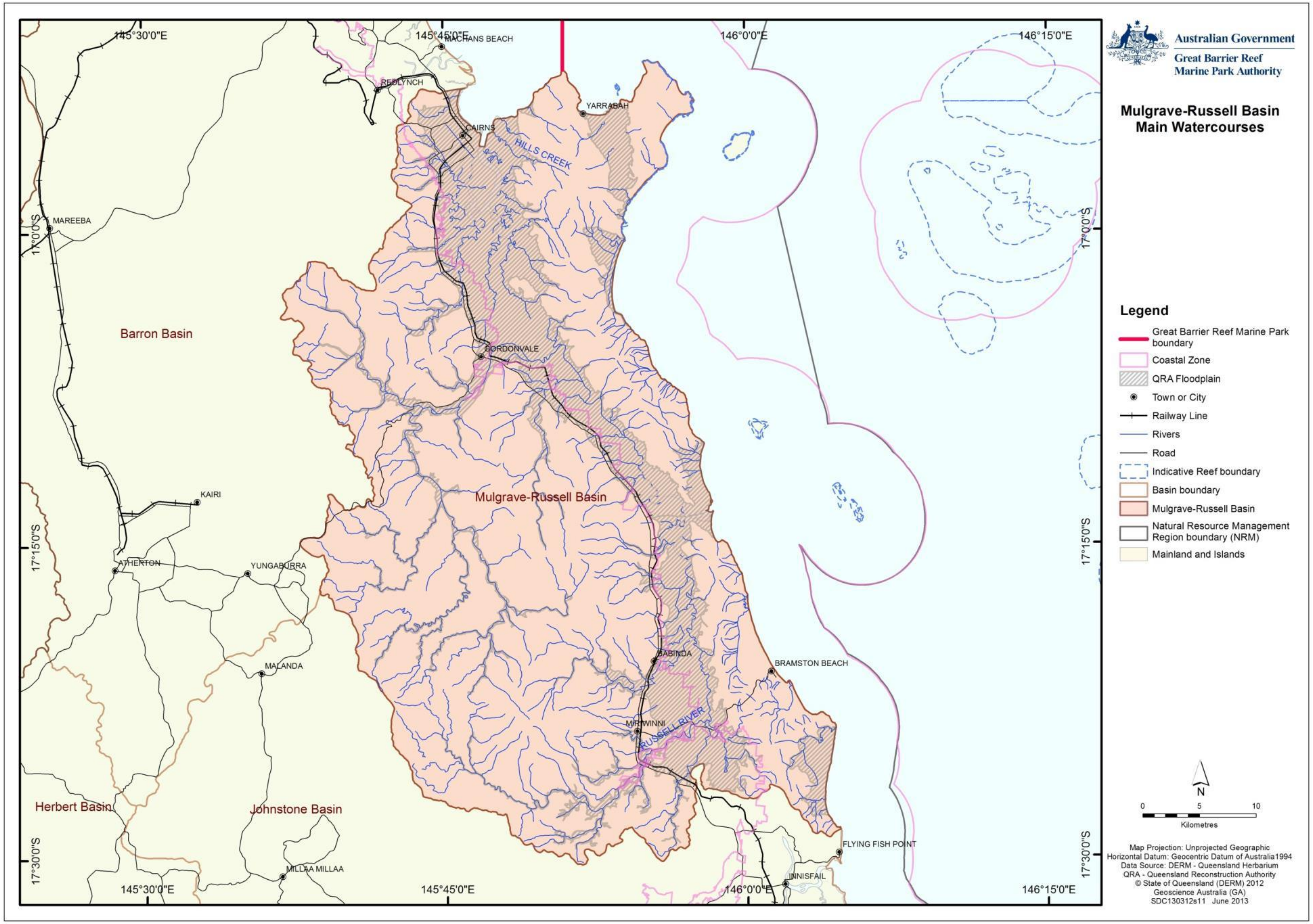


Figure 2.5.1: Major waterways in the Mulgrave-Russell basin considered in this assessment

Underground hydrology and groundwater dependant ecosystems

The Cairns Regional Council has a surface water extraction point in the Behana Creek Gorge that supplies the southern parts of Cairns Regional Council area. Behana Creek water is extracted directly from a small weir on the creek under license from the Department of Natural Resources and Water (NRW) with a nominal annual entitlement of 16,060 ML per year. An environmental flow schedule applies to the extraction of water from the creek. This has lowered the volume of water moving down this system but not to a state where it poses a risk to the aquatic connectivity or groundwater connectivity.

Cairns Regional Council has endorsed the Mulgrave River Aquifer as a potential future water supply source for Cairns, following an extensive investigation into the engineering and environmental feasibility. The intent is to develop Stage 1 of the Mulgrave River Aquifer with a view to develop Stage 2 of the aquifer subject to environmental impact assessment.[37] The ground water extraction proposed by the Cairns Regional Council is 15 ML/day with consideration of up to 40 ML/day based on approval conditions. The bore fields are proposed to be located either side of the lower section of Behana Creek.

Dry season flow rates of 25 ML/day have been measured in the lower section of Behana Creek by Mulgrave Landcare. During this low-flow period the creek maintains an average depth of 0.3 metres and a width of six metres with exposed areas of sand at the base of the creek channel. Local landholders have expressed concerns about the accuracy of the modelling used to assess the impact this proposal would have on ground water volumes and the flow of Behana Creek.

The Russell River (and Babinda Creek) experiences the highest amount of rainfall of any location in Australia (recording an annual rainfall of over 4200 millimetres each year at Babinda). This area would therefore be a preferred option for groundwater supply to Cairns.

Groundwater from the Wet Tropics region, including sites from the Mulgrave-Russell catchment were found to contain relatively 'low' nitrate concentrations (< 20 mgL^{-1} as NO3 or < 4.5 mgL^{-1} as NO3-N) compared to other regions in north eastern Australia.[38] Although these concentrations are considered low compared to drinking water guidelines they are likely above ecological guidelines.[39]

Chapter 3: Impacts on the values

3.1 Drivers of change

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

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.[40]

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 the Wet Tropics region for temperature, rainfall, evaporation and extreme events.[41]

The climate change impacts that will affect tropical rainforest ecosystems are increased temperature, changes in water balance and hydrology, and extreme weather events.[14] Woodlands in the Mulgrave-Russell will be most affected by invasive plant species, 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 the water balance and hydrology.[14]

Table 3.1.1: Regional climate change predictions for the Wet Tropics region

Element	Prediction
Temperature	There has been minimal change in the average annual temperature in Far North Queensland over the last decade (from 24.4°C to 24.5°C). Projections indicate an increase of up to 3.9°C by 2070, leading to annual temperatures well beyond those experienced over the last 50 years. By 2070, Cairns may have more than eight times the number of days over 35°C (increasing from an average of four per year to an average of 34 per year by 2070).
Rainfall	Average annual rainfall in the last decade fell by more than two per cent compared to 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 22 per cent to a decrease of 26 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 cent by 2070.
Extreme events	The 1-in-100-year storm tide event is projected to increase by 37 cm in Cairns if certain conditions eventuate. These conditions are a 30 cm sea-level

Element	Prediction
	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 driver for much of the land use change that has occurred in the Mulgrave-Russell basin.

Historically, sugar cane production underpinned the economy within the Mulgrave-Russell basin. The Mulgrave Central Mill crushes approximately 1.3 million tonnes of sugar cane each year sourced from 17,000 hectares of land. This generates 160,000 tonnes of sugar, the majority of which is exported through the Cairns City Port. At the very southern end of the basin in the vicinity of the Eubanangee Swamp, the sugar cane produced is generally processed by the South Johnstone Sugar Mill located to the south west of the town of Innisfail just to the south of the Russell Mulgrave basin. These two mills are owned by MSF Sugar Ltd.[42] Recent investments by this company have seen some grazing and managed forestry lands within the basin returning to sugar production.

Tourism is now the major economic driver in the basin and continues to be a focus for economic growth. Growth industries in the region include tropical expertise and services; service and support of regional mineral resource sector; supporting growth in near neighbours of the Asia Pacific region and the carbon economy. The proposed expansion of the Cairns City Port will offer economic opportunities linked to increased freight capacity, cruise ship servicing, and growth in the naval base HMAS Cairns.[43]

Technical development

Technical developments, primarily the availability of low cost heavy earthmoving equipment, have forever changed the Mulgrave-Russell basin floodplain. This has provided capacity to build extensive drainage networks, transforming wetlands and parts of the river flood plains into areas with the capacity to grow sugar cane. This has resulted in a loss of the ecological functions these environments once provided (Figure 3.1.1). Small streams and seasonal creeks have been deepened and channelised increasing flow rates and altering their ecological functions.

Figure 3.1.1: Cane drainage channel under construction in the 1970s (image DEHP)

Population growth

Intensive urban residential development is mostly confined to the northern end of the basin and is linked to the city of Cairns. Locations for housing are limited in the Mulgrave-Russell basin due to the Wet Tropics World Heritage Area to the west. Proposed future residential expansion servicing Cairns will be restricted to the corridor south of Cairns between the communities of Edmonton and Gordonvale. Known as the Mount Peter Development Area, a projected population of 50,000 people by 2031 has been identified for this area.

Small towns and communities to the south of Cairns have maintained stable populations for some time. Regional planning strategies and the economic drivers in this area create a low likelihood of future population growth occurring in these small communities.

3.2 Activities and impacts

The dominant land use in the Mulgrave-Russell basin today is dryland production, consisting predominantly of sugar cane. Land use for 1999 and 2009 is shown in Table 3.2.1. Figure 3.2.1 shows 1999 land use, with the areas of change between 1999 and 2009 shown in Figure 3.2.2.

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

	Mulgrave-Russell basin land use (ha)	**1999**	**2009**
	Conservation, natural environments (inc. wetlands)	150,338	149,110
	Forestry - production	0	482
	Grazing natural vegetation	7,492	10,223
	Intensive animal production	1,379	88
	Intensive commercial	1,981	2,562
	Intensive mining	91	113
	Intensive urban residential	4,477	6,389
	Production - dryland	28,937	25,520
	Production - irrigated	1,384	1,361
	Water - production ponded pastures	0	0
	Water storage and transport	1,711	1,998
	Not Mapped	407	351
	Total Area (h)	198,197	198,197

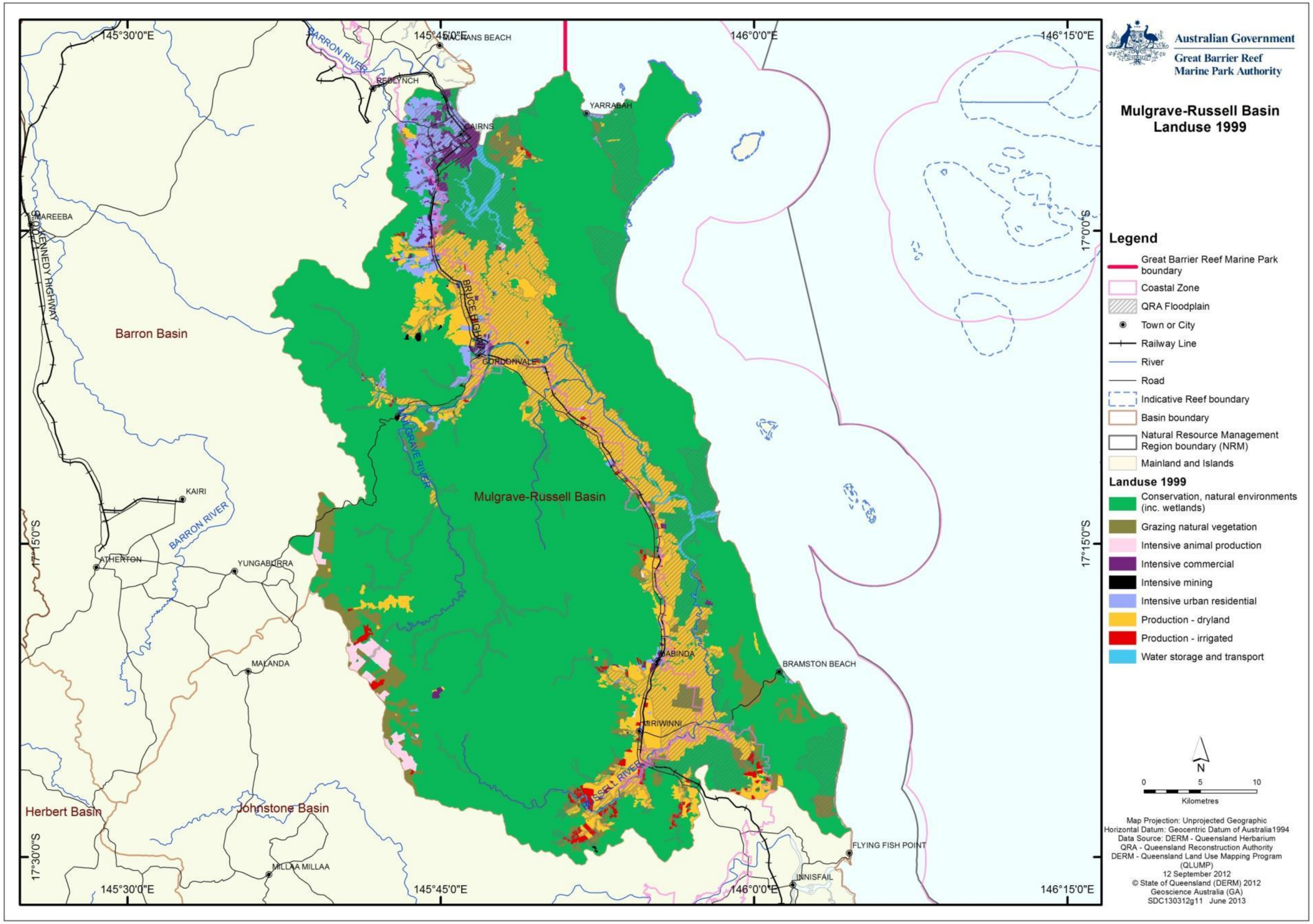


Figure 3.2.1: Map of land use for the Mulgrave-Russell basin based on 1999 QLUMP data

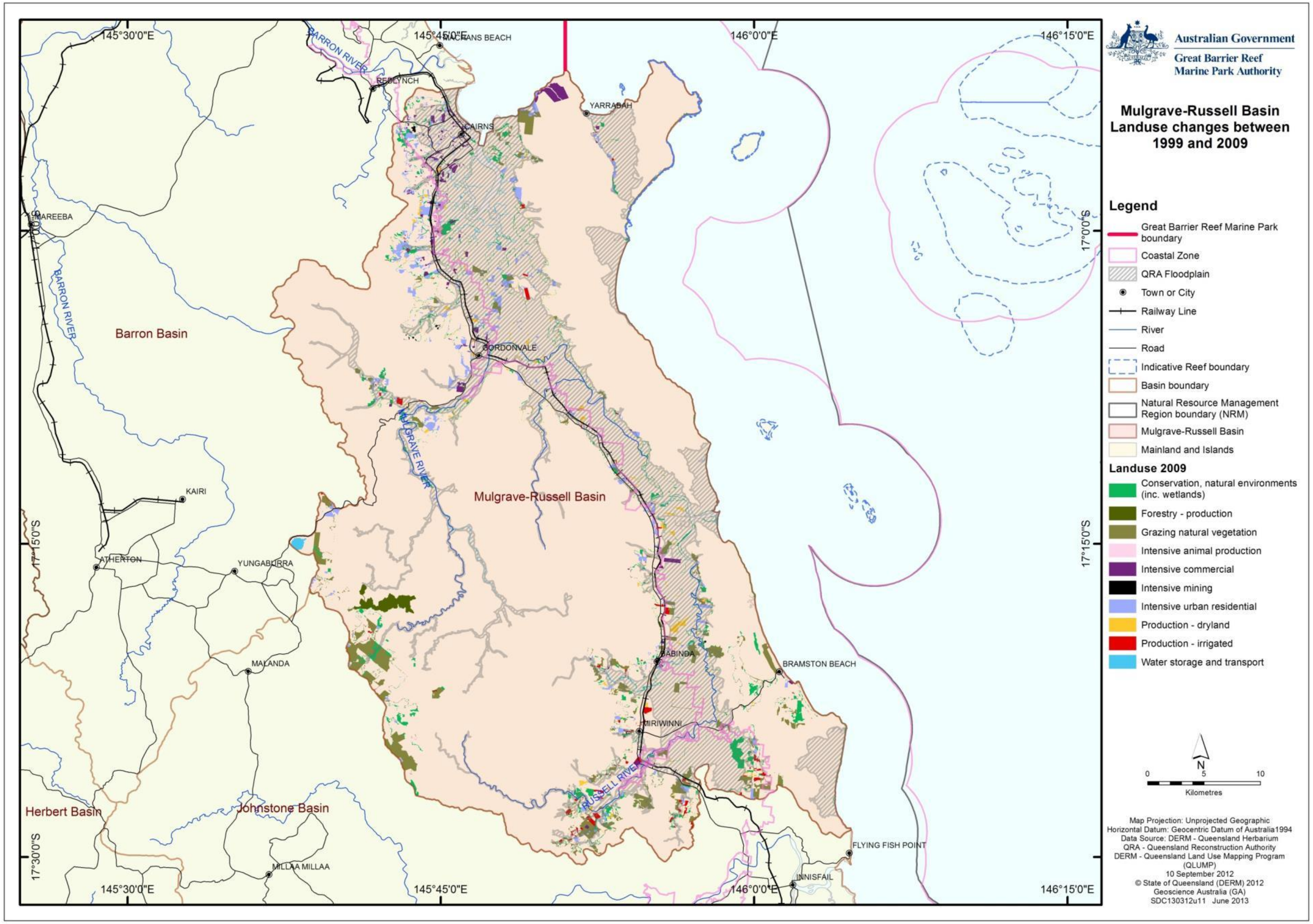


Figure 3.2.2: Map showing areas of changed land use in the Mulgrave-Russell basin based on 1999 and 2009 QLUMP data

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 metres Australian Height Datum or within five kilometres 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.

Table 3.2.2: Major land use categories (hectares) for the Mulgrave-Russell basin coastal zone in 1999 and 2009 based on Queensland Land Use Mapping Program data

	Land use area (ha) - Mulgrave-Russell Coastal Zone	1999	2009
	Conservation, natural environments (inc. wetlands)	48,469	47,818
	Forestry - production	0	0
	Grazing natural vegetation	2,732	3,403
	Intensive animal production	49	29
	Intensive commercial	1,383	1,865
	Intensive mining	0	17
	Intensive urban residential	1,882	2,508
	Production - dryland	14,750	13,566
	Production - irrigated	109	148
	Water - production ponded pastures	0	0
	Water storage and transport	1,537	1,613
	Not Mapped	407	351

3.3 Actual and potential impacts

There have been some major landscape scale changes within the Mulgrave-Russell basin which have been shown to impact on the receiving marine environment. Other developments in the basin may be relatively small in area however may contribute significantly to the cumulative impacts on the World Heritage Area.

Forestry

Forestry in the Mulgrave-Russell is limited to an area of production forestry in the Tablelands area. There have been unconfirmed reports of topsoil from this area discolouring downstream reaches of otherwise pristine river systems.

Grazing natural vegetation

There has been an increase in grazing in the Mulgrave-Russell basin between 1999 and 2009 data. This has occurred mostly in the upper catchment on the eastern edge of the Atherton Tablelands, where there has been a shift from dairy to grazing. In the lower catchment there has been a transition to grazing in some areas of previously marginal sugar cane land.

Grazing on the eastern edge of the Atherton Tablelands occupies a small area of the upper catchment of the Mulgrave-Russell basin. Investigations by Mulgrave Landcare members have identified this area, though well-grassed, as a source of red soil loss to the Mulgrave River during high rainfall events.

Grazing in the lower basin has increased over the last 15 years though still only occupies a relatively small land area when compared to sugar cane production. Grazing in this area remains a source of sediment loss during peak rain periods. The high rainfall of the area means grazing lands are generally well grassed throughout the year. Stream access points for drinking are the major source of sediment loss in this area.

Intensive animal production

There has been a shift from intensive animal production (mostly dairy) in the Tablelands to grazing. There are also two small barramundi hatcheries and grow out aquaculture facilities in the Little Mulgrave River sub-basin. These developments are unlikely to have any significant impact on the World Heritage Area.

Intensive commercial

The city of Cairns and its associated urban and industrial areas occupies the Trinity Inlets western catchments. A large landfill site (now closed), ship building and slipway industries, bulk sugar cane storage and loading facility, and facilities to accommodate and service the commercial fishing fleet occupy reclaimed lands adjacent to the Trinity Inlet in the Cairns city suburb of Portsmith. These lands were once mangrove and salt marsh habitats that have been built up with dredge spoil during the development of the port in the 1950s and 1960s.[44]

Intensive mining

Mining of quarry material occurs south of Mount Peter.

Intensive urban residential

The urban footprint of Cairns, bounded by the ocean to the east and the Wet Tropics World Heritage Area to the west has led to an increase of urban areas southwards. This is expected to continue with the progress of the proposed Mount Peter urban development. This will result in a decline of sugar cane land in this area and a corresponding change in ecological functions provided by these modified systems. Run-off from urban areas will continue to impact on water quality entering the World Heritage Area as retention time run-off waters within urban catchments are reduced by deepening and modifying existing waterways to support engineered drainage.

Water supply needs have been identified as an issue with the expansion of the urban footprint. Water supplies are currently supplemented by a dam on Behana Creek. A proposal has been put forward to extract groundwater from the aquifer that supplements flows in Behana Creek. This will likely draw down the watertable during the dry season and threaten fish passage in this system. A better option would be to remove water from aquifers in the Russell River basin, which receives substantially more rainfall than the Mulgrave River system.

The Cairns Regional Council whose local government area covers most of the Mulgrave-Russell basin has adopted a number of sustainability initiatives and strategies linked to regional sustainability, climate change, Natural Resource Management, and biodiversity protection (refer to: http://www.cairns.qld.gov.au/environment).

Production – dryland

There has been a slight decrease in dryland production in the Mulgrave-Russell basin with a corresponding increase in irrigated banana production.

The widespread adoption of best management practices by sugar cane producers in the Mulgrave-Russell basin sees the practice of "trash blanketing" employed throughout the sugar cane lands of the area. Trash blanketing is the process by which the discarded plant material generated during the mechanical harvesting of the sugar cane is left on the paddock to form a thick blanket. The harvesting process leaves the sugar cane plants' root stock (stool) in the ground from which the next crop shoots (rattoon) through the trash blanket. The trash blanket has a significant impact in reducing top soil loss from sugar cane lands during rain and flood events.

The crop cycle for sugar cane lasts between four and seven years from planting to replanting. To replant the crop the old stool is ploughed out and a new sugar cane plant (plant stem segment called a billet) is planted. During this phase of the crop cycle the trash blanket is incorporated into the soil during the plough out process. The soil loses the protection of the trash blanket at this stage of the crop cycle and is susceptible to losses during rain and flood events. Industry representatives suggest that approximately 15 per cent of the sugar cane lands are in this state in any one year.

Best Management Practices (Figure 3.3.1) such as subsurface fertiliser placement and herbicide application methods that significantly reduce the volumes of herbicides applied (50 per cent reductions) have been widely adopted by sugar cane farmers during the Caring for our Country Reef Rescue program.[45] Terrain Natural Resource Management staff responsible for the delivery of the Reef Rescue program note that 96 per cent of sugar cane agriculture lands in the Mulgrave sub-basin and 88 per cent in the Russell sub-basin are now receiving subsurface fertiliser application.[46] These best management farming practices, coupled with the trash blanketing, are having positive effects on reducing sediment, nutrient, and chemical losses from the floodplain of the Mulgrave-Russell basin.[16]

Figure 3.3.1: Top – The wide spread adoption of best management practices by sugar cane producers in the Mulgrave-Russell basin sees the practice of "trash blanketing" employed throughout the sugar cane lands of the area. The trash blanket is created when the green cane is harvested. The trash is left in the paddock to cover the soils with the new sugar cane crop shooting through the trash blanket. The trash blanket has a significant impact in reducing top soil loss from cane lands during rain and flood events and thus has a significant positive effect on improving water quality. Bottom – Best Management Practices such as subsurface fertiliser placement have been widely adopted by sugar cane farmers during the Caring for our Country Reef Rescue program. In the image above the large disks at the front of the fertiliser implement slit open the soil and cane root stock (split stool) to allow the fertiliser to be placed below the surface of the ground. The split stool is then closed as the implement passes over. Sub-surface fertiliser application reduces nutrient losses from cane fields to receiving waterways during rainfall and flooding events. This results in improved water quality outcomes for the World Heritage Area

Agricultural development in the past has led to the exposure of acid sulphate soils. Acid sulphate soils are predominantly associated with areas of Quaternary alluvium with high levels of organic matter and sulphidic material present.[47] Acid and toxic concentrations of metals can be released into the environment when acid sulfate soils become oxidised with air exposure.[47] The Queensland Department of Environment and Resource Management and Queensland Acid Sulfate Soil Investigation Team (QASSIT) mapped the lower section of the Mulgrave River as being potential acid sulfate soil.[47] These soils are in areas dominated by mangrove and melaleuca wetlands, and are tidally influenced in most cases. Acid sulfate problems exist for some farmers around Mutchero Inlet (north of Babinda) where vegetation clearing and ground tilling (for sugar cane) has resulted in the generation of acid sulfate conditions and a resultant loss in agricultural productivity.

Production – irrigated

Banana horticulture in the lower catchment has increased over the last 15 years though still only occupies a relatively small land area when compared to sugar cane production. Banana horticulture is a source of sediment loss during peak rain periods. In the banana industry the growing adoption of grassed inter rows is reducing sediment losses. Nutrient application by fertigation (fertiliser application through irrigation systems) reduces fertiliser losses from farms as the nutrients are absorbed into the soil. The adoption of fertigation is not widespread within the banana industry in the Mulgrave-Russell basin.

Banana horticulture has a high reliance on pesticides including fungicides. These are generally applied via aerial spraying. The sugar, banana, and cattle producers (led by their peak bodies) are embracing best management farming practices that reduce their impacts on coastal ecosystems. Capacity building provided by Caring for our Country Reef Rescue program[45] has enabled many farmers with the desire to move to current Best Management Practice to do so. Other irrigated cropping in the basin includes turf farms (limited) and dry season sprinkler irrigation in some areas.

Water – marsh/wetland production

There is no marsh/wetland production identified in the Mulgrave-Russell basin.

Water – intensive use and water-storage and treatment

The main waste water treatment plant for the city of Cairns discharges into Trinity Inlet. Managed by the Cairns Regional Council the waste water is treated to a tertiary level of AA+. The smaller Edmonton plant also discharges into the Trinity Inlet. The Gordonvale treatment plant discharges into the Mulgrave River while the Babinda Treatment Plant discharges into the Babinda Creek. The status of wastewater treatment in the Mulgrave-Russell basin is summarised in Table 3.3.1.

Table 3.3.1: Wastewater treatment plants of the Mulgrave-Russell basin

Urban centre	Wastewater treatment
Cairns (southern WWTP)	Tertiary AA+
Yarrabah	Unknown
Edmonton	Secondary C
Gordonvale	Secondary C (fine screening, oxidation, clarification, chlorination)
Bramston Beach	Approximately 110 on-site sewage management systems (OSSMS)
Babinda	Secondary C (course screening, trickling filter, humus tank, chlorination) + some OSSMS in outskirts of town (mostly septics)
Mirriwirri	Approximately 100 OSSMS (mostly septics)
Ella Bay	Proposed onsite treatment and irrigated disposal

The Cairns Regional Council has a surface water extraction point in the Behana Creek gorge that supplies the southern parts of Cairns Regional Council area. Behana Creek water is extracted directly from a small weir on the creek under license from the Department of

Natural Resources and Water (NRW) with a nominal annual entitlement of 16,060 ML per year. An environmental flow schedule applies to the extraction of water from the creek.

Cairns Regional Council has endorsed the Mulgrave River Aquifer as a potential future water supply source for Cairns, following an extensive investigation into the engineering and environmental feasibility.

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 Mulgrave-Russell basin have been modified and their current state is poor due to decades of substantial modifications to the floodplain and floodplain function. The 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.

Coastal ecosystems that have been most affected are forests, woodlands, grass and sedgelands, rainforests, forested floodplains, freshwater wetlands and estuaries (Table 4.1.1). Approximately 377 hectares of grass and sedgelands have been lost in this basin, mostly from the floodplain and coastal zones. Floodplain rainforest, woodlands and freshwater wetlands have had the greatest proportion of loss in the Mulgrave-Russell basin. The upland areas however remain in near pristine condition and are afforded protection as part of the Wet Tropics World Heritage Area.

Table 4.1.1: Percentage of remaining coastal ecosystems in the Mulgrave-Russell basin, Mulgrave-Russell basin coastal zone and the Mulgrave-Russell basin floodplain. Red cells indicate areas with less than 10 per cent remaining; orange 10-30 per cent; yellow 31-50 per cent and green greater than 50 per cent. Note these figures provide no information about ecosystem condition or functionality

Percentage remaining of coastal ecosystems in the Mulgrave-Russell basin	Rainforests	Forests	Woodlands	Forested floodplain	Grass and sedgelands	Heath and shrublands	Freshwater wetlands	Estuaries
Basin wide	76	64	63	98	1	99	53	82
Floodplain	26	18	60	98	1	98	44	82
Coastal Zone	69	56	63	100	1	98	72	82

Between 2006 and 2009, 20 hectares of coastal ecosystems were modified, those being 18 hectares of forest, one hectare of rainforest and one hectare of heath and shrublands. The current state of coastal ecosystems in the Mulgrave-Russell basin is summarised in Table 4.1.2.

Table 4.1.2: Summary of the current state of coastal ecosystems in the Mulgrave-Russell basin

	Coastal ecosystem	Current condition
	Rainforests	Rainforests on the floodplain have been significantly modified, with 74 per cent lost to other land uses. A further hectare was lost between 2006 and 2009.
	Forests	Heavily impacted with 36 per cent modified more used for grazing. Only 18 per cent of forests on the floodplain and 44 per cent of forests in the coastal zone remain.
	Woodlands	Reduced in extent by 27 per cent with much of the remainder under grazing regimes.
	Forested floodplain	Almost all pre-clear forested floodplain remains (currently 599 hectares).
	Grass and sedgelands	Poor. Only five hectares of the original 377 hectares of grass and sedgelands remain.
	Heath and shrublands	Good. 3,615 hectares of heath and shrublands remain, with minimal loss.
	Freshwater wetlands	Almost half of the Mulgrave-Russell basin wetlands have been modified. Most loss has occurred on the floodplain.
	Estuaries	Mangrove systems have declined in extent by 1,008 hectares.

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

Table 4.2.1 provides a brief summary of the current pressures and future outlook for coastal ecosystems in the Mulgrave-Russell basin. The main activity that will likely impact on the health and resilience of coastal ecosystems in the Mulgrave-Russell basin into the future is the expansion of Cairns urban footprint.

Urban encroachment onto sugar cane lands at the northern end of the basin adjacent to the Wet Tropics World Heritage Area and associated impacts on water quality are the most likely impact on the matters of national environmental significance in the future in the Mulgrave-Russell basin.

Whilst programs such as Reef Plan are encouraging uptake of better land management practices in agricultural lands, the impacts associated with urban residential developments are more difficult to manage. Impacts from urban residential areas can include increases in hydrocarbons, herbicide and fertiliser applications, introduction of pests into adjacent natural areas and increase of plastics, toxicants and pharmaceuticals.

The proposed expansion of the Port of Cairns and the associated capital works dredging and associated ongoing dredging maintenance has the potential to impact the Trinity Inlet Estuary and the adjoining inshore marine ecosystems of the World Heritage Area.

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

Pressure	Current status (1999-2009)	Description	Future outlook	Description
Urban development	Increase	Urban residential increased by 30% (approximately 25% for the coastal zone) between 1999 and 2009.	Increase	Urban centres are expected to increase further southwards along the floodplain with the Mount Peter urban community for example.
Port development	No change	N/A	Increase	Expansion proposed to allow cruise ship access.
Agriculture (production)	Decrease	Agriculture production (dryland and irrigated) has declined by 11% between 1999 and 2009.	Uncertain	Some loss likely to occur as a result of urban encroachment from the Cairns urban expansion.
Irrigation infrastructure	No change	No additional water infrastructure.	Uncertain	Water extraction from Behana Creek proposed to supplement Cairns water supply.
Grazing	Increase	Grazing has increased by 27% between 1999 and 2009.	Uncertain	Subject to market demands. Marginal cane land is increasingly shifting towards grazing.
Introduced species	Uncertain	Terrestrial and aquatic weeds are well established throughout the basin. The African fish *Tilapia* are also well established and may pose a threat to the unique fishes of 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. Expansion of irrigation infrastructure may increase extent of aquatic and terrestrial weeds. Urban development may foster further spread of some ornamental species.
Climate Change	Uncertain	Not assessed.	Increase	Increasing intensity of episodic events, droughts and changes in rainfall patterns all likely to impact on coastal

Pressure	Current status (1999-2009)	Description	Future outlook	Description
				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.	Uncertain	Amendments proposed for the *Vegetation Management Act 1999.*
Commercial intensive	Increase	Increased from 1,981 hectares in 1999 to 2,562 hectares in 2009.	Increase	Expected to increase along with the expansion of Cairns.

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 afford 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

It was estimated that over half of the freshwater wetlands in the Mulgrave-Russell basin have been cleared since European settlement.[48] Soil erosion rates measured at a site near Babinda were amongst the highest (135 t/ha of soil lost per year) within the Wet Tropics.[49] However the implementation of management practices such as reduced or no tillage and green sugar cane trash blanketing successfully reduced soil erosion in sugar catchments to less than15 t/ha per annum.[49,50]

Additionally, catchment-based targets to improve in-stream health in the Mulgrave-Russell basin include the restoration of riparian vegetation as well as the improved management of wetlands (control of aquatic weeds). These actions would improve in-stream health and may also contribute in the reduction of nitrite concentrations in-stream base flow sourced from groundwater.[39] Moreover, acid sulphate soils in this region also require remediation and management.

The Reef Rescue Program has resulted in many growers adopting improved management practices and undertaking training courses for nutrient management ('six easy steps' method) and integrated weed management.[51] It was estimated that 21 per cent of the sugar cane industry across the Wet Tropics region had improved their management practices as a result of the Reef Rescue incentive program. Grants were awarded in the Mulgrave River catchment to apply split-stool, sub-surface, variable rate fertiliser application, improve soil management through zonal tillage and controlled traffic, legume planter, and improve herbicide management (shielded sprayer). The aim of these improved practices is the reduction of sediment run-off, nutrients and pesticides.[51]

Recent changes to Queensland Government policies may have implications for the effectiveness of the program into the future. The removal of the Queensland Coastal Plan and the amalgamation of many of the State Planning Policies into one may have future implications for coastal ecosystems. The *Wild Rivers Act 2005* was repealed in 2012, allowing mining operations opportunities to develop in close proximity in otherwise near pristine riverine areas. Conflicting planning (conflicting use) continues to occur which can jeopardise connectivity and compromise ecological functions.

Reef Plan (2009) set 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 set for the Reef catchment area by the Great Barrier Reef Marine Park Authority. Improved sugar cane management practices have been designed to benefit the Reef and water quality targets have been set for the export of pollutants from the Mulgrave-Russell River catchment. To achieve the water quality targets for the region, a reduction of 80 per cent in DIN loads, a 62 per cent reduction in photosystem-II herbicide loads and a 20 per cent reduction in sediment loads (and associated PN and phosphorus loads) delivered from the Mulgrave River catchment are required.

A reduction in nutrient levels, especially within the Wet Tropics region, is necessary to mitigate crown-of-thorns starfish outbreaks.[8] However, two additional precautionary management measures have been suggested to maintain low crown-of-thorns starfish densities in high-risk areas such as Green Island: 1) large permanent fish closures to allow fish populations to reach carrying capacity to safeguard against cascading changes in food webs and 2) targeted efforts by divers to remove some of the crown-of-thorns starfish before aggregation and spawning commences.[8]

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 high temperatures as a consequence of climate change will likely see a decline in intertidal, coastal and estuarine seagrass meadows in the World Heritage Area.[52] Ocean acidification as a result of increasing CO_2 on the other hand is expected to enhance seagrass production.[53]

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

The Mulgrave-Russell 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. Key impacts identified on coastal ecosystems include:

- Infill of low lying woodlands, forests and rainforests to accommodate expanding urban development has reduced overland hydrology thereby reducing capacity to deliver ecological processes.
- Funneling of stormwater from urban developments into mangroves, potentially causing localised losses of keystone crab populations, reduces residence time (thus impacting on biogeochemical processes) and transfers pollutants directly into the World Heritage Area.
- Widespread minor fish barriers, mostly road culverts located on lower order streams may be restricting fish passage for some species.
- Sand build up in waterways changing stream and river flow rates and their physical dynamics that contribute to increased bank erosion, loss of habitat (deep holes and riffles) and the ecological functions these provide.
- Drainage and flooding as a result of landscape scale modifications is occurring in some parts of the floodplain, reducing capacity of some coastal ecosystems to provide ecological functions.
- Reduced delivery of physical, biological and biogeochemical processes due to a reduction in retention time of water as a result of drainage networks resulting in a rapid delivery of nutrients, pesticides and sediments to inshore marine waters.
- Loss of bank stability due to loss of riparian vegetation and subsequent erosion and greater delivery of sediments to the World Heritage Area.
- Though there has been some improvement in water quality leaving the Mulgrave-Russell basin, levels of nutrients, pesticides and sediments are still significantly above desired target levels determined to benefit the World Heritage Area.
- Establishment of feral weed species, including weeds of national significance, contributing to loss of ecological functions provided by wetlands and riparian zones.
- Exposure of acid sulphate soils in some areas.

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

Current impacts on Coastal Ecosystems	Trend 1999-2009	Current likely impacts as a result 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, however no further losses expected.	No change likely to occur.
Farm run-off	Improvements as a result of increasing rates of Best Management Practice uptake.	Improvements to water quality expected, although delayed due to lag effects.	Dependant on extent of new horticulture and uptake of Best Management Practice.	Water quality expected to improve.
Groundwater changes	No change.	None.	Reduced habitat for some fish species from proposals to extract groundwater for Cairns urban area.	Reduction of fish habitat (and potential species loss for some rare species identified in this basin).
Stream/river bank erosion	Increasing as a result of extreme weather events. Legacy issues from historical clearing.	Increase in suspended sediments and turbidity in coastal waters; increase in sediment (sand) build up in waterways.	Management actions (e.g. Reef Plan) underway to restore riparian areas, sand extraction trials underway.	Likely to improve under uptake of Best Management Practice and restoration projects.
Declining water quality	Improvements in recent years.	Decline in inshore ecosystem health and resilience, implicated in crown-of-thorns starfish outbreaks.	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	Sand has built up in some areas. No dams or weirs in this basin. Some road crossings acting as barriers.	Reduction/loss of connectivity and fish passage.	No changes expected.	As for current impacts.
Introduced terrestrial weeds	Established throughout the basin (mostly in modified	Singapore daisy creating monospecific stands in some	Control practices underway in some areas.	Reduction in extent of fish habitat, may impact

Current impacts on Coastal Ecosystems	Trend 1999-2009	Current likely impacts as a result on the World Heritage Area	Future likely impacts on Coastal Ecosystems	Future likely impacts on the World Heritage Area
	landscapes).	waterways that are reducing habitat diversity for aquatic species (although may be minimising erosion).		some endemic fish species.
Changed overland hydrology	Most development/ modification has occurred on the floodplain and coastal zone including wetland drainage for production (sugar cane).	Changes to connectivity and water retention which has impacted on all ecological processes, declining water quality.	Impacts likely to continue.	Likely decline in water quality and aquatic biodiversity in the GBRWHA.
Acid sulphate soils	Uncertain.	Detrimental to aquatic life downstream of the exposed area, especially estuaries.	Impacts likely to continue unless remedied. Ongoing remedial action occurring at Trinity Inlet site. Legislation in place to prevent further exposure.	Impacts should reduce over time.

Water quality

The status of coastal ecosystems, ecosystem processes and connectivity all determine the health and resilience of the World Heritage Area. Any changes to these elements reflect the integrity of the system and often show impacts through declining water quality. The Great Barrier Reef Outlook Report[30] identified declining water quality as one of the greatest threats to the long-term health and resilience of the Great Barrier Reef. As a result, substantial investments have been made to improve land based practices with the goal of halting the decline in water quality.

The Mulgrave-Russell basin is one of the wettest areas in Australia with high run-off to rainfall ratios and frequent run-off events.[18] The average annual rainfall on the coastal plain in the Mulgrave-Russell exceeds 3000 mm/year, with 60 per cent of the annual rainfall occurring in the summer wet season (December-March).[18] Due to the steep topography of the region and the close proximity of mountain peaks (Mount Bellenden Ker and Mount Bartle-Frere) to the coastline (<25km), transit times between coastal rainfall and oceanic discharge are very rapid, suggesting minimal residence times.[18] No flow data is currently available to analyse specific hydrological behaviour of drainage lines within the Babinda drainage scheme, however daily river height data for the Russell River and Babinda Creek show that large flow events occur multiple times per year and persist for short periods of time.[18] Due to the small catchment areas and steep stream topography, the system is very responsive to high intensity rainfall events, resulting in very rapid changes to river height that are associated with rapid transmission of floods through drainage systems.[18] An average of 60 per cent of the annual rainfall within the Mulgrave-Russell catchment is converted to surface run-off which leaves the basin.[48] These major discharges from the combined Russell and Mulgrave rivers contribute to the frequent flood plumes within the Reef lagoon.[18]

The Mulgrave-Russell catchment is one of the larger catchments in the Wet Tropics in terms of area, rainfall, and discharge to the Reef lagoon.[48] Much of the sugar cane in both the Russell and Mulgrave flood plain is grown on former flood plain and wetland areas. Since sugar cane is not likely to survive in low lying areas where there is a lot of rain (sugar cane cannot sustain more than approximately three days of waterlogging before the cane dies), extensive drainage of wetlands has been established. The Russell River and Babinda Creek are major drainage lines bounding the Babinda Drainage scheme area, and are approximately 65 kilometres and 22 kilometres long, with catchment areas of approximately 56,000 hectares and 9,200 hectares, respectively. Both systems drain the eastern escarpment of the Great Dividing Range, an area adjacent to Wyvuri swamp, where an extensive, deep drainage network exists to allow sugar cane to be grown (Figure 4.3.1).[18] While this is an extreme case in the Mulgrave-Russell basin, all sugar cane lands need extensive drainage resulting in the natural floodplain dynamics being extensively modified throughout the basin.

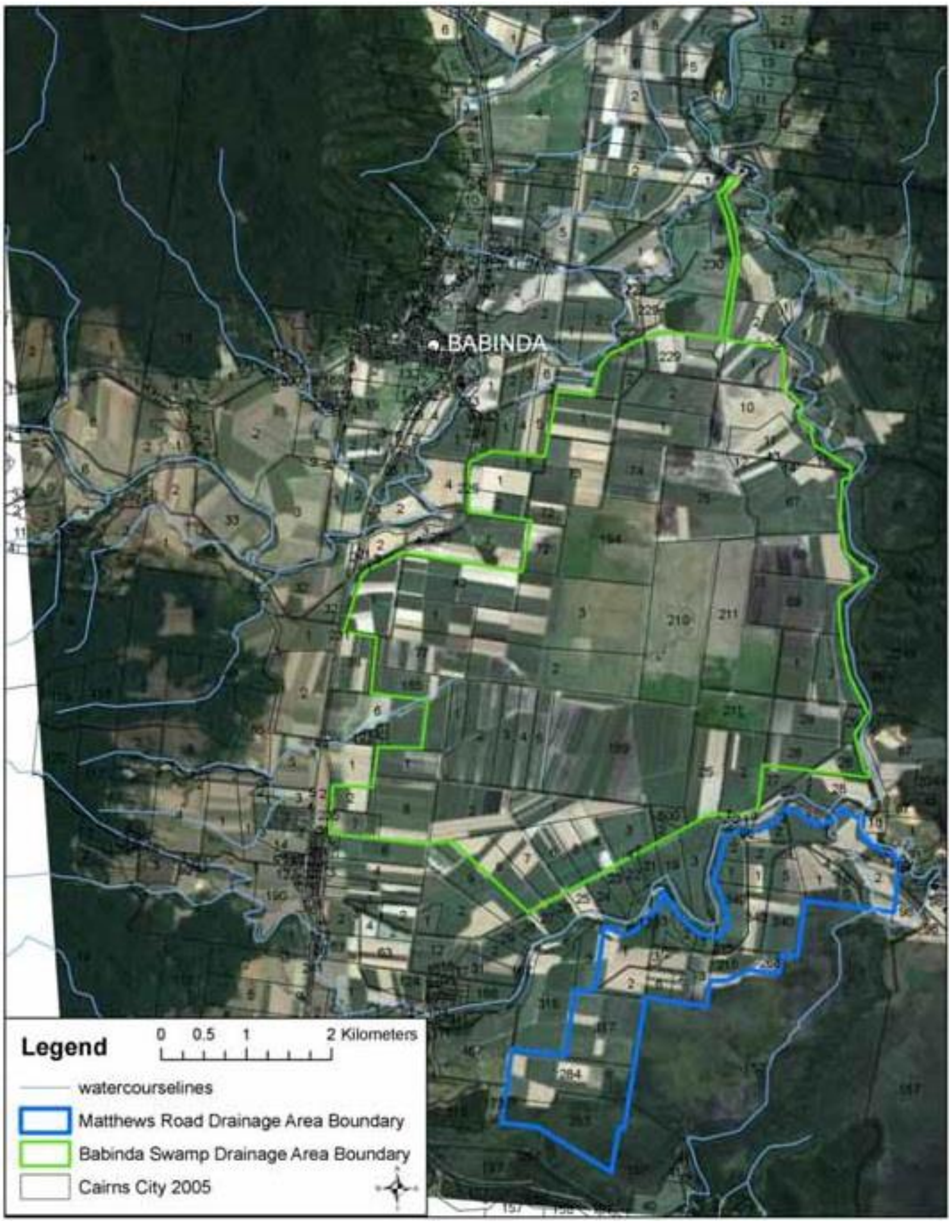


Figure 4.3.1: Boundaries of the Babinda Community Drainage and the Matthews Road Drainage Schemes

Under natural conditions the Babinda Swamp would rarely have fallen below 0.3m of the soil surface and free water at the surface would be common.[18] Since this region has been drained and cleared for sugar cane cultivation and improved pastures (to a smaller extent), certain sections have been subject to substantial surface shrinkage (sometimes over one metre) as a result of peat shrinkage following removal of water.[18] High watertables remain in the profile for much of the year, with water rarely decreasing below one metre depth from the surface even though considerable areas have been artificially drained.[54]

Figure 4.3.2 provides an example of the relationships between pressures, state and impact from increased pollutants being delivered to the Great Barrier Reef.[55] 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[56,57,58] 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.[55]

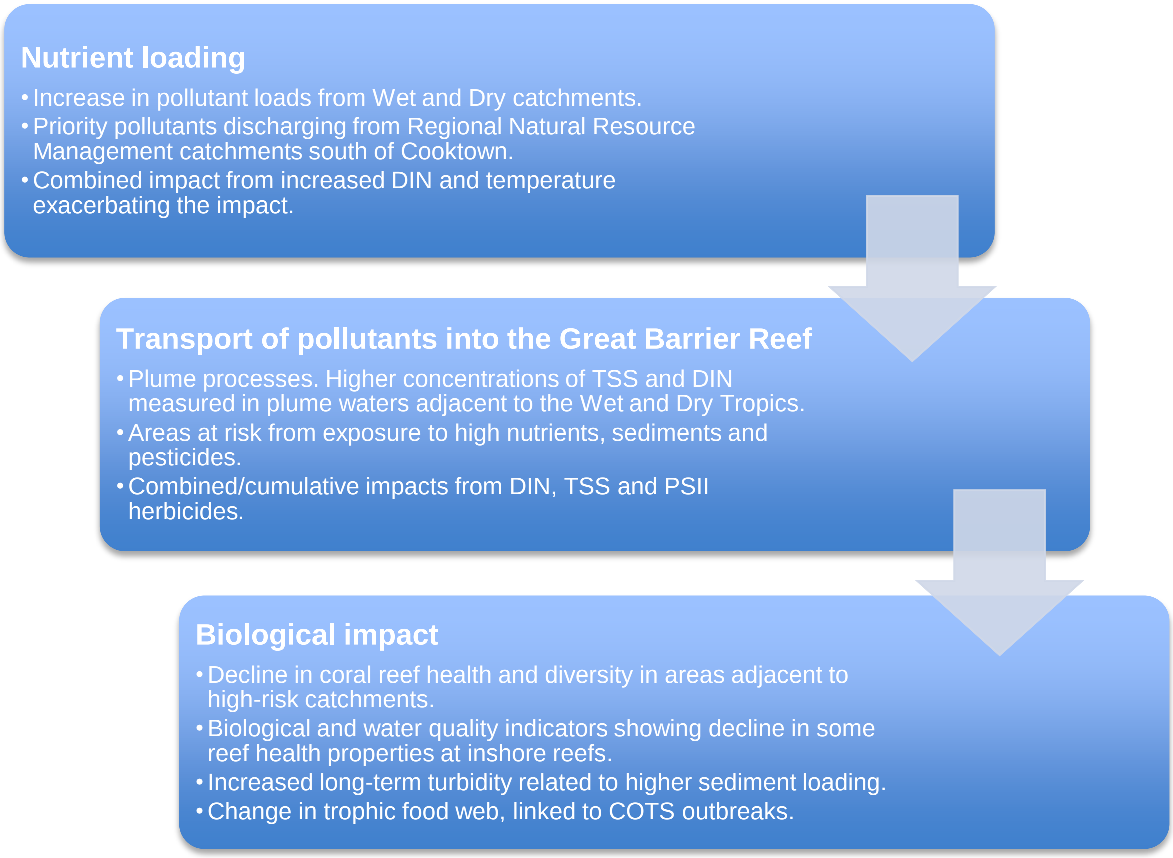


Figure 4.3.2: Pathway from nutrient enrichment to biological impact from total suspended solids (TSS); dissolved inorganic nitrogen (DIN); photosynthesis inhibiting herbicides (PSII); and crown-of-thorns starfish (COTS)

The impacts of increasing sediments and nutrients on coral reefs (Figure 4.3.3) and seagrass (Figure 4.3.4) include shading, reduced resilience and reduced recruitment.[55] Abundances of a range of other reef associated organisms have also been shown to change along the water quality gradient.[55]

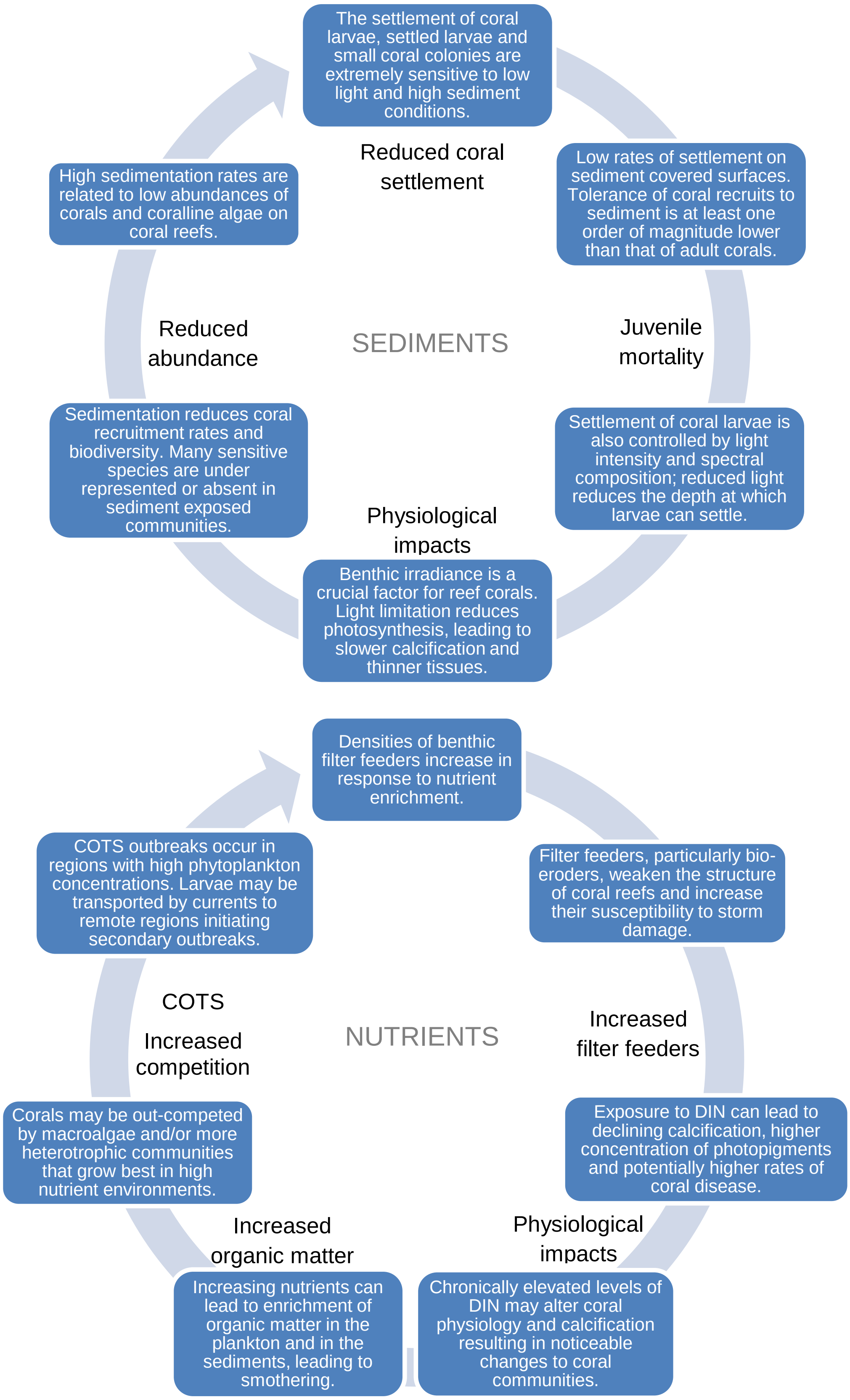
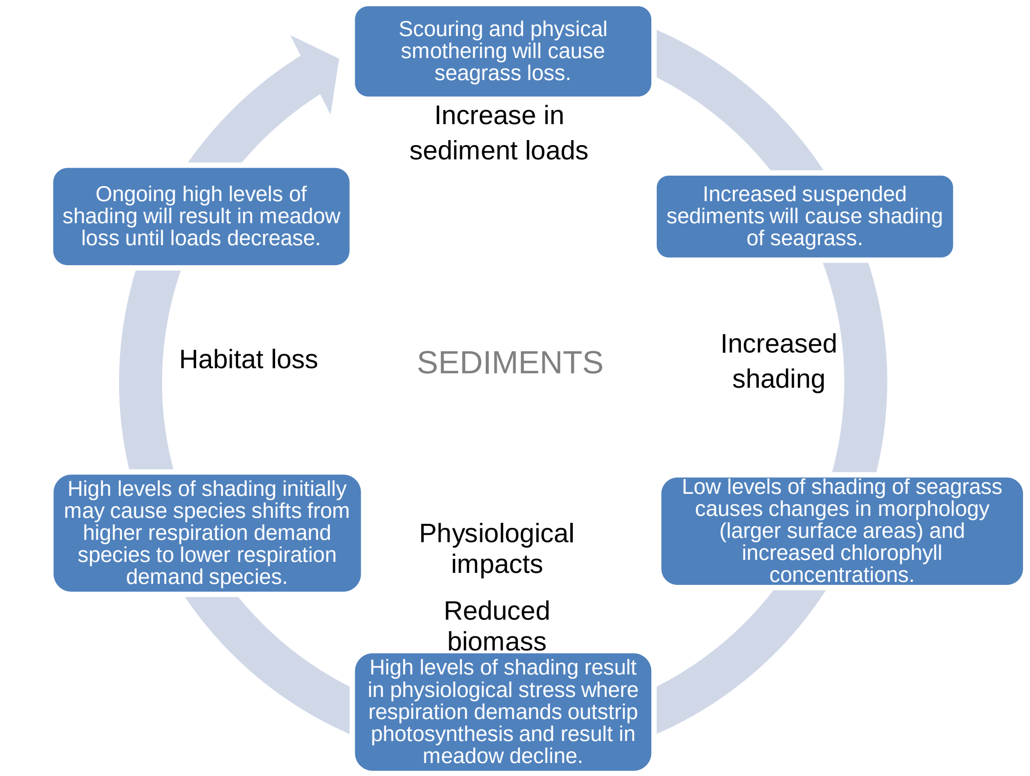


Figure 4.3.3: Potential and known impacts of increasing nutrients and sediments on coral reefs[55]



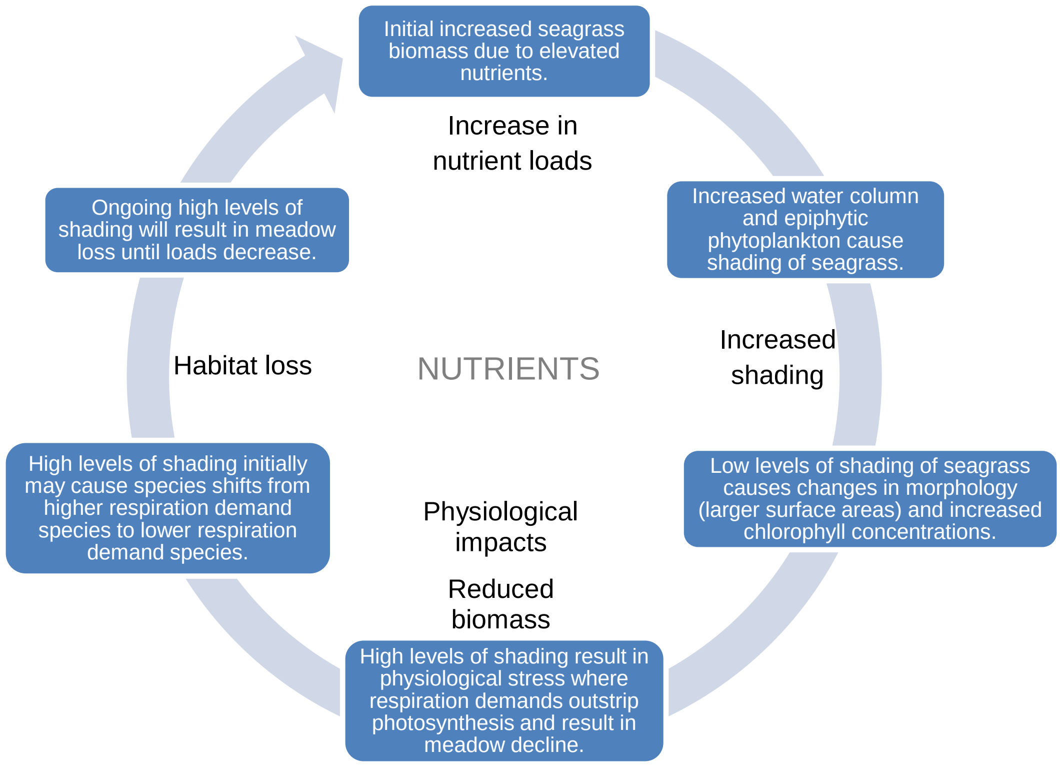


Figure 4.3.4: Potential and known impacts of increasing nutrients and sediments on seagrass beds[55]

Inshore reefs found within the Wet Tropics region of the Reef have been identified as containing coral reefs with relatively low diversity, which has been linked to poor water quality.[3,4,33,34] In addition, a serious problem that is of particular concern in the inshore area surrounding the Mulgrave-Russell basin is the crown-of-thorns starfish. Based on the analyses of 2258 coral reef surveys of 214 reefs on the Reef, a loss of 50.7 per cent coral cover has been measured in the previous 27 years up to 2012.[34] Predation by crown-of-thorns starfish poses an extreme risk to coral reefs and currently accounts for 42 per cent of the estimated total loss in coral cover over this time period.[34]

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 of these ecosystems from further loss and impacts and restoration efforts should 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.

Coastal ecosystems outside of these zones should be retained where possible. As it stands today, the Mulgrave-Russell basin can no longer afford to lose any more coastal ecosystems. There is a strong need to restore ecological processes through improvements to land use management, ecological sustainable design and ecosystem restoration. The floodplain coastal ecosystems are currently at greatest risk.

The coastal ecosystems in the Mulgrave-Russell basin have changed significantly over the last century. These changes are mostly irreversible and future management needs to be adaptive and innovative. The changes to hydrology and the establishment of African and South American weeds have forever changed the coastal ecosystems in much of this basin. New management design is required to adapt to the changed hydrology. This needs to occur strategically at a whole of landscape scale. Modelling of whole of basin river flows needs to be done so that down-stream impacts of proposed remediation works (such as bank revetment) can be determined and adaptive management employed.

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. Coastal development was seen as providing economic benefits for local communities and beachside housing was seen as a right. Current legislation should prevent recurrence of many of these issues however management actions to recognise and rectify these problems are rare. Areas within this basin are contaminated by acid sulphate soils, riverbank erosion is still occurring due to upstream channelisation, and loss of riparian vegetation and weed species are reducing habitat for species with connections to the Reef. Funding for coastal repair is now needed to rectify these legacy issues and restore ecosystem health and resilience.

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 Mulgrave-Russell basin include:

- Limit further loss of remaining coastal ecosystems.
- Increased protection provided to remaining coastal ecosystems.
- 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.
- Prioritise investment in programs that support the growth in knowledge (and the wide adoption) of best management farm and land management practices that reduce nutrient, pesticide and sediment loss from agricultural lands in rainfall run-off.
- 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.
- Low levels of well managed grazing should be considered for riparian areas where introduced grasses dominate and where these grasses either pose a fire risk to well established riparian forests or where these grasses are choking waterways and removing oxygen from them.
- Hydrological regimes need to be holistically managed to assist conservation and restoration activities.
- Improve and incorporate urban storm water management strategies into established and new urban developments including strategies to capture and limit the impacts of "first flush" flows during rain events.

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. The floodplain in the Mulgrave-Russell basin has been heavily modified. Actions that can be taken to reduce pressure on the floodplain include:

- Limit further loss of remaining coastal ecosystems.
- Increased protection provided 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.
- Prioritise investment in programs that support the growth in knowledge (and the wide adoption) of best management farm and land management practices that reduce nutrient, pesticide and sediment loss from agricultural lands in rainfall run-off.
- Improve connectivity between remnant coastal ecosystems within the floodplain.

- 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.
- Consistent with Queensland planning provisions, future urban and industrial developments that cannot be sited outside of the floodplain should be constructed to current best practice, employing principles such as water sensitive urban design, gross pollutant traps and tertiary sewage treatment. Improve and incorporate urban storm water management strategies into established urban developments including strategies to capture and limit the impacts of "first flush" flows during rain events.
- Low levels of well managed grazing should be considered for riparian areas where introduced grasses dominate and where these grasses either pose a fire risk to well established riparian forests or where these grasses are choking waterways and removing oxygen from them.
- Hydrological regimes need to be holistically managed to assist conservation and restoration activities.

Riparian zones and waterways

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

- Restore connectivity and function of wetland remnants and modified wetland systems with particular consideration of sugar cane lands with marginal or negative production outputs.
- Develop weed management in functioning wetland and riparian ecosystems to ensure these areas continue to provide their ecosystems services
    - Strategic weed management programs that continue after restoration projects are completed should be included in project planning and funding considerations if riparian and wetland restorations are to achieve their goals of maintaining the restored ecological functions they provide.
- 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 and should consider adjacent land use.
- Seek to protect or reinstate in-stream habitat to provide improved flow regulation and fish habitat structure.
- Low levels of well managed grazing should be considered for riparian areas where introduced grasses dominate and where these grasses either pose a fire risk to well established riparian forests or where these grasses are choking waterways and removing oxygen from them.
- Limit construction of dams and weirs in this basin where they might impact on coastal ecosystems or the Marine Park, and consider the lowering or removal of causeways that act as barriers to improve connectivity.
- Further development adjacent to waterways should not increase point and non-point source pollutants entering waterways.

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:

- Limit further loss of wetlands.
- Improve connectivity of wetlands, and between wetlands and the World Heritage Area. Restore connectivity and function of wetland remnants and modified wetland systems with particular consideration to sugar cane lands with marginal or negative production outputs.
- Increased protection of remaining wetlands.
- Develop weed management in functioning wetland and riparian ecosystems to ensure these areas continue to provide their ecosystems services
    - Strategic weed management programs that continue after restoration projects are completed must be included in project planning and funding considerations if riparian and wetland restorations are to achieve their goals of maintaining the restored ecological functions they provide.
- Restore wetlands where possible.
- Control and management of introduced species that compromise wetland health.

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 are in direct connection with the health of the marine environment to which they drain, and have therefore been of increasing concern for the long-term health of the Marine Park.[59] Actions that could be taken include:

- Appropriate modification of fish barriers to improve fish populations through increased access and opportunity for species migration.
- Undertake a study of the hydrological flows for the Mulgrave and Russell rivers as they are today with a focus on prioritising management actions that are targeted at preventing bank erosion so as to minimise downstream impacts. Management actions need to be holistic and may include sand extraction from rivers, re-creation of deepwater pools and installation of engineered log jams to reduce flow velocity.

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 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.

4.5 Potential Management Actions

This report has been developed as a baseline for the Mulgrave-Russell 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 and resilience of the World Heritage Area requires greater protection of, and restoration of important ecological processes and functions provided by the Mulgrave-Russell basin coastal ecosystems. Actions that would increase protection and restore processes and function include:

1. Greater protection, restoration and management of remnant and riparian vegetation in the floodplain.
2. Greater protection, restoration and management of freshwater wetlands which have been reduced from 1854 hectares to 984 hectares.
3. Restore connectivity of streams, rivers and waterways to improve fish passage through restoration of fish habitat (deep water pools, log jams).
4. Improve connectivity between remnant coastal ecosystems, with preference to the freshwater wetlands and associated floodplain ecosystems.
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 such as Reef Plan best practice initiatives for agriculture.
6. Limit further development of irrigated cropping in the basin to reduce the risk of nutrients causing further crown-of-thorns starfish outbreaks.

4.6 Knowledge gaps

Water quality monitoring in the Mulgrave-Russell basin, including ground water quality monitoring has been relatively limited compared to other basins of the catchment.[60] Monitoring of in-stream water quality may assist with coordinated efforts to manage nutrient loss to the Reef and potentially curb future crown-of-thorns starfish outbreaks.

New species of freshwater fish are still being discovered in the high velocity rapids in this basin and many systems are yet to be surveyed. Given the highly restricted distribution of some of these fish further intense survey work is recommended to identify high value conservation sites for unique fish species.

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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.[61]
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)*.[62]
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 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	✓	✓				✓	✓

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
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	✓	✓			✓	✓	✓
Seabirds	✓	✓		✓	✓	✓	✓
Shorebirds	✓	✓		✓	✓	✓	✓
Whales	✓	✓		✓	✓	✓	✓
Dolphins	✓	✓			✓	✓	✓
Dugongs	✓	✓				✓	✓
Ecosystem Processes – Physical processes							

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
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	✓	✓				✓	✓

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
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 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	✓	✓				✓	✓

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
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	✓	✓				✓	✓

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
Social relationships						✓	✓
Health benefits						✓	✓

Appendix D – Threatened species of the Mulgrave-Russell basin

Birds

Casuarius casuarius johnsonii
Erythrotriorchis radiates
Fregetta grallaria grallaria
Geophaps scripta scripta
Rostratula benghalensis (sensu lato)
Sternula nereis nereis

Fish

Stiphodon semoni

Frogs

Litoria nyakalensis
Litoria rheocola
Nyctimystes dayi
Taudactylus acutirostris
Taudactylus rheophilus

Mammals

Bettongia tropica
Dasyurus hallucatus
Dasyurus maculatus gracilis
Megaptera novaeangliae
Phascolarctos cinereus (combined populations of QLD, NSW and the ACT)
Pteropus conspicillatus
Rhinolophus philippinensis (large form)
Saccolaimus saccolaimus nudicluniatus

Plants

Actephila foetida
Alloxylon flammeum
Aponogeton bullosus
Archontophoenix myolensis
Arenga australasica
Arthraxon hispidus
Canarium acutifolium var. acutifolium
Carronia pedicellata
Chingia australis
Dendrobium superbiens
Diplazium cordifolium
Diplazium pallidum
Drosera schizandra
Durabaculum mirbelianum
Durabaculum nindii
Eleocharis retroflexa
Eucryphia wilkiei

Fimbristylis adjunct
Hexaspora pubescens
Hodgkinsonia frutescens
Huperzia filiformis
Huperzia lockyeri
Huperzia marsupiiformis
Huperzia phlegmarioides
Huperzia prolifera
Lastreopsis walleri
Mesua sp. Boonjee (A.K.Irvine 1218)
Myrmecodia beccarii
Phaius australis
Phaius tancarvilleae
Plectranthus gratus
Plesioneuron tuberculatum
Polyscias bellendenkerensis
Ristantia gouldii
Sauropus macranthus
Streblus pendulinus
Syzygium hodgkinsoniae
Taeniophyllum muelleri
Tylophora rupicola
Zeuxine polygonoides

Reptiles

Caretta caretta
Chelonia mydas
Dermochelys coriacea
Eretmochelys imbricate
Lepidochelys olivacea
Natator depressus

Sharks

Pristis clavata

Appendix E – Migratory species of the Mulgrave-Russell basin

Aves (Birds)
Bar-tailed Godwit
Black-faced Monarch
Black-tailed Godwit
Broad-billed Sandpiper
Cattle Egret
Common Sandpiper
Curlew Sandpiper
Double-banded Plover
Eastern Curlew
Fork-tailed Swift
Great Egret, White Egret
Great Knot
Greater Sand Plover, Large Sand Plover
Grey Plover
Grey-tailed Tattler
Latham's Snipe, Japanese Snipe
Lesser Sand Plover, Mongolian Plover
Little Curlew, Little Whimbrel
Marsh Sandpiper, Little Greenshank
Oriental Plover, Oriental Dotterel
Pacific Golden Plover
Painted Snipe
Red Knot, Knot
Red-necked Stint
Ruddy Turnstone
Rufous Fantail
Sanderling
Sarus Crane
Satin Flycatcher
Sharp-tailed Sandpiper
Spectacled Monarch
Terek Sandpiper
Whimbrel
White-bellied Sea-Eagle
White-throated Needletail
Mammalia (Mammals)
Dugong
Humpback Whale
Reptilia (Reptiles)
Flatback Turtle
Green Turtle
Hawksbill Turtle

Leatherback Turtle, Leathery Turtle, Lute Turtle
Loggerhead Turtle
Olive Ridley Turtle, Pacific Ridley Turtle
Salt-water Crocodile, Estuarine Crocodile

Appendix F – 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 functions for the Great Barrier Reef[63]

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 functions for the Great Barrier Reef[63]

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 G – Mulgrave-Russell basin water quality report

Mulgrave - Russell River Basin (provided by TropWATER)

1. Introduction

The Mulgrave- Russell River basin (Fig. 1) covers approximately 1,914 km^2 within the Wet Tropics of North Queensland and is fed by two main river catchments; the Russell River and the Mulgrave River. The Russell River catchment is situated in the south and covers 602 km^2 with a population of 1,700 people that principally inhabit the towns of Babinda and Miriwinni.[1] The two key tributaries of the basin are the Russell River and Babinda Creek. The Mulgrave River catchment is situated in the north and covers an area of 1312 km^2. This region includes parts of Cairns (Gordonvale and Edmonton) and smaller towns such as Fishery Falls, Little Mulgrave and Yarrabah, containing a population of 75,000 people.[1] The key tributaries of the Mulgrave catchment are the Mulgrave River, Little Mulgrave River, Behana Creek and Trinity Inlet.

The main land use of both the Russell and Mulgrave rivers is conservation and natural/'relatively natural' lands, which collectively comprise 79% and 77% of the area, respectively. The remainder of the Russell River catchment is comprised of sugar agriculture (18.5%) in the middle-lower sections, dairy farming (0.6%) in the upper catchment, irrigated fruit trees (1.6%) and rural residential lands (0.2%) are found scattered throughout.[1] The remainder of the Mulgrave River catchment is comprised of sugar agriculture (13%), urban lands (5.3%) and 'water' (4.0%) in the middle-lower sections of the catchment, while small areas containing dairy farms and plantation forestry are found in the upper catchment.[1]

There are no point sources of pollutant discharge or ports and harbours within the Russell-Mulgrave River catchment.

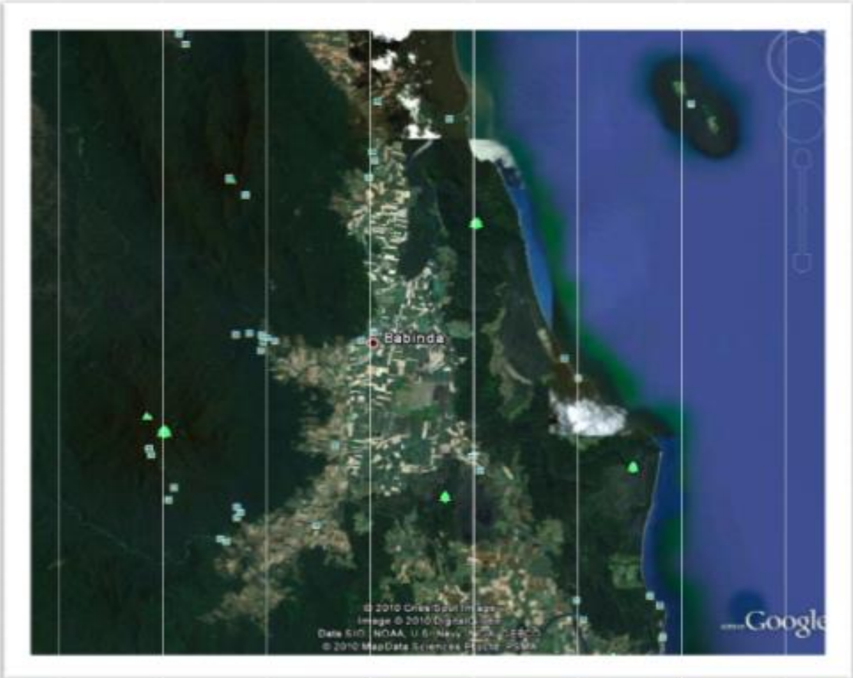

Figure 1: Sugarcane in the Russell-Mulgrave catchment. Source: Google Earth, downloaded October 2010

2. Hydrology and drainage

The Mulgrave-Russell basin is one of the wettest areas in Australia with high run-off to rainfall ratios and frequent run-off events.[2] The average annual rainfall on the coastal plain in the Mulgrave- Russell exceeds 3000 mm/year, with 60% of the annual rainfall occuring in the summer wet season (December-March).[2] Due to the steep topography of the region and the close proximity of mountain peaks (Mount Bellenden Ker and Mount Bartle-Frere) to the coastline (<25km), transit times between coastal rainfall and oceanic discharge are very rapid, suggesting minimal residence times.[2] No flow data is currently available to analyse specific hydrological behaviour of drainage lines within the Babinda drainage scheme, however daily river height data for the Russell River and Babinda Creek show that large flow events occur multiple times per year and persist for short periods of time.[2] Due to the small catchment areas and steep stream topography, the system is very responsive to high intensity rainfall events, resulting in very rapid changes to river height that are associated with rapid transmission of floods through drainage systems.[2] An average of 60% of the annual rainfall within the Russell-Mulgrave catchment is converted to surface run-off that leaves the basin.[3] These major discharges from the combined Russell and Mulgrave rivers contribute to the frequent flood plumes within the Great Barrier Reef lagoon.[2]

The Russell-Mulgrave catchment is one of the larger catchments in the Wet Tropics in terms of area, rainfall and discharge to the Great Barrier Reef lagoon.[3] Much of the sugarcane in both the Russell and Mulgrave flood plain is grown on former wetland areas. Since cane is not likely to survive in low lying areas where there is a lot of rain (sugarcane cannot sustain more than approx. three days of water logging before the cane dies), extensive drainage of wetlands has been established. The Russell River and Babinda Creek are major drainage lines bounding the Babinda Drainage scheme area, and are approx. 65 km and 22 km long, with catchment areas of approx. 560 km^2 and 92 km^2, respectively. Both systems drain the eastern escarpment of the Great Dividing Range, an area adjacent to Wyvuri swamp, where an extensive, deep drainage network exists to allow cane to be grown (Fig. 2). While this is an extreme case in the Russell-Mulgrave, all cane lands need extensive drainage, hence the natural floodplain dynamics have been extensively modified along the coast.

Under natural conditions the Babinda Swamp would rarely have fallen below 0.3m of the soil surface and free water at the surface would be common.[2] Since this region has been drained and cleared for sugarcane cultivation and improved pastures (to a smaller extent), certain sections have been subject to substantial surface shrinkage (sometimes over 1m) as a result of peat shrinkage following removal of water.[2] High water tables remain in the profile for much of the year, with water rarely decreasing below 1m depth from the surface even though considerable areas have been artificially drained.[4]

3. Basin water quality

a) Water quality

1) Status of monitoring in basin and rivers

Water quality monitoring in the Russell-Mulgrave River catchment has been relatively limited compared to other catchments of the Great Barrier Reef.[1] During 1997-1998, “Waterwatch”, an event-based volunteer program was run by the Queensland Department of Natural Resources and the Great Barrier Reef Marine Park Authority (GBRMPA).[5]

The Reef Rescue Marine Monitoring Program monitors the mouth of the river before and after flooding events on an annual basis.

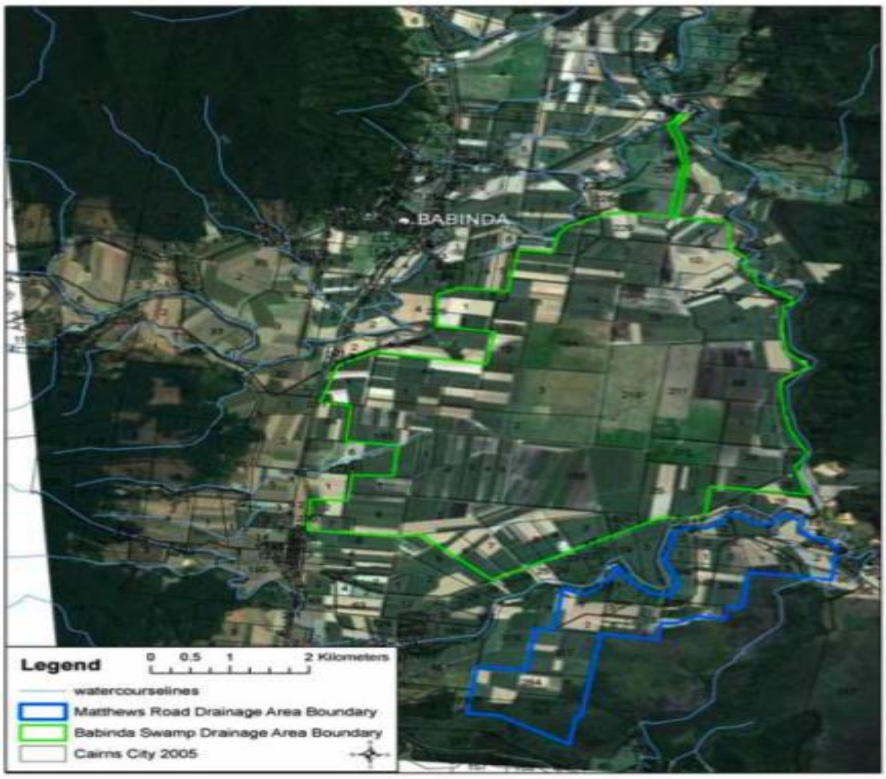

Figure 2: Boundaries of the Babinda Community Drainage and the Matthews Road Drainage Schemes. Source:[2]

2) Status of water quality in basin and rivers

The results of "Waterwatch" showed 'high' levels of phosphorus and particulate nitrogen during flood conditions, with highest concentrations measured in streams draining fertilised agricultural lands. Concentrations of dissolved inorganic nitrogen (DIN) and phosphorus (DIP) were highest during the first significant flow of the stream, while particulate nitrogen (PN) varied directly with river flow and typically peaked during major seasonal flood events. Streams draining from intensive agriculture lands remained elevated in DIN throughout the wet season and during flow events. When compared with other river basins within the Wet Tropics, the Russell-Mulgrave generates the highest DIN load on an annual basis.[6]

Groundwater from the Wet Tropics region, including sites from the Russell-Mulgrave catchment were found to contain relatively 'low' nitrate concentrations (< 20 mgL^{-1} as NO_3 or < 4.5 mgL^{-1} as NO_3-N) compared to other regions in north eastern Australia[7]. Although these concentrations are considered low compared to drinking water guidelines they are likely above ecological guidelines.[1]

Ten estuarine sites in the Mulgrave-Russell basin were ranked (details of the ranking scheme can be found in Cox et al. 2005[8]) and found to contain elevated levels of nutrients compared with other waterways in north Queensland. Three of the ten sites were ranked poor for oxidised nitrogen, and one site was ranked poor and three sites in moderate condition for ammonia concentrations.[8] Furthermore, four sites were in poor condition for filterable reactive phosphorus and two of the ten sites were ranked poor for dissolved oxygen levels. All ten sites were ranked poor for chlorophyll a concentrations.[8]

Various insecticides that are widely applied in the sugar industry have been detected within the Russell-Mulgrave catchment. Chlorpyrifos and fipronil were detected by passive samplers[9] and imidacloprid was detected from plume sampling in the 2009/2010 wet season.[10] This detection of chlorpyrifos is a concern since the ANZECC and ARMCANZ (2000) guideline for this insecticide in freshwaters (0.01 µg/L and 0.00004 µg/L^{-1} for the 95% and 99% protection values, respectively) are within this detection range.[1] There are currently no guidelines for the evaluation of the toxic effects of fipronil or imidachloprid.

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

Indicators of in stream health such as water quality, hydrology, geomorphology, riparian vegetation, aquatic macrophytes, macro-invertebrates and freshwater fish were investigated and compared between the Russell catchment (Woopen Creek and Babinda Creek) and the Mulgrave catchment (Little Mulgrave River and Behana Creek).[11] The study indicated the importance of intact riparian zones with an adequate buffer for in stream health in areas adjacent to agricultural lands. Woopen and Babinda creeks had relatively poor bank structure resulting from low riparian vegetation and were considered in poorer condition than the waterways studied in the Mulgrave River Catchment. Riparian vegetation was particularly poor in Babinda Creek, which was infested with invasive weeds (i.e. Singapore daisy, Para grass) that caused channelised flows, increased flow velocity and stream incision. Macro-invertebrate taxa (~20%) and fish species were lower in Babinda Creek compared to Behana Creek.

4. Coastal water quality

a) Water quality

1) Status of monitoring in coastal areas

The Reef Rescue Marine Monitoring Program monitors the near shore and offshore sites from the river before and after flooding events on an annual basis.

2) Water quality data

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.[12] The values predicted for the Wet Tropics are provided in Table 1. All variables 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, Fitzroy, Burnett Mary), the Wet Tropics contained: the second highest values of SS, PN and PP and the lowest offshore chlorophyll values. Total dissolved nitrogen (TDN) and total dissolved phosphorus (TDP) were highest in the Wet Tropics, with cross-shelf changes also most pronounced for TDN. Particulate phosphorus (PP) and total nitrogen (TN) values were highest and cross-shelf changes most pronounced in the Wet Tropics and Burdekin regions, while total phosphorus (TP) values were highest in the Burdekin followed by the Wet Tropics.

Table 1: Mean annual values of water quality variables predicted in 3 cross-shelf regions of the Wet Tropics

Variable	Coastal	Inner Shelf	Outer Shelf	Across all zones
Secchi depth (m)	4.7 ± 0.5	11.0 ± 0.5	17.0 ± 1.0	14.5 ± 0.9
Chl a (µg L^{-1})	0.9 ± 0.04	0.5 ± 0.03	0.3 ± 0.03	0.4 ± 0.03
SS (mg L^{-1})	5.0 ± 0.3	1.6 ± 0.1	0.7 ± 0.1	1.3 ± 0.1
PN (µmol L^{-1})	2.3 ± 0.1	1.5 ± 0.1	1.0 ± 0.1	1.2 ± 0.1
PP (µmol L^{-1})	0.16 ± 0.01	0.08 ± 0.00	0.06 ± 0.01	0.08 ± 0.01
TDN (µmol L^{-1})	7.6 ± 0.2	6.5 ± 0.2	5.4 ± 0.3	5.8 ± 0.3
TDP (µmol L^{-1})	0.35 ± 0.02	0.27 ± 0.02	0.20 ± 0.02	0.23 ± 0.02
TN (µmol L^{-1})	10.0 ± 0.3	8.2 ± 0.3	6.8 ± 0.4	7.4 ± 0.4
TP (µmol L^{-1})	0.52 ± 0.03	0.37 ± 0.03	0.26 ± 0.04	0.31 ± 0.03

Flood events generally take place annually during the wet season (November – April) and are enhanced during cyclonic events. Flood plumes from the Wet Tropics region (Fig. 3), especially the Russell-Mulgrave River catchment, travel northwards around Cape Grafton and cover the outer shelf area north east of Green Island.[13,14] Within the Wet Tropics region, 218 coral reefs and 71 seagrass beds are located within the high to very high plume water exposure categories, covering a total area of 1839 km^2.[15] An assessment of in shore ecosystems exposed to different categories of surface pollutants within the Wet Tropics region (Table 2) showed a total of 1,925.79 km^2 of coral reefs and 186.85 km^2 of seagrass beds are exposed to PSII, TSS and DIN.[15]

Flood plumes from the Russell-Mulgrave rivers were monitored following catchment rainfall events associated with Tropical Cyclones Sadie (1994), Violet (1995), Justin (1997), Sid (1998), Rona (1998), of which detailed results can be found in Devlin (1997), Devlin et al. (2001) and Devlin and Brodie (2005).[13,16,17] During most cyclone related rainfall events the majority of particulate materials (sediments and particulate nutrients) were trapped within 10km of the coastline, while dissolved materials such as nitrate were dispersed in the plume waters up to 100's of km from the river mouths.

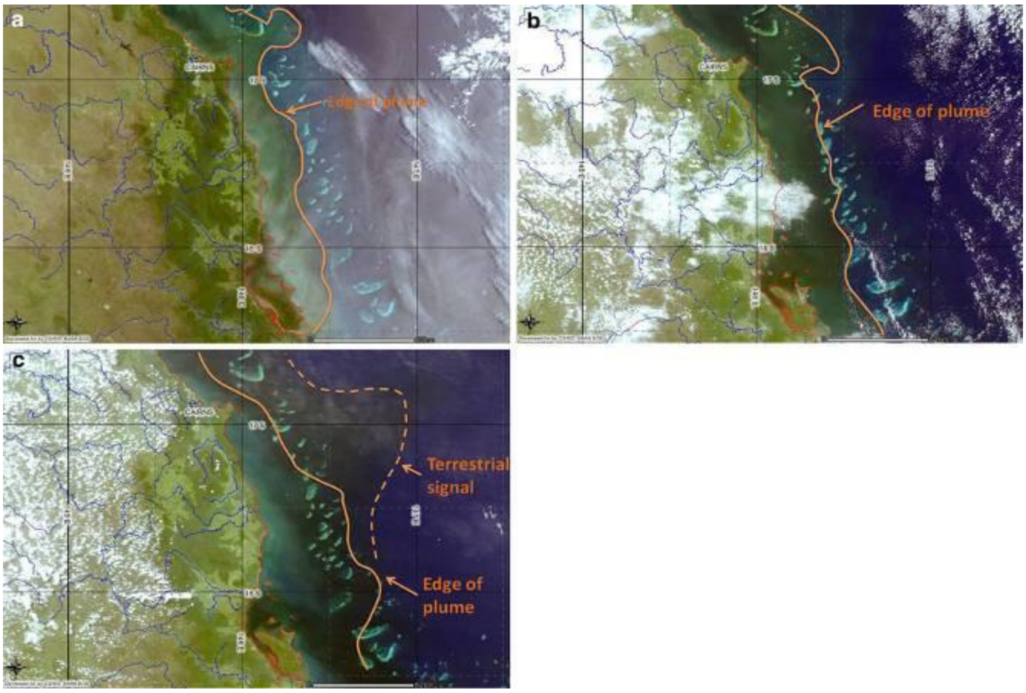

Figure 3: Satellite image of visible flood plume waters from the Wet Tropics rivers on the (a) 9th, (b) 11th and (c) 13th February, 2007. The plume moved from inner shelf waters on the 9th to the Coral Sea by the 13th February, 2007[2]

An assessment of in shore ecosystems exposed to different categories of surface pollutants within the Wet Tropics region (Table 2) showed a total of 1,925.79 km^2 of coral reefs and 186.85 km^2 of seagrass beds are exposed to PSII, TSS and DIN.[15]

Table 2: Number and area of exposed coral reefs and seagrass beds to surface pollutants in the Wet Tropics region. Photosynthesis inhibiting pesticides and herbicides (PSII), total suspended solids (TSS) and dissolved inorganic nitrogen (DIN)

Exposure			**Coral reefs**		**Seagrass beds**	
PSII	**TSS**	**DIN**	**Num.**	**Km^2**	**Num.**	**Km^2**
0.00	0.00	0.00	0	0.00	0	0.00
0.23	0.10	0.24	0	0.00	0	0.00
0.46	0.20	0.49	0	0.00	0	0.00
0.68	0.30	0.73	42	272.95	0	0.00
0.91	0.40	0.98	83	865.49	0	0.00
1.14	0.50	1.22	187	787.35	90	186.85
				1,925.79		**186.85**

Source:[15]

A series of maps were created to examine the exposure areas of herbicides for the GBR based on a combination of data from flood plume water quality monitoring and satellite imagery.[18] The offshore area adjacent to the Mulgrave-Russell Basin was ranked as 'medium-high' for herbicide exposure. The current modelled best estimates of total PSII herbicide loads delivered to the coast is 2,060 kg/yr (Table 3), however more direct monitoring data is necessary from the region in order to calculate future loads. With the implementation of the Reef Rescue program (2009/2010) PSII herbicide values decreased to 1,903 kg/yr, which is a 7.6% improvement.

A series of maps were created to examine the exposure areas of suspended sediments for the Great Barrier Reef based on a combination of data from flood plume water quality monitoring and satellite imagery.[18] Sugarcane agriculture is responsible for the greatest anthropogenic loads of sediment to the Great Barrier Reef in the Mulgrave-Russell basin.[6] The offshore area adjacent to the Mulgrave-Russell basin was ranked as 'medium" for sediment exposure. Recently modelled estimates of suspended sediment export from the Mulgrave-Russell basin (Table 3) showed that the total export in 2008/2009 (166,000 t/yr) had increased 4-fold compared to pre-development loads (67,000 t/yr). However, after the implementation of the Reef Rescue program (2009/2010) values decreased to 164,000 t/yr, which is a 2.1% improvement. The Russell-Mulgrave is ranked fourth highest in the Wet Tropics region for current and anthropogenic suspended sediment loads to the Great Barrier Reef, and second highest for loads of suspended sediment per basin area delivered to the Great Barrier Reef (Brodie et al. 2009). Although the modelled outputs are considered accurate, coordinated monitoring programs are necessary to help refine these estimates. After the implementation of the Reef Rescue program in 2008, an improvement in load values was observed for TSS, DIN, PN, TN, PSII herbicides, PP and TP.

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)	67	166	164	99	164	2.1	2.1
DIN (t/yr)	233	539	519	306	519	6.5	6.5
DON (kt/yr)	327	549	549	223	0	0	0.0
PN (t/yr)	642	709	705	67	705	5.9	5.9
TN (t/yr)	1,201	1,797	1,773	596	1,773	4.0	4.0
PSII (kg/yr)	0	2,060	1,903	2,060	1,903	7.6	7.6
DIP (t/yr)	11	35	35	24	0	0	0
DOP (t/yr)	18	23	23	4	0	0	0
PP (t/yr)	64	110	108	46	108	4.4	4.4
TP (t/yr)	93	168	166	74	166	2.7	2.7

Source:[19]

b) Ecological effects of water quality and hydrological changes in coastal areas
In shore reefs found within the Wet Tropics region of the Great Barrier Reef have been identified as containing coral reefs with relatively low diversity, which has been linked to poor water quality.[20,21,22] In addition, a serious problem that is of particular concern in the inshore area surrounding the Mulgrave-Russell basin are crown-of-thorns starfish (or COTS) (*Acanthaster planci*). Based on the analyses of 2,258 coral reef surveys of 214 reefs in the Great Barrier Reef, a loss of 50.7% coral cover has been measured in the 27 years up until 2012.[23] Predation by COTS poses an extreme risk to coral reefs and currently accounts for 42% of the estimated loss in coral cover.[23]

Nitrate and orthophosphate promote the formation of phytoplankton blooms and increased biomass of larger phytoplankton species (> 2 µm), which are the primary food source of COTS larvae.[24] Enhanced nutrient supplies are transported in plumes northward from the Wet Tropics, in particular from the Mulgrave-Russell basin. The Wet Tropics flood plumes (including plumes sourced from the Russell-Mulgrave River) travel around Cape Grafton and cover the outer shelf area from Green Island northwards.[13,14] Chlorophyll *a* concentrations within these plumes have been measured above 2 µg l^{-1}, which is over double the range measured within other areas of the Great Barrier Reef (0.2 – 0.8 µg l^{-1}.[25] These high chlorophyll *a* values are of particular concern since an experiment conducted by Fabricius et al. (2010) showed that the odds of *A. planci* larvae finishing development increases approximately 8-fold with every doubling of chlorophyll concentrations up to 3 µg l^{-1}. [26] Green Island and the surrounding area exposed to Wet Tropics flood plumes is believed to be an initiation area for COTS outbreaks, after which the larvae are transported southward by currents.[24,26]

5. Other potential pollutants

The loss of sugar juice during mechanical cane harvesting increases the biochemical oxygen demand (BOD), especially during the first irrigation following harvest.[27] Consequently, dissolved oxygen (DO) levels in streams and wetlands are reduced, resulting in fish kills when DO levels fall below critical points.[27]

Acid sulfate soils are predominantly associated with areas of Quaternary alluvium with high levels of organic matter and sulphidic material present.[28] Acid and toxic concentrations of metals can be released into the environment when acid sulfate soils become oxidised with air exposure.[28] The Queensland Department of Environment and Resource Management and Queensland Acid Sulfate Soil Investigation Team (QASSIT) mapped the lower section of the Mulgrave River as being potential acid sulfate soil.[28] These soils are in areas dominated by mangrove and melaleuca wetlands, and are tidally influenced in most cases. Acid sulfate problems exist for some farmers around Mutchero Inlet (north of Babinda) where vegetation clearing and ground tilling (for sugarcane) has resulted in the generation of acid sulfate conditions and a resultant loss in agricultural productivity.

6. Management

a) In basin for basin

It was estimated that over half of the freshwater wetlands in the Mulgrave-Russell basin have been cleared since European settlement.[3] Soil erosion rates measured at a site near Babinda were amongst the highest (135 t/ha of soil lost per year) within the Wet Tropics[29], however, the implementation of management practices such as reduced/no tillage and green cane trash blanketing successfully reduced soil erosion in sugar catchments to <15 t/ha.[27,29]

Additional catchment-based targets to improve in-stream health in the Mulgrave-Russell basin include the restoration of riparian vegetation as well as the improved management of wetlands (control of aquatic weeds). These actions would improve in-stream health and may also contribute in the reduction of nitrite concentrations in-stream base flow sourced from groundwater.[1] Moreover, acid sulphate soils in this region also require remediation and management.

b) In basin for Great Barrier Reef

The Reef Rescue Program has resulted in many growers adopting improved management practices and undertaking training courses for nutrient management ('six easy steps' method) and integrated weed management.[30] It was estimated that 21% of the cane industry across the Wet Tropics Region had improved their management practices as a result of the Reef Rescue incentive program. Grants were awarded in the Mulgrave River catchment to apply split-stool/sub-surface/variable rate fertiliser application, improve soil management through zonal tillage and controlled traffic, legume planter, and improve herbicide management (shielded sprayer). The aim of these improved practices is the reduction of sediment run-off, nutrients and pesticides.[30]

Reef Plan (2009) set specific 'water quality' targets for the reduction of pollutant loads to the Great Barrier 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 set for the Great Barrier Reef catchment area by the Great Barrier Reef Marine Park Authority. Improved sugarcane management practices have been designed to benefit the Great Barrier Reef and water quality targets have been set for the export of pollutants from the Russell-Mulgrave River catchment. To achieve the water quality targets for the region, a reduction of 80% in dissolved inorganic nitrogen (nitrate) loads, a 62% reduction in photosystem-II herbicide loads and a 20% reduction in sediment loads (and associated particulate nitrogen and phosphorus loads) delivered from the Mulgrave-River catchment are required.

A reduction in nutrient levels, especially within the Wet Tropics region, is necessary to mitigate COTS outbreaks.[26] However, two additional precautionary management measures have been suggested to maintain low COTS densities in high-risk areas such as Green Island: 1) large permanent fish closures to allow fish populations to reach carrying capacity to safeguard against cascading changes in food webs and 2) targeted efforts by divers to remove some of the COTS before aggregation and spawning commences.[26]

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