# Status of marine and coastal natural assets in the Fitzroy Basin

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# Executive Summary

The Fitzroy Basin Natural Resource Management (NRM) region is adjacent to the Great Barrier Reef World Heritage Area and includes urban centres, industrial and agricultural activity, major ports, tourism, fisheries and aquaculture. Increases in intensive agriculture, coastal development, port activity and declining water quality have been identified as issues across the region.

The Fitzroy Basin region is recognised for its diverse and unique marine and coastal environments, which includes coral reefs, seagrass meadows, coastal wetlands, estuaries, continental and offshore islands and the species they support. Some of these species are listed as threatened or vulnerable under either the Australian *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* and/or Queensland *Nature Conservation Act 1992*, and have significant cultural values. Marine and coastal ecosystems also support important tourism and fisheries industries that depend on the healthy natural resources of the region.

The Fitzroy region marine condition remained poor in 2011–12 and 2012–13. Inshore water quality has declined due to the influence of the Fitzroy River floods but was still assessed as 'good', while inshore seagrass meadows were assessed as being in 'poor' condition, and coral reefs were assessed as being in 'very poor' condition (Thompson et al. 2013; McKenzie et al. 2014). The influence of flooding on the water quality within the region has contributed to the decline in coral reef condition to the 'very poor' rating in 2012–13. In the 2012–13 reporting period seagrass condition in the region remained 'poor', driven largely by a decline in seagrass reproduction to 'very poor'. Reef intertidal seagrass meadows have experienced the greatest declines (McKenzie et al. 2014), as have inshore reefs (Thompson et al. 2013).

In the summer of 2012–13, ex-tropical cyclone Oswald delivered above-average rainfall to the Great Barrier Reef (GBR) catchment. This system tracked southwards along the coast and flooded many rivers from Cairns to Bundaberg, including the Fitzroy River in Rockhampton. The Calliope, Boyne and Burnett rivers also had above-median discharge in 2012/13 (State of Queensland 2013). The flooding effects of ex-tropical cyclone Oswald severely impacted producers in the Fitzroy region, and damaged coral reefs and seagrass meadows. In addition, ex-tropical cyclone Tasha in 2013 and tropical cyclone Marcia in 2015 affected the region's marine and coastal environments. These have likely contributed to the 'poor' marine ecosystem condition in the Fitzroy region.

Assessment of the current status of key marine and coastal assets in the Fitzroy Basin region has identified a number of assets that are in poor or very poor condition. These include inshore coral reefs, inshore and reef seagrass meadows, dugong, turtles, dolphins, low-lying islands, and species of climate-sensitive seabirds.

Key drivers of change include poor water quality; climate extremes; coastal development, which includes ports and shipping; and the cumulative impacts of these pressures. The increasing frequency of intense flood events in this region has significantly impacted on inshore reefs in the Keppel Island group and projections that this will continue does not bode well for these inshore ecosystems. The region is impacted by industrial development and associated water quality discharges, and the future status and values of marine and coastal assets will depend on management of these and other pressures including catchment activities.

# 1. Introduction

The Fitzroy Basin NRM region in central Queensland covers 156,000 km$^2$ (catchment and marine areas) and extends from the Carnarvon Ranges in the west to the coast, and consists of six basins: the Fitzroy, Styx, Shoalwater, Water Park, Calliope and Boyne (Figure 1). The region has significant agricultural and resource industries, with Queensland's largest multi-commodity port supporting these industries: the Port of Gladstone and the smaller Port Alma Shipping Terminal in the Fitzroy delta. The Fitzroy Basin itself comprises of six major rivers that are part of a network of 20,000 km of waterways, and is the largest river basin discharging into the iconic Great Barrier Reef (GBR) lagoon, and the largest river system draining to the Australian east coast. The region includes 125 islands on the Capricorn Coast, the largest being Curtis Island off Gladstone and within port limits, as well as the Keppel Island and Capricorn-Bunker groups that support nesting and migratory species, fisheries and marine tourism. The region also includes the military's Shoalwater Bay Training Area, which covers 4,545 km$^2$ including the Warginburra Peninsula, the Torilla Peninsula, Townshend and Leicester islands, and a substantial area of the Shoalwater Bay hinterland north of Byfield. The area has been used exclusively for defence training activities since 1965.

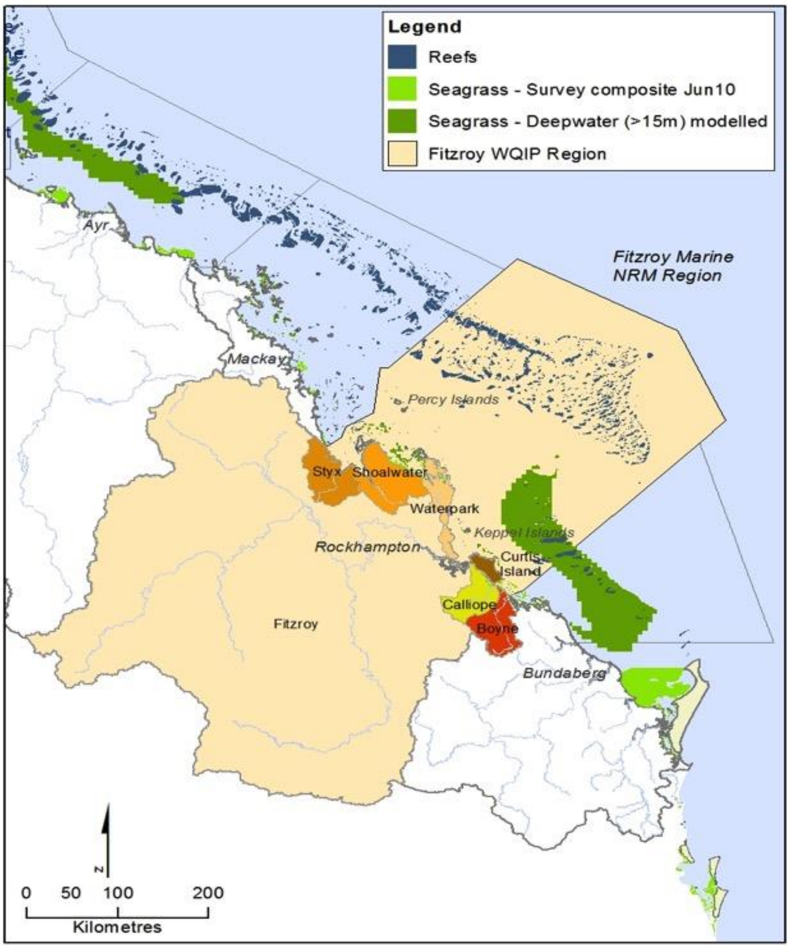


*Figure 1. Map of Fitzroy Basin marine region and catchments.*

The Fitzroy region supports a population of about 230,000 people who live and work in a number of urban and rural centres. The major towns are Rockhampton, Gladstone, Calliope, Emerald, Blackwater, Yeppoon and Biloela. Agriculture is the major land use, with up to 90% of the landscape used to produce food (predominately beef from grazing) and for cropping (mainly grain, and also irrigated cotton inland). Local grazing and cropping enterprises are worth AUD1.2 billion annually, 66% being from grazing, and contribute 23% to Queensland's grazing income (ABS 2014). The region includes the majority of Queensland's coal mines — a multi-billion dollar industry – and in 2013, there were 36 operating coal mines in the Fitzroy Basin that produced approximately 152 million tonnes of saleable coal, or 80% of Queensland's coal production (DSDIP 2013). While coal mining leases cover only 4.5% of Basin land area, coal exploration leases are in place more extensively across the region, and coal mining is the largest asset in terms of production value (FBA 2008). Freshwater and marine ecosystems have been assessed as being at *high risk* from suspended sediment, nutrients and herbicides originating primarily from grazing and cropping (State of Queensland 2013; Brodie et al. 2013a).

Water Quality Improvement Plans (WQIP) aim to reduce pollution being released into aquatic ecosystems with high ecological, social and/or recreational values. The Fitzroy WQIP covers six basins directly flowing to the GBR and is being developed in partnership with industry, government, science and community to build on existing catchment-scale WQIPs. The WQIP will integrate with the Central Queensland Strategy for Sustainability 2030 and incorporate aspirations from community-based catchment plans. A key element of developing the WQIP is the integrated assessment of the benefits and costs of achieving water quality targets required to protect the values of the GBR.  This will draw on the findings of this report, which identifies the main marine and coastal assets in the Fitzroy Basin region, and assesses their status and trends.

Marine and coastal assets in the Fitzroy region include diverse habitats—coral reefs, seagrass meadows, estuaries, coastal wetlands and islands—and the species they support. The Fitzroy's overall inshore marine condition was assessed as poor. Inshore seagrass meadows were assessed as poor with coral reefs declining from poor to very poor condition in 2012–13 (Thompson et al. 2013; McKenzie et al. 2014). Many marine and coastal species in the region are of conservation concern, such as dugong, humpback whale, dwarf minke whale, six species of marine turtle, and many seabird species, and coastal bird species such as Capricorn yellow chat and beach stone-curlew. Other species that are considered rare in the GBR, such as the Indo-Pacific humpback dolphin, are found in the region and use critical marine habitats. The Fitzroy region includes beach scrub habitats (vine forests on coastal sands) along the Capricorn Coast, which are a component of the critically endangered ecological community *Littoral rainforest and coastal vine thickets of Eastern Australia* under the EPBC Act 1999 (see Table 1). These marine and coastal assets have ecological, social and cultural importance, and also support important industries such as tourism and fisheries that depend on healthy ecosystems.

# 2. Coastal natural assets: status and trends

The Fitzroy Basin region contains a significant length of coastline that includes estuaries, coastal wetlands (tidal and ephemeral freshwater) and numerous coastal islands and cays. Notable among these are the continental islands of Curtis, Facing and Townshend, the inshore Keppel Island group, and the offshore Capricorn-Bunker group of islands. Below is a summary of the coastal assets of the region, the biodiversity of flora and fauna they support, and the status and trends in their condition.

## 2.1. Estuaries

Coastal bays and estuaries form a transition zone between river and ocean environments and are subject to both marine influences, such as tides, waves, and the influx of salt water; and riverine influences, such as flows of fresh water and sediment. These two influences provide high levels of nutrients in both the water column and sediment, making estuaries among the most dynamic and productive natural habitats in the world. Estuaries vary in their dominant habitat type, and can be comprised of primarily mangroves, shallow seagrass meadows or intertidal flats, or a combination of all three.

Estuaries in the Fitzroy Basin region are located at the major river mouths—Fitzroy, Boyne and Calliope rivers—as well as along the smaller river deltas (for example Ross Creek and Kinka Creek). These estuaries make up 7.7% of total estuary extent in the entire GBR catchment (GBRMPA 2013). Their major constituent habitats are coastal mangroves and coastal marine plains—important coastal habitats in the region that support critically endangered birds—and they are considered in more detail below.

The Fitzroy Basin contains numerous freshwater wetlands, floodplains and lagoon systems that are fertile nursery areas for fish species such as barramundi. Wetlands have suffered degradation with only a few of these systems remaining in good condition (Packett et al. 2009). The construction of the Fitzroy barrage, completed in 1970, has shortened the length of the Fitzroy estuary by half its natural tidal range, resulting in loss of habitat and changes to the natural hydrodynamic characteristics (Connell et al. 1981). Barrages modify the natural tidal freshwater exchange, limiting access for species requiring freshwater and saltwater connections under typical weather conditions. Recent recurring flood events in this basin have seen improved fish connection resulting in a greater number of species migrating further inland.

There are a number of important estuaries in the region. These include the Fitzroy River delta, which is the only estuary of the largest seaward draining catchment on Australia's east coast. It also includes the Shoalwater and Corio Bay Area, which is a Ramsar internationally important wetland and contains a protected military training area, and the estuaries of Gladstone Harbour, a highly modified tidal wetland that includes the Port of Gladstone and significant industrial activities (see Appendix A). These estuaries provide important breeding and nursery habitat for many species of fish and invertebrates (some commercially fished), and marine megafauna, including dugong and green turtles. The health of the Fitzroy River delta was scored as 'B – good' in 2013–14 and 'C – fair' in 2012–13, based mostly on water quality indicators (Fitzroy Partnership for River Health Annual Report Card [1]). Gladstone Harbour was scored 'C – Satisfactory' for water quality (Gladstone Healthy Harbour Partnership's 2014 Pilot Report Card[2]).

The Port Curtis region, which incorporates the Port of Gladstone, is a macro-tidal estuarine system. The Port of Rockhampton is situated on the southern edge of the delta of the Fitzroy River, at Port Alma. Some factors influencing port water quality include localised industrial emissions and port-related activities such as the impacts of shipping, land reclamation, port development and maintenance. The factors influencing water quality in the Ports of Gladstone and Rockhampton are described by the Ports Synthesis study conducted for the Fitzroy WQIP (Flint et al. 2015). Because the two ports in the Fitzroy region are located in estuarine systems and close to regional cities they are also vulnerable to declining water quality resulting from agricultural and industrial land-use in the catchments and downstream effects of urban stormwater.

Intertidal seagrass meadows in the Fitzroy region are located on the large sand/mud banks in sheltered areas of the region's estuaries and coasts, particularly in Shoalwater Bay and Port Curtis. Although fewer seagrass species occur in these estuarine environments compared to reef environments, they are still important coastal habitats that provide critical nursery and feeding grounds for many marine species. SeagrassWatch monitoring of estuarine seagrass meadows in 2011–12 assessed their condition to be 'moderate' with notable increases in their abundance, and since 2007–08 estuarine seagrass meadows have fluctuated between 'poor' and 'moderate' condition. Estuarine seagrass meadows in the region have experienced repeated flood events in recent years that have influenced their condition. However their condition was poorest in 2006–07, when they were assessed as being 'very poor', attributed to high temperature stress during that summer period (McKenzie et al. 2014).

## 2.2. Coastal wetlands

Coastal wetlands provide valuable ecosystem services such as habitat and breeding sites for migratory waterbirds and threatened species, nursery habitat for fish including commercially and recreationally important species, and social values including recreation (DSEWPAC 2012). Queensland's wetlands play a crucial role in filtering terrestrial run-off, thereby protecting the GBR from land-based pollution (GBRMPA 2009). It is now widely recognised that coastal wetlands are important ecosystems under considerable development pressure (Anorov et al. 2008).

Wetlands often provide protection from climatic events by acting as wildlife refuges during drought, mitigating flood impacts and acting as a buffer to wave action and tidal surges. Vegetated wetlands may also improve climate change resilience for coastal areas through providing services that moderate direct effects of climate change (e.g. storm buffering). These and other wetland functions, including erosion control, recreational value, carbon sequestration, and support for commercial

[1] http://riverhealth.org.au/ Accessed June 2015
[2] http://rc.ghhp.org.au/report-cards#resultPanelEnvironmental Accessed June 2015

fisheries can be economically valued. Globally, wetland services were valued nearly 20 years ago at USD14 trillion per year (Constanza et al. 1997).

Despite the long-acknowledged importance of coastal wetlands, loss and degradation in Australia has been estimated at more than 50% over the past 200 years (Finlayson 2000), while in Queensland wetland losses may be even higher, at between 70 and 90% (GBRMPA 2009). Some wetland-associated vegetation types are now considered threatened and coastal development (particularly clearing or modifying wetlands, mangroves and other vegetation) has been identified as one of the most significant threats to the GBR ecosystem (GBRMPA 2009). Further threats to wetlands are the continuing influence of past management practices (for example barrier construction, clearing) as well as damage caused by pest animals, grazing, illegal dumping, weeds, pollution, and changes to upstream flows and water quality (Flint et al. 2014). Global climate change and sea level rise forecasts suggest further wetland loss is likely in future (Traill et al. 2010). Their proximity to oceans and reliance on rainfall put coastal wetlands at particular risk from climate change (Williams et al. 2012).

The Fitzroy Basin and coastal catchments region has approximately 1,430 km$^2$ of estuarine coastal wetlands (Queensland Wetland*Info*[3]), characterised by wetlands with marine water that is diluted with freshwater of terrestrial origin. Mangroves are often the dominant flora in tidal coastal wetlands and act as refugia and feeding grounds for a variety of marine species. At least 13 mangrove species have been recorded in the Fitzroy estuary and 23 species in Shoalwater Bay (Directory of Important Wetlands in Australia[4]). Saltmarsh wetlands and grass-sedge wetlands are also prominent in the Fitzroy region (Eberhard 2012).

Palustrine wetlands are vegetated, non-riverine or non-channel systems such as billabongs and marshes. There are approximately 670 km$^2$ of palustrine wetlands throughout the Fitzroy region (Queensland Wetland*Info*[3]). Palustrine wetlands that are located in the coastal zone have an important role in filtration of terrestrial waters during periods of high flow and provide seasonal habitat for many species of fish, birds, invertebrates and aquatic reptiles and amphibians.

The Fitzroy coastal catchments include palustrine wetland habitats (vegetated marshes). For example, in the Shoalwater catchment these occur as low-lying coastal swamp habitats, parabolic dunes and parallel beach ridges that act as a reservoir for freshwater springs (Queensland Wetland*Info*[3]). Coastal palustrine wetlands of particular importance in the region are the marine plains that provide extensive waterbird breeding habitats including for the Australian painted snipe (listed as Vulnerable under the NCA and Endangered under the EPBC Act), and are the primary habitat for bird species of concern including zitting cisticolas and Capricorn yellow chats (listed as Endangered under the NCA and Critically Endangered under the EPBC Act) (Houston et al. 2013) (Table 1; see also Table 9 for conservation status of marine species). Proportions of wetland habitats in the drainage basins of the Fitzroy, and their changes in extent, are described in Table 2. Notably, palustrine wetland areas in the Shoalwater and Styx catchments have increased in extent due to the

[3] http://wetlandinfo.ehp.qld.gov.au/wetlands/facts-maps/ Accessed March 2015
[4] http://www.environment.gov.au/cgi-bin/wetlands/list.pl Accessed March 2015

construction of bund walls (tidal exclusion dams), resulting in the conversion of estuarine wetlands into freshwater ponded pastures.

**Table 1. Conservation status of habitats and fauna in wetlands of the Fitzroy Basin and coastal catchments. (From Australian *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*[5] and Queensland *Nature Conservation Act (NCA) 1992*[6])**

| Description | EPBC | NCA |
|---|---|---|
| *Habitats* | | |
| Beach scrubs (vine forests on coastal sands): component of the critically endangered ecological community "Littoral rainforest and coastal vine thickets of Eastern Australia" on the Capricorn Coast | Critically endangered | No status |
| *Fauna* | | |
| Capricorn yellow chat (*Epthianura crocea macgregori*) | Critically endangered | Endangered |
| Australian painted snipe (*Rostratula australis*) | Endangered | Vulnerable |
| Star finch (eastern subspecies) (*Neochmia ruficauda ruficauda*) | Endangered | Endangered |
| Beach stone-curlew (*Esacus neglectus)* | No status | Vulnerable |
| Fitzroy River turtle (*Rheodytes leukops*) | Vulnerable | Vulnerable |
| White-throated snapping turtle (*Elseya albagula*) | Critically endangered | Least concern |
| Water mouse (*Xeromys myoides*) | Vulnerable | Vulnerable |
| Grey-headed flying-fox (*Pteropus poliocephalus)* | Vulnerable | Least concern |
| Honey blue-eye (*Pseudomugil mellis*) | Vulnerable | Vulnerable |
| Tusked frog (*Adelotus brevis*) | No status | Vulnerable |
| Kroombit tinkerfrog (*Taudactylus pleione*) | Critically endangered | Endangered |
| Kroombit treefrog (*Litoria kroombitensis*) | No status | Endangered |

[5] http://www.environment.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl?wanted=fauna#mammals_extinct March2015
[6] http://www.ehp.qld.gov.au/wildlife Accessed March 2015

| | | |
|---|---|---|
| Boggomoss snail (*Adclarkia dawsonensis*) | Critically endangered | Not listed |
| Migratory birds (many species – see listings on Queensland Wetland*Info*[7]) | Migratory (JAMBA and CAMBA) | |

EPBC – *Environment Protection and Biodiversity Conservation Act 1999*; NCA – Queensland *Nature Conservation Act 1992*.

The inland waterways of the Fitzroy Basin are heavily modified, and flows are artificially regulated by 28 dams and weirs for water security (FBA 2008). The Connors River is the only major tributary in the Fitzroy Basin that is not modified, although it flows into regulated downstream rivers. Palustrine, lacustrine (lakes and open water wetlands), riverine and artificial/modified wetlands are extensive throughout the Fitzroy Basin. Many of these habitats are ephemeral (seasonally dry) but are also prone to extensive flooding (Flint et al. 2013). The seven major tributaries of the Fitzroy Basin are Callide Creek, Comet River, Dawson River, Isaac River, Mackenzie River, Nogoa River and the Fitzroy River, which collects waters from all other rivers and streams of the Fitzroy Basin and meets the coast at the Fitzroy River delta. The Fitzroy River is barraged 56 km upstream of the delta, halving the river's natural tidal influence (Connell et al. 1981).

The large size of the Fitzroy Basin and the variability resulting from natural variations in climate, flow, geography, geology and soils as well as variations relating to diverse anthropogenic activities, are reflected in variable water quality across the Basin's many wetlands (Flint et al. 2013). The Fitzroy Partnership for River Health reports annually on aquatic ecosystem health of the Fitzroy Basin. The 11 freshwater catchments of the Fitzroy Basin are each scored separately, and grades of 'B – good' or 'C – fair' have been reported for the catchments over the four reports released to date (2010–11 to 2013–14)[8], with the latest report for 2013–14 rating the Basin as 'B – good' overall.

There are 18 nationally important wetlands in the Fitzroy Basin and coastal catchments, 11 of which can be classified as coastal (Figure 2, see also Appendix A). The region contains a Ramsar wetland of international importance in the Shoalwater and Corio bays wetland (described in detail on the Queensland Wetland*Info* website[9]) located in the Shoalwater and Water Park catchments, a threatened wetland habitat and various threatened species of wetland fauna (Table 2, Appendix A). The Shoalwater Bay Training Area includes portions of several nationally and internationally important wetlands, and the area is considered to be of particularly high natural integrity and high species diversity (Department of Defence 2008). There are three freshwater fish taxa that are endemic to the Fitzroy region: these are the Fitzroy golden perch (*Macquaria ambigua oriens*), southern saratoga (*Scleropages leichardti*) and leathery grunter (*Scortum hillii*).

[7] http://wetlandinfo.ehp.qld.gov.au/wetlands/facts-maps/ Accessed March 2015
[8] http://riverhealth.org.au/ Accessed July 2015
[9] http://wetlandinfo.ehp.qld.gov.au/wetlands/facts-maps/ramsar-wetland-shoalwater-and-corio-bays-area/ Accessed March 2015

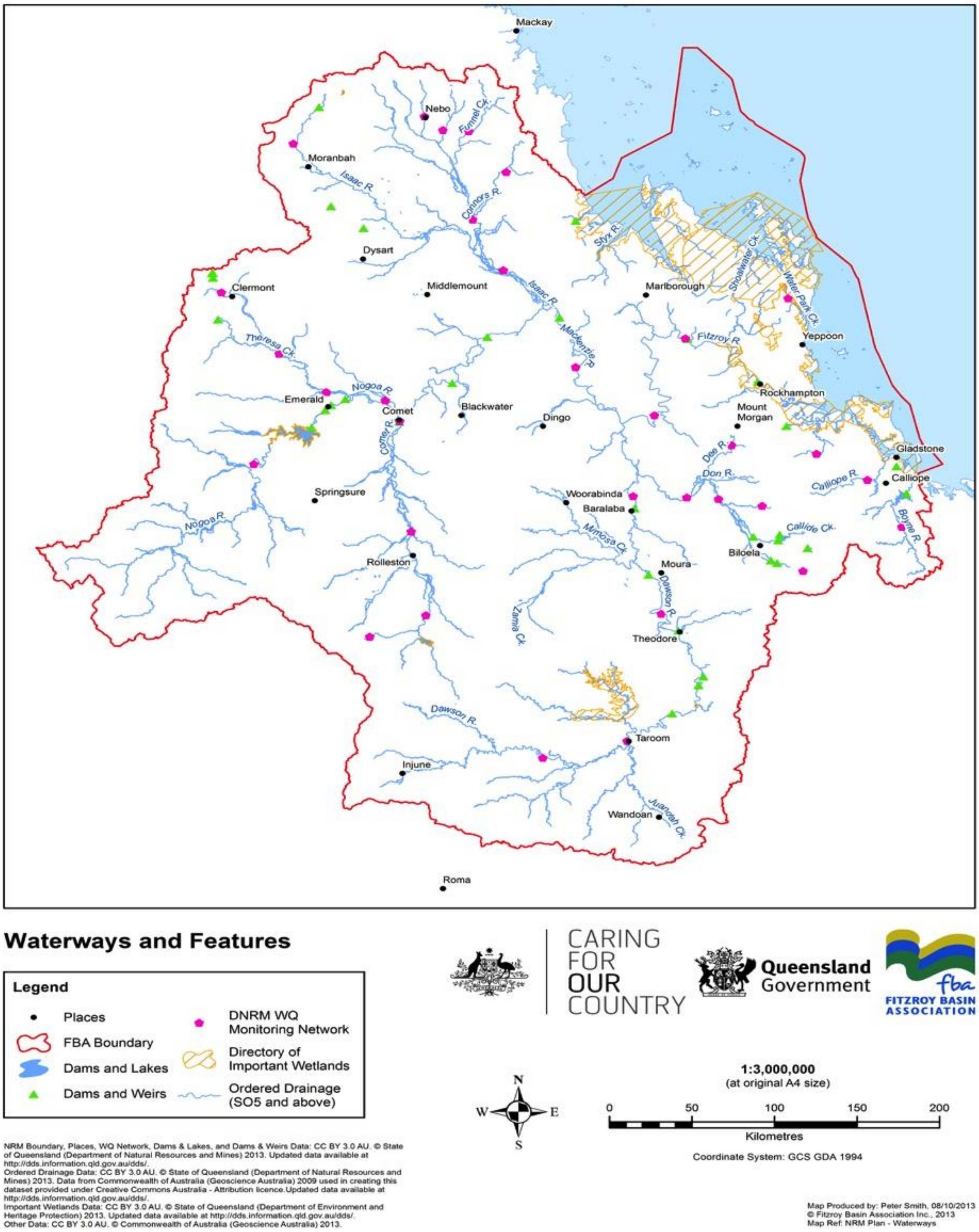


*Figure 2. Wetland areas of the Fitzroy Basin and coastal catchments, showing nationally important wetlands listed in the Directory of Important Wetlands of Australia, including RAMSAR sites.*

**Table 2. Area of wetland systems and their extent change for the Fitzroy Basin and coastal catchments. (From Wetland*Info*[10])**

| Drainage basin | System | Number of wetlands | Area | Wetland area | Total area | Change in extent 2005–2009 | Change in extent 2001–2005 | 2001/ Pre-clearing |
|---|---|---|---|---|---|---|---|---|
| | | | km² | % | % | km² | km² | % |
| **Fitzroy** | **Total** | | **2,762.2** | **100.0%** | **1.9%** | **8.3** | **18.6** | **76.2%** |
| | Artificial / highly modified | | 500.1 | 18.1% | 0.4% | 9.7 | 27.6 | n/a |
| | Estuarine | | 292.9 | 10.6% | 0.2% | 0.0 | -1.2 | 87.7% |
| | Lacustrine | 6,539 | 52.1 | 1.9% | 0.0% | 0.0 | 0.1 | 89.4% |
| | Palustrine | | 368.9 | 13.4% | 0.3% | -0.3 | -1.3 | 46.0% |
| | Riverine | | 1,548.2 | 56.0% | 1.1% | -1.1 | -6.6 | 78.6% |
| **Styx** | **Total** | | **412.8** | **100.0%** | **13.7%** | **0.0** | **0.5** | **98.3%** |
| | Artificial / highly modified | | 6.2 | 1.5% | 0.2% | 0.2 | 0.7 | n/a |
| | Estuarine | | 300.5 | 72.8% | 10.0% | -0.3 | 0.0 | 97.2% |
| | Lacustrine | 192 | 0.4 | 0.1% | 0.0% | 0.2 | 0.0 | n/a |
| | Palustrine | | 53.3 | 12.9% | 1.8% | 0.0 | 0.0 | 179.4% |
| | Riverine | | 52.5 | 12.7% | 1.7% | -0.1 | -0.2% | 95.6% |
| **Shoalwater** | **Total** | | **551.5** | **100.0%** | **15.3%** | **0.4** | **0.9** | **86.1%** |
| | Artificial / highly modified | | 5.1 | 0.9% | 0.1% | 0.5 | 1.1 | n/a |
| | Estuarine | | 339.7 | 61.6% | 9.4% | 0.0 | 0.0 | 64.6% |
| | Lacustrine | 187 | 0.7 | 0.1% | 0.0% | 0.0 | 0.0 | n/a |
| | Palustrine | | 149.5 | 27.1% | 4.1% | 0.0 | 0.0 | 1124.3% |
| | Riverine | | 56.5 | 10.2% | 1.6% | -0.1 | -0.1 | 71.8% |
| **Waterpark** | **Total** | | **409.6** | **100.0%** | **22.3%** | **0.1** | **-0.1** | **88.3%** |
| | Artificial / highly modified | | 1.2 | 0.3% | 0.1% | 0.3 | 0.1 | n/a |
| | Estuarine | | 259.0 | 63.2% | 14.1% | -0.2 | -0.2 | 94.3% |
| | Lacustrine | 374 | 0.2 | 0.0% | 0.0% | 0.0 | 0.0 | n/a |
| | Palustrine | | 92.1 | 22.5% | 5.0% | 0.0 | 0.0 | 93.8% |
| | Riverine | | 57.2 | 14.0% | 3.1% | 0.0 | 0.0 | 70.2% |
| **Calliope** | **Total** | | **94.7** | **100.0%** | **4.2%** | **0.0** | **1.5** | **87.8%** |
| | Artificial / highly modified | | 3.0 | 3.1% | 0.1% | 0.0 | 1.6 | n/a |
| | Estuarine | | 79.9 | 84.4% | 3.6% | 0.0 | 0.0 | 91.4% |
| | Lacustrine | 60 | 0.0 | 0.0% | 0.0% | 0.0 | 0.0 | n/a |
| | Palustrine | | 0.9 | 1.0% | 0.0% | 0.0 | 0.0 | 11.2% |
| | Riverine | | 10.9 | 11.5% | 0.5% | 0.0 | 0.0 | 75.2% |
| **Boyne** | **Total** | | **118.1** | **100.0%** | **4.7%** | **0.1** | **5.4** | **80.7%** |
| | Artificial / highly modified | | 54.7 | 46.3% | 2.2% | 0.1 | 5.6 | n/a |
| | Estuarine | | 16.2 | 13.7% | 0.6% | 0.0 | 0.0 | 63.8% |
| | Lacustrine | 30 | 0.1 | 0.1% | 0.0% | 0.0 | 0.0 | n/a |
| | Palustrine | | 0.3 | 0.2% | 0.0% | 0.0 | 0.0 | 26.0% |
| | Riverine | | 46.8 | 39.7% | 1.9% | 0.0 | -0.3 | 90.2% |
| **Curtis Island** | **Total** | | **151.7** | **100.0%** | **26.3%** | **0.0** | **0.0** | **99.9%** |
| | Estuarine | | 142.6 | 94.0% | 24.7% | 0.0 | 0.0 | 99.9% |
| | Palustrine | 30 | 7.5 | 4.9% | 1.3% | 0.0 | 0.0 | 99.2% |
| | Riverine | | 1.6 | 1.0% | 0.3% | 0.0 | 0.0 | 99.9% |

Areas do not include marine or estuarine waters but do include estuarine wetland vegetation (e.g. mangroves and tidal flats).

[10] www.wetlandinfo.ehp.qld.gov.au/wetlands Accessed March 2015

## 2.3. Islands and cays

Curtis and Balaclava islands are coastal islands that are part of the Great Barrier Reef World Heritage Area and National Heritage Listing. Curtis, Balaclava and Facing islands are also at the centre of a developed industrial area and subject to significant human influence (Figure 3). Curtis Island is one of Queensland's largest continental islands at 46,600 ha, and only 500 m from the mainland at its closest point. Curtis Island includes a number of protected areas including a national park, marine parks, conservation parks, state forests and a declared fish habitat area. It also supports infrastructure associated with industrial development. Despite this, Curtis Island still has large areas of high biodiversity, undeveloped bushland, closed scrub and forests, heathlands, beach scrub, estuaries, lagoons, parabolic dune fields, beaches and headlands. It also includes one of the few remaining and extensive undeveloped coastal wetlands in the Southeast Queensland bioregion and is recognised in the Directory of Important Wetlands of Australia (Curtis Island Management Statement 2012) (see Appendix A).

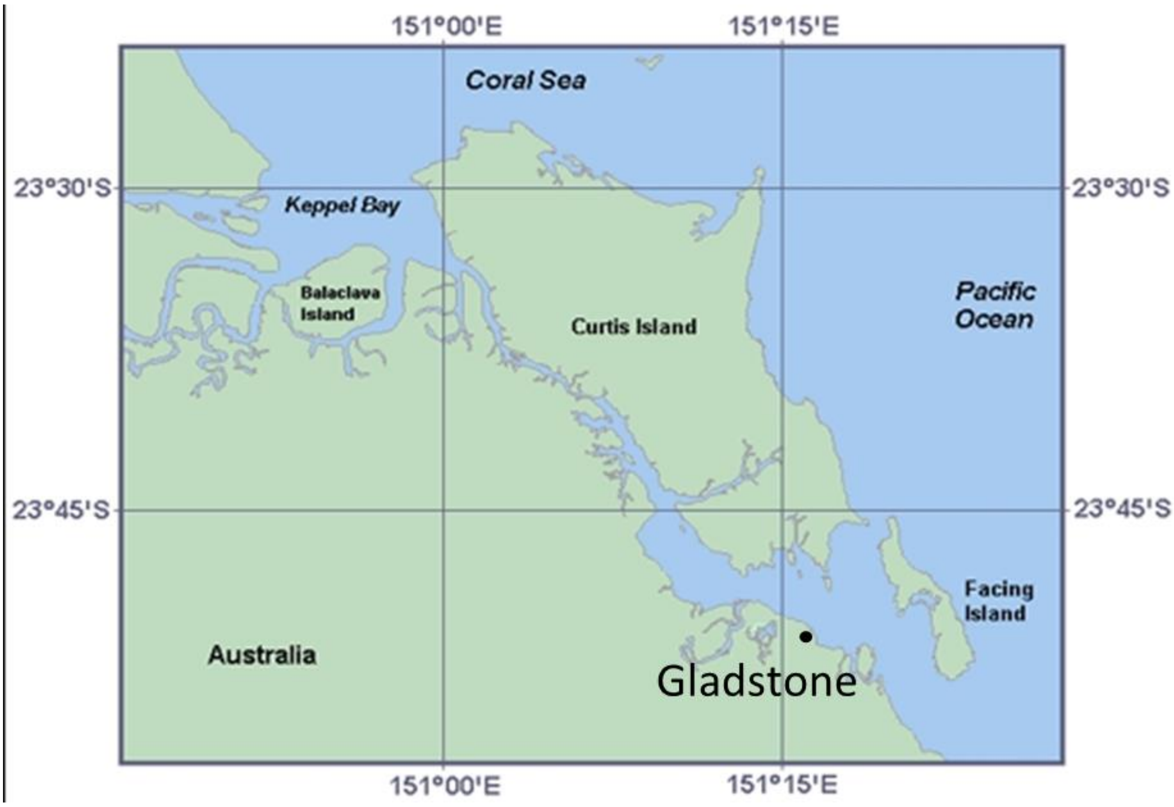


*Figure 3. Coastal islands of Balaclava, Curtis and Facing islands in the Fitzroy region.*

Many of the island's natural ecosystems have been altered by historic and current grazing uses and are in a recovering phase. As a result, the Curtis Island Management Area conserves 20 regional ecosystems, including three that are listed as 'endangered' and seven listed 'of concern' under the

Queensland Vegetation Management Act 1990 (Curtis Island Management Statement 2012). The island has 400 species of vascular plants and is nationally important for shorebirds.

The island's habitats support 20 species of conservation significance such as turtles and dugong, and are also important to a number of threatened and migratory coastal bird species (such as the yellow chat and eastern curlew). There are rocky fringing reefs on the east of the island, and a number of intertidal wetlands and fringing mangrove communities on and around the island, such as The Narrows. These communities provide habitat and nurseries for many marine species. The Narrows is a passage inside Curtis Island that connects the Fitzroy estuary with Port Curtis (Sheaves et al. 2006), and is one of only four tidal passages in Australia.

Balaclava Island is in the Keppel Bay estuary and is listed on the Register of the National Estate along with the Narrows and Peak Island (Eberhard 2012). Approximately 15 km offshore from the Keppel Bay estuary are the Keppel Islands. The Keppel Islands are a group of 16 continental islands with fringing coral reefs that have moderate to low diversity of fish and coral communities (Thompson et al. 2013), high average coral cover (Maynard et al. 2007; Diaz-Pulido et al. 2009), and consist of corals with growth rates higher than seen elsewhere in the GBR (Diaz-Pulido et al. 2009). The islands are popular tourist destinations and are also accessed extensively by recreational fishers and pleasure boats. The islands include diverse areas of flora and fauna, such as swamp mahogany forests on Great Keppel Island.

The Capricorn-Bunker group of islands and the Swains Cays are located 80 km and between 120 and 250 km from the mainland respectively, and are both generally considered to represent offshore environments. Their islands and cays and adjoining waters provide critical nesting, breeding and feeding habitat for globally significant animals including endangered species of seabirds (for example the little tern and fairy tern) and marine turtles. The Swains Cays are the most remote cays in the GBR and their surrounding waters provide remote calving grounds for humpback whales (*Megaptera novaeangliae*). There are nine coral/sand cays plus incipient islands currently only emergent at low tide, with simple vegetation communities of grasses and herbs that are often transient (Heatwole et al. 1996).

Pest animals have impacted on the condition of many islands in the region, with strategic pest management reducing impacts on some islands. For example, cattle and horse on leasehold land on Curtis Island are known to move into protected areas, damaging vegetation and transferring pest plants that can then impact on native habitats. On the Capricorn-Bunker Islands, pisonia *(Pisonia grandis)* forests are being impacted by soft scale insect populations and current control measures include baiting ants, introducing biological controls such as lady beetles, and revegetating highly impacted islands such as Tryon Island (Batianoff et al. 2009). House mice have been documented on some islands in the region, and are a known disease vector that can damage native vegetation seed stock. Current control programs on North West and Heron islands are baiting and trapping mice with the ultimate goal of eradication.

# 3. Marine assets: status and trends

The total area of the Fitzroy marine NRM area, as defined by the Great Barrier Reef Marine Park Authority (GBRMPA), is 85,515 $km^2$, the area of mapped reefs is 4,855 $km^2$ and the area of monitored sub-tidal seagrass and modelled deep-water seagrass is 5,775 $km^2$ (Brodie et al. 2013a). The Fitzroy marine region lies within the GBR World Heritage Area, listed in 1981 for its outstanding universal values under all four natural criteria[11] at the time of listing.

The region includes coastal bays, mangrove-lined estuaries, near-shore intertidal flats, seagrass habitats, coral reefs, deep-water seagrass meadows, wider continental shelf and open-ocean pelagic habitats. These various habitats are connected by water movements that transport larvae, sediment, nutrients and adult organisms. The marine component of the Fitzroy region contains 12 reef and 12 non-reef bioregions (primary level of marine biodiversity classification) (Table 3).

**Table 3. Bioregions of the Fitzroy marine area from north to south. Reef bioregions are coloured blue and non-reef bioregions orange. (From Day et al. 2002; GBRMPA website[12]).**

| Bioregion | Description | Location |
|---|---|---|
| RHL Hard Line Reefs | Geomorphologically distinct. Extensive outer barrier, set well back from edge of continental slope. Fish communities less diverse, but similar to Swain Reefs and Whitsundays. Strong influence from Broad Sound, high tidal energy. Current-swept channels with steep walls, sheltered leeward-reef communities with low diversity but high abundances of selected species. | Offshore |
| RK Strong Tidal Inner Mid-shelf Reefs | High turbidity and very high water column productivity. Distinct from RHW and RHE. Rich bivalve, sponge and ascidian (sea squirt) dominated communities on leeward reef slopes. Distinct fish communities (including baitfish) with lower diversity. Strongly influenced by Broad Sound tidal node. | Mid-shelf |
| RE5 High Tidal Fringing Reefs | Very high turbidity, thus habitat for light-avoiding benthos at the base of the reefs. Strong coastal influence and unusually strong currents for inshore area, strong tidal movements and high tidal range.<br>Well-developed fringing reefs, with poor hard and soft coral communities, but rich gorgonian and algal communities. | Inshore |
| RE6 Incipient Reefs | Area has lots of algae and only incipient reefs. Very high turbidity and tidal movements. Strong southern influences on coral and algal species. | Inshore |
| RE7 Tidal Mud Flat Reefs | Greatest tidal range and tidal movements on the GBR. Higher turbidity than RE5 and RE6. Very few reefs or corals, but distinct algal communities. | Inshore |
| RSWN Coral Sea Swains-Northern Reefs | Near edge of continental slope. Northerly aspect. Biologically distinct with strong influence of Coral Sea fauna and some similarities to northern outer-shelf reefs, but lower diversity of hard and soft coral species. | Offshore |
| RSWM Swains Mid | Very sheltered. Biologically distinct communities from Swains | Offshore |

[11] http://www.gbrmpa.gov.au/about-the-reef/heritage/great-barrier-reef-world-heritage-area Accessed 2015
[12] http://www.gbrmpa.gov.au/zoning-permits-and-plans/rap/research-and-planning Accessed 2015

| | | |
|---|---|---|
| Reefs | Outer Reefs (RSWO). Many cays. Fuzzy boundary with RHE. | |
| RHE Strong Tidal Mid-shelf Reefs (East) | High energy/high tidal movement. Turbid water. East Australian Current splits so that there is an eddie in the open area where there are small well-spaced reefs. Many smaller fish – possibly high recruitment area. High water column productivity. Biologically distinct (fish). Leeward parts of reefs dominated by filter-feeders. Fuzzy boundary with RSWM. | Mid-shelf |
| RSWO Swains Outer Reefs | Set back from shelf edge. Easterly aspect. Lower influence of Coral Sea fauna than RSWN. Biologically distinct from Mid Swains (RSWM), more similar to Capricorn-Bunker Outer Reefs (RCB1). Communities on flanks and leeward sides dominated by xeniids, a large and very characteristic group of soft corals, unique in their ecology and biology. | Offshore |
| RE8 Coastal Southern Fringing Reefs | Dominated by episodic Fitzroy River flood plumes. Southern influence in algal species.<br>Fringing reefs around high continental islands with high cover of hard and soft coral and algae, but low coral diversity. | Inshore |
| RCB1 Capricorn-Bunker Outer Reefs | RCB1 & RCB2 oceanographically isolated, may be biologically distinct from the rest of GBR. Set back from edge of continental shelf but very exposed due to local currents. Distinct differences in coral trout populations compared with the Swain Reefs and elsewhere on the GBR. High soft coral diversity. | Offshore |
| RCB2 Capricorn-Bunker Mid-shelf Reefs | RCB1 & RCB2 oceanographically isolated, may be biologically distinct from rest of GBR. More turbid, more protected and more algae than RCB1, characteristic of mid-shelf area. Good turtle feeding habitat. | Mid-shelf |
| NA3 High Nutrient Coastal Strip | Terriginous mud and high levels of nutrients from the adjoining land.<br>Seagrass in sheltered coastal strip sites only. Good turtle and dugong feeding habitat. Wet tropical influence for much of the coast. | Inshore |
| NA4 Inshore Terrigenous Sands | Strong Broad Sound tidal influence. Very mobile sands, little algae or seagrass. | Inshore |
| NB6 Inner Shelf Lagoon Continental Islands | Strong currents, gravel and hydroids around Pine Peak Island. Some gorgonians and low reef sites, water very turbid. Seagrass meadows in some bays. | Inshore |
| NB7 Mid-shelf Lagoon | Muds dominate, minimal algae or seagrass. Very steep, extensive benthos, gravel, low sponge diversity but only 21% of species are similar to those in southern lagoonal reefs. Mobile sand dunes influenced by strong East Australian Current. | Mid-shelf |
| NB8 Capricorn-Bunker Lagoon | *Halimeda* and seagrass up to 50% cover. Mixing of southern inshore and tropical inshore sponge species, 28% not yet found elsewhere. | Mid-shelf |
| NTE Eastern Pelagic Platform | Gentle broad slope. Mostly fine pelagic sediments with several long (30 nm) E-W shoals of extensive plate corals to 5-10 m depth. A number of mobile sand banks have formed under East Australian Current. | Offshore |
| NL5 Swains Inter Reef | Rich sponge fauna, 26% not yet recorded elsewhere on GBR, and only 31% of species occurring in both<br>Swain and Capricorn-Bunker regions. Complex and rocky in places, with lower tidal current than in NL4.<br>Fuzzy boundary with NL4. Some *Halimeda*, and some seagrass in patches in middle Swains. | Offshore |

| | | |
|---|---|---|
| NU Terraces | Characterised by hard substrate seafloor terraces at depths of 90-300 m terraces punctuated by shoals to depths of around 10 m. | Offshore |
| NO Capricorn Trough | Deep oceanic influence. Mix of pelagic (e.g. foraminifera) and *Halimeda* seabed deposits. Very fuzzy boundary between NO and NB7. | Mid-shelf |
| NN Capricorn-Bunker Banks | Pre-reef *Halimeda* deposits around Capricorn-Bunker reefs. Diverse sponge fauna (187 species), mostly different from southern fauna (NB8), slightly more similar to northern island-group faunas (NL5). | Mid-shelf |
| X4 Capricorn-Bunker Inter Reef | Deep water, offshore area. | Offshore |
| X8 Southern Embayment | Deep water, offshore area. | Offshore |

This report focusses on the key marine habitats that support a high diversity of flora and fauna, primarily coral reefs and seagrass meadows. These highly diverse ecosystems support marine industries including tourism (mainly to the Keppel and Capricorn-Bunker islands and reefs) and recreational beach activities worth AUD252 million in 2011–12 (Deloitte Access 2013; Rolfe and Gregg 2012). They also support recreational and commercial fisheries that target reef fish, mud crabs and inshore species such as barramundi and mangrove jack. The fisheries are estimated to be worth AUD10 million and AUD35 million annually respectively. (GBRMPA 2013). In addition, they support coastal aquaculture ventures for finfish and red claw crayfish worth AUD300,000 annually (EHP 2011). Below is a summary of the region's marine assets, the biodiversity they support, and the status and trends in their condition.

## 3.1. Coral reefs

Coral reefs are a major ecosystem component of tropical marine environments in the GBR, and there are estimated to be 4,855 $km^2$ of reefs in the Fitzroy marine region (Brodie et al. 2013a), representing approximately 13% of total reef area in the GBR (excluding the northern Torres Strait part). The region has inshore reefs, primarily fringing reefs around the Keppel Islands; mid-shelf reefs in the Capricorn-Bunker Group, although their characteristics resemble more offshore reefs; and the remote Swains reefs that are located on the outer continental shelf. Reefs in the Keppel Islands have relatively high coral cover and diversity for inshore reefs, with representatives from 68% of the ~244 coral species previously described for the southern GBR (Jones et al. 2011).

Inshore reefs in Keppel Bay lie along a water-quality gradient away from the Fitzroy River, which influences the composition and dynamics of benthic communities (Thompson et al. 2013). Peak and Pelican islands' reefs are situated in relatively turbid and nutrient-rich waters compared to the fringing reefs further offshore. At these reefs, benthic communities differ markedly between the reef flat (at a depth of 2 m) and reef slope (at a depth of 5 m), illustrating the substantial differences in light conditions due to high turbidity. Although water quality is not measured at Peak Island, the low coral cover, low density of juvenile corals, high cover of macroalgae along with a lack of substantial reef development suggest that the environmental conditions at this location are marginal for most coral species. Further offshore, reefs become dominated by the family Acroporidae (branching species *Acropora intermedia* and *A. muricata*) on the reef flat and reef slope (Thompson et al. 2013).

On GBR inshore reefs, the incidence of disease has shown repeated increases following major flood events (Thompson et al. 2011) and has been documented in corals in the Fitzroy region (Thompson et al. 2013). Australian Institute of Marine Science Long-Term Monitoring Program (AIMS LTMP) surveys in 2014 observed low incidences of coral disease on Capricorn-Bunker reefs and on three of the five reefs in the Swain sector. The number of cases of White Syndrome coral disease at Gannett Cay Reef had doubled from previous year but was still low. The incidence of White Syndrome disease at East Cay was the highest yet recorded at that reef, and was substantially higher than the long-term average for GBR reefs in the same position on the continental shelf. Counts of *Drupella* spp. were generally low or within the range of previous surveys in Capricorn-Bunker and Swain reefs. The large numbers of *Drupella* spp. recorded in 2013 at Gannett Cay had decreased, but were still high compared with the average for the GBR[13].

AIMS LTMP surveys in 2014 also recorded average coral cover for mid-shore and offshore reefs at Capricorn-Bunker and Swains reefs as 10-30% (AIMS website[14]). There are clear signs of recovery in mid- and offshore reefs after the damaging and widespread effects of severe tropical cyclone Hamish in 2009. Survey conducted in 2007 prior to tropical cyclone Hamish recorded the highest hard coral cover GBR-wide on reefs in the Capricorn-Bunker group of 55% (AIMS 2013). Since tropical cyclone Hamish, high numbers of coral recruits have been observed at all mid- and offshore reefs surveyed, suggesting that coral recovery is underway.

Results of the Reef Rescue Marine Monitoring Program (MMP) inshore reef surveys show a decline in coral cover from about 50% in 2005 to about 20% in 2012, with the condition of coral reefs assessed as ‘very poor’ in 2012–13 (Thompson et al. 2013). All indicators of reef health have shown declines in 2012–13, including coral cover that declined to ‘very poor’, the rate of change in coral cover and the density of juveniles were both ‘very poor’, while macroalgae remained ‘poor’ indicating high cover that can outcompete coral recruits for substrate. The number of juvenile coral colonies has remained relatively stable (Figure 4; Thompson et al. 2013).

[13] www.aims.gov.au Accessed 2015
[14] http://www.aims.gov.au/reef-monitoring/capricorn-bunker-and-swains-2014 Accessed 2015

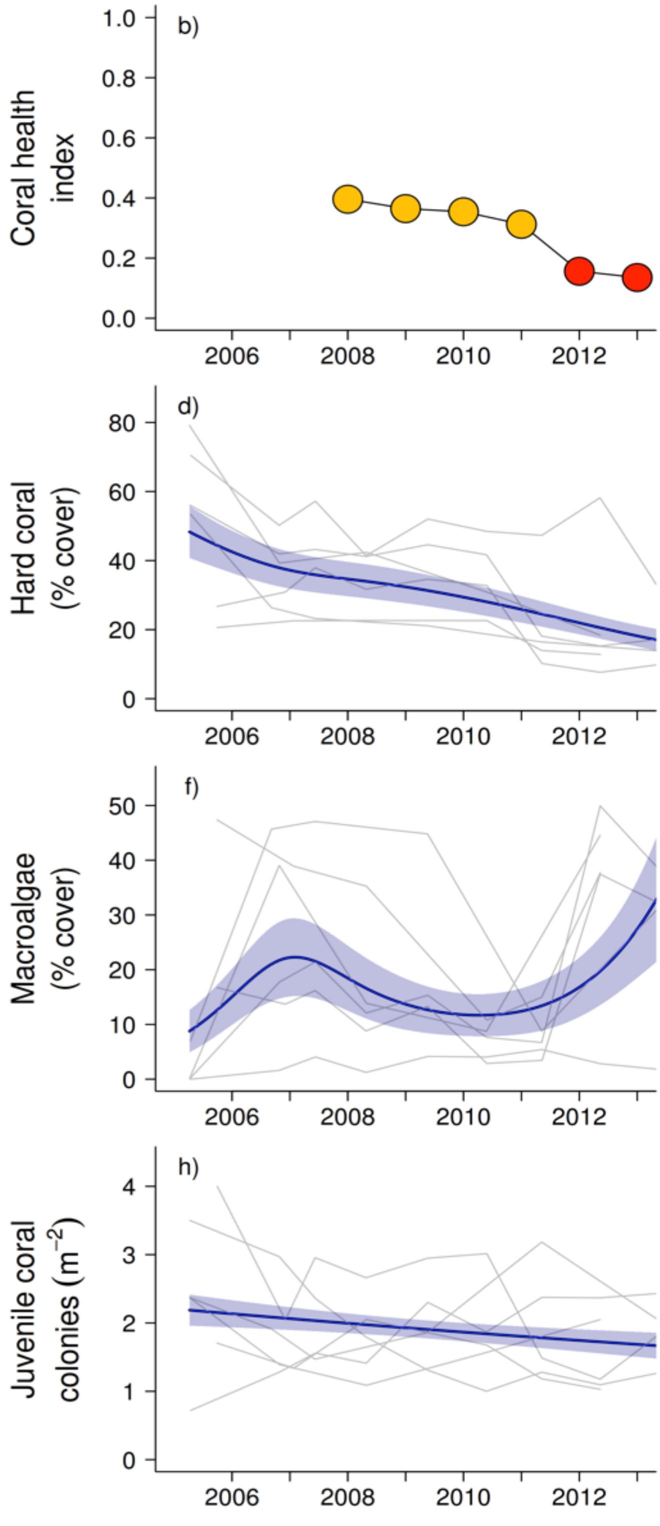


**Figure 4.** **Coral health index for inshore reefs in the Fitzroy marine area. Colour coding: dark green- 'very good'; light green-'good'; yellow – 'moderate; orange – 'poor'; red – 'very poor'. Trends in Foram index and benthic community variables are represented by blue lines with blue shaded areas defining 95% confidence intervals, grey lines represent observed profiles averaged over depth at individual reefs (Source: Thompson et al. 2013).**

Analysis of AIMS long-term monitoring data for the Southern Region[15] shows current hard coral cover has declined significantly from 37.4% in 1985 to 8.2% in 2012, exceeding the estimated 50% decline GBR-wide on inshore and mid-shelf reefs over the past 27 years (De'ath et al. 2012). This severe decline has been attributed in part to coral predation by crown-of-thorns starfish (COTS) but the greatest impacts in the Southern Region have been from cyclones and storms, especially in the period 2009–2012. Coral cover losses from bleaching were negligible in this region (De'ath et al. 2012) despite a localised bleaching event in 2006 around the Keppel Islands that experienced significant bleaching but recovered within two years (Maynard et al. 2007; Diaz-Pulido et al. 2009).

Severe storms in 2008, 2010 and 2013 reduced coral cover on northerly exposed inshore reefs in the Keppel Islands, and most notably at Barren Island in 2008 and 2013 (Thompson et al. 2013). Temperature records highlight a period of prolonged high temperatures over the summer of 2005–06 that led to widespread bleaching of coral communities at all inshore reefs surveyed with the exception of Peak and Pelican islands (Diaz-Pullido et al. 2009). Recovery from recent flooding and storms has been compromised by a persistent bloom of macroalgae, high levels of disease and low densities of juvenile corals, all linked to the influence of flood waters. Exposure to low salinity flood waters from the Fitzroy River in 2011 caused a marked reduction in coral cover and juvenile densities down to at least a 2 m depth on reefs inshore of Great Keppel Island (Thompson et al. 2013).

In mid-shelf and offshore reefs, Reef Check monitoring of 15 reef sites around Heron Island in the Capricorn-Bunker Group since 2001 shows that all indicators of reef health are generally positive and stable. The average hard coral cover in 2014 was 37.6% (ranging from 4% to 76%), which represents a slight decrease from 2013 (41%) but is similar to the average coral cover recorded in 2011 of 37%. Soft coral cover and sponge abundance were both low, and no COTS were observed. There was negligible recently killed hard coral at any of the sites surveyed; however, coral damage was recorded at most sites, as were low levels of bleaching and disease (Salmond et al. 2014).

The overall condition of inshore reefs in the Fitzroy region has continued to decline since 2010, and in 2013 was assessed as being in 'very poor' condition (Table 4; Thompson et al. 2013). This is due to a significant decline in coral cover from the impacts of flooding in early 2011 due to ex-tropical cyclone Tasha, which caused a massive flood plume that inundated reefs up to 12 km offshore. It also caused 40–100% coral mortality due to low salinity on Keppel Island fringing reefs down to a depth of 8 m (Jones and Berkelmans 2014). In January 2013 ex-tropical cyclone Oswald also caused moderate flooding of the Fitzroy River and was followed by a general increase in macroalgal cover, high levels of coral disease and coral loss. The diversity of most reefs that were monitored has also declined, with the cover of *Acroporidae* corals declining since 2010 (Thompson et al. 2013). These declines in coral are similar to those documented after the previous big flood event in 1991 (van Woesik et al. 1995).

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[15] The study analysed coral cover in three broad zones of the GBR; these figures are from the southern zone (20.0–23.9°S), which includes the Fitzroy marine region.

**Table 4. Status of inshore coral reefs in the Fitzroy region between 2008 and 2013: ■ = very good (0.80-1.00), ■ = good (0.60 - <0.80), ■ = moderate (0.40 - <0.60), ■ = poor (0.20 - <0.40), ■ = very poor (0 - <0.20). (From Thompson et al. 2013)**

| | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|
| Coral cover | 0.54 | 0.54 | 0.46 | 0.29 | 0.21 | 0.13 |
| Macroalgae | 0.38 | 0.29 | 0.54 | 0.67 | 0.29 | 0.21 |
| Juvenile coral | 0.04 | 0.08 | 0.13 | 0.08 | 0.08 | 0.04 |
| Cover change | 0.62 | 0.54 | 0.29 | 0.21 | 0.04 | 0.17 |
| **Report Card Score** | 0.40 | 0.36 | 0.35 | 0.31 | 0.16 | 0.14 |

Inshore reefs adjacent to the low rainfall Fitzroy Basin rivers are exposed irregularly (one to three times per decade) to a combination of low salinity water, suspended sediments, particulate and dissolved nutrients and pesticides (Bainbridge et al. 2009; Devlin & Schaffelke 2009; Devlin et al. 2012b; Lewis et al. 2012). In comparison, mid- and outer-shelf reefs are exposed even less frequently and to diluted concentrations of pollutants (Devlin et al. 2012b). At regional scales the cover of Acroporidae corals has declined in the Fitzroy region and the recovery of reefs in the Keppel Islands after this major loss of coral is likely to take 10 to 15 years based on historical recovery periods from a similar flood event in 1991 (Jones & Berkelmans 2014).

Estimates of the number of fish species in the GBR range from 1200 to 2000, with 1500 often cited as a reasonable estimate (Cappo & Williams 1998). Coral reef habitats exhibit the greatest species richness, followed by mangrove and seagrass/estuarine environments. Long-term monitoring has identified strong spatial patterns in reef fish species distribution, particularly across the continental shelf, with higher diversity offshore (Sweatman et al. 2008).

Thousands of fish, shark, invertebrate and other fauna species depend on, and are associated with, the structures created by corals, including demersal fish (e.g. coral trout (*Plectropomus spp.*) and red-throat emperor *Lethrinus miniatus*)), near-shore pelagic fish (e.g. species of mackerel, tuna), invertebrates (e.g. tropical lobster, sea cucumbers, crabs, molluscs), turtles (e.g. green, hawksbill) and sharks (e.g. blacktip and whitetip reef sharks). Maintaining the structural complexity of reef frameworks is vitally important to the biodiversity and health of the Fitzroy marine ecosystem. The majority of large, mobile fish families and damselfish, increased in abundance in the 13 years of LTMP monitoring to 2007 (AIMS 2013).

Significant declines in coral cover and habitat complexity in Keppel Island fringing reefs due to major disturbances — coral bleaching in 2006 and flooding in 2010, 2011, 2013 — caused subsequent declines in reef fish abundance and diversity, and pronounced shifts in fish assemblage structure. Coral trout density declined in response to the loss of live coral, with post-disturbance refuges for spawning stocks surviving within no-take (green) zones that escaped the worst effects of the disturbances (Williamson et al. 2014). However, recent studies have shown the limitations of no-take zones in mitigating the impacts of declining water quality on Keppel reefs (Wenger et al. 2015).

Similarly, in the Capricorn-Bunker group and Swains Cays, parts of the reefs directly exposed to prevailing wind and waves have had most hard corals removed by storms in 2008 and tropical cyclone Hamish in 2009 (AIMS 2010 surveys). On exposed reef sites, the reefscape is without structural complexity and the abundance and diversity of fish declined, with large groups of neon damselfish (*Pomacentrus coelestis*) one of the few fish species to increase in abundance after such habitat destruction (AIMS online report[16]). Similar changes were recorded following major storms in the late 1980s and coral and fish communities took over a decade to recover.

## 3.2. Seagrass meadows

Seagrass meadows are a major ecosystem component of tropical marine environments in the GBR. Seagrasses provide nursery areas for many species of fish and invertebrates (e.g. tiger prawns, sandfish and red emperor), and feeding grounds for many species of adult demersal fish (e.g. barramundi and black jew), dugong and turtles. Seagrass meadows are also permanent habitats for a wide range of invertebrates, such as sea cucumbers and molluscs.

There are estimated to be 241 km$^2$ of shallow seagrass areas (<15 m depth) in the Fitzroy region, representing 0.2% of total seagrass area in the GBR (Table 5; McKenzie et al. 2010) and 5,775 km$^2$ total seagrass area including modelled deep-water meadows (Brodie et al. 2013b). Intertidal seagrass meadows in the Fitzroy region are located on the large sand/mud banks in sheltered areas of the region’s estuaries and coasts, and occur on the fringing reef flat habitats of offshore islands (McKenzie et al. 2014). Seagrass meadows in the southern Fitzroy region tend to be intertidal, on the large sand/mud banks in sheltered areas of the estuaries, as well as deepwater beds beyond the reach of dugong (Coles et al. 2007). Environmental drivers include high turbidity and desiccation, which is linked primarily to the large tide regime. Seagrasses are naturally ephemeral with seasonal and annual variation high, and therefore their location and cover can change from year to year. Reproductive effort of seagrasses is generally greater in coastal and estuarine habitats by nearly three times that of reef habitats (McKenzie et al. 2012).

**Table 5. Area of seagrass shallower than 15 m in the NRM regions and entire GBR (from McKenzie 2010) within the boundaries of the Great Barrier Reef World Heritage Area.**

| NRM | Area of seagrass (km$^2$) | % of GBRWHA |
|---|---|---|
| Cape York | n/a | n/a |
| Wet Tropics | 201 | 16 |
| Burdekin | 551 | 45 |
| Mackay Whitsunday | 154 | 13 |
| **Fitzroy** | **241** | **20** |
| Burnett Mary | 73 | 6 |

[16] http://www.aims.gov.au/docs/research/monitoring/reef/ltm2010-11-12.html Accessed 2015

| GBR | 1,220 | 100 |
|---|---|---|

The MMP includes three monitoring locations in the Fitzroy region: Shoalwater Bay, Great Keppel Island and Gladstone outer Harbour. The program includes sampling at intertidal sites in reef, coastal and estuarine locations. The results show declines in 2011–12 mainly in coastal meadows in the Fitzroy region, which appear to be the consequence of local scale disturbances (e.g. sediment or sand bank movement). In contrast, seagrass abundance observed in the estuarine meadows of the Fitzroy region in 2011–12 were some of the highest recorded since monitoring was established (Figure 5).

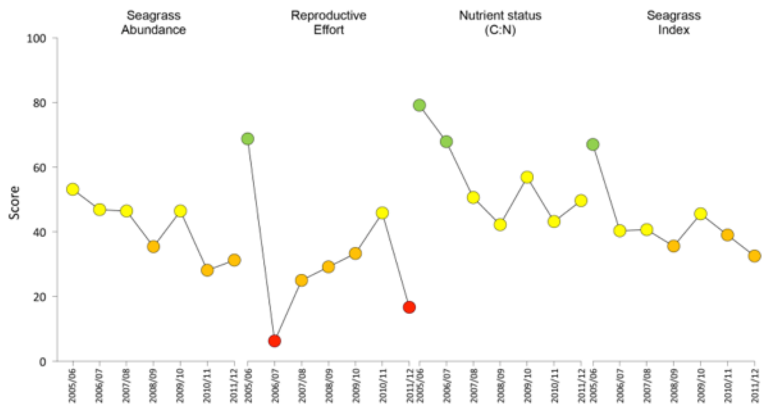


**Figure 5. Report card of seagrass status indicators and index for the Fitzroy NRM region (averaged across sites). Values are indexed scores scaled from 0-100; ■ = very good (80-100), ■ = good (60 - <80), ■ = moderate (40 - <60), ■ = poor (20 - <40), ■ = very poor (0 - <20) (Source: McKenzie et al. 2014).**

Despite this high abundance of estuarine seagrass, the MMP gave an overall rating of 'poor' for all habitat types due to other indicators of seagrass health, such as 'poor' to 'very poor' reproductive effort and the 'very poor' condition of reef seagrass (Table 6).

**Table 6. Long-term status of seagrass meadows based on abundance in reef and coastal habitats Fitzroy region: July 2005 – May 2012 ■ = very good (80-100), ■ = good (60 - <80), ■ = moderate (40 - <60), ■ = poor (20 - <40), ■ = very poor (0 - <20). (From McKenzie et al. 2014)**

| Habitat type | 2005/06 | 2006/07 | 2007/08 | 2008/09 | 2009/10 | 2010/11 | 2011/12 |
|---|---|---|---|---|---|---|---|
| Reef intertidal | 0 | 0 | 13 | 6 | 6 | 13 | 6 |
| Coastal intertidal | 81 | 81 | 100 | 75 | 81 | 31 | 25 |
| Estuarine intertidal | 25 | 13 | 44 | 25 | 50 | 34 | 47 |

Values are indexed scores scaled from 0-100

Key environmental drivers of seagrass change in the region include exposure at very low tide and high turbidity. Seagrass abundance remained relatively stable across habitats and was rated 'poor' overall in 2011–12 and 2012–13 by the MMP. Reproductive effort was 'very poor', suggesting a low capacity to recover from disturbance. The nutrient status of seagrass tissue was 'moderate' overall and variations between habitats reflected differences in nutrient and light availability. Seagrass nutrient status scores (using only the carbon to nitrogen ratio) improved in the Fitzroy region from 2010 to 2011. Reef intertidal seagrass meadows were assessed as 'very poor', the worst condition of all habitat types in the region (Table 7; McKenzie et al. 2014).

**Table 7. Seagrass status (community & environment) for the Fitzroy region: July 2011 – May 2012 ■ = very good (80-100), ■ = good (60 - <80), ■ = moderate (40 - <60), ■ = poor (20 - <40), ■ = very poor (0 - <20). (From McKenzie et al. 2014)**

| **Habitat** | Abundance | Reproductive Effort | Nutrient status (C:N ratio) | **Seagrass Index** |
|---|---|---|---|---|
| Reef intertidal | 6 | 25 | 17 | **16** |
| Coastal intertidal | 25 | 0 | 46 | **24** |
| Estuarine intertidal | 47 | 25 | 87 | **53** |
| **Fitzroy overall** | 31 | 17 | 50 | **33** |

Values are indexed scores scaled from 0-100

Although seagrass abundance was low at reef intertidal habitats prior to the extreme weather events of 2011, it remained low throughout 2011–12 and meadow extent declined. The extent of the meadows in coastal habitats remained stable in 2011–12; however, seagrass abundance declined in the coastal meadows and increased in estuarine meadows. The decline in the coastal meadows may be a consequence of local-scale disturbances, evident by the increase of the colonising seagrass species *Halophila ovalis.* The seagrass abundances observed at the estuarine meadows in 2011–12 were some of the highest recorded since monitoring was established in the region. Although reproductive health declined relative to the previous monitoring period, an increase in the seed banks at estuary and coast locations indicates a high recovery potential. Of greatest concern, however, are reef intertidal habitats where seed banks declined or remained absent coupled with poor reproductive health, suggesting recovery may be slow and seagrasses will be vulnerable to major disturbances. Observations of how reef seagrass meadows recover from recent poor ecological health will be important to evaluate the longer-term capacity of seagrasses to recover from disturbance, that is, their resilience (McKenzie et al. 2014).

Seagrass leaf tissue nutrients varied between habitats across the region. Seagrass tissue ratios suggest nitrogen limitation in estuary habitats, while phosphorous and nitrogen were surplus to carbon requirements in coast and reef habitats. The primary source of elevated nitrogen in coastal habitats is likely to be run-off of land-based fertiliser. Epiphyte abundance remained relatively unchanged, except on reef habitats where it increased to pre-2010 values. Adequate light was available for growth at coastal habitats; however, there was limited data for reef and estuarine habitats (McKenzie et al. 2014).

Daily light in shallow habitats can be affected by water quality, cloud cover and the depth that seagrasses grow, and affects the exposure of seagrasses to full sunlight at low tide and thus photosynthesis (Anthony et al. 2004; Fabricius et al. 2012). However, the differences in daily light among seagrass sites are mostly due to site-specific differences in water quality. These differences are consistent with spatial patterns in water quality observed at larger spatial scales (Devlin et al. 2013; Schaffelke et al. 2013) and confirm the role of water clarity in the observed patterns of canopy light. The relationship between changes in seagrass cover and light availability has been used to develop light metrics and a threshold of change (Collier et al. 2012) since low light levels are a major driver of changing seagrass abundance (Chartrand et al. 2012). In Shoalwater Bay, this threshold is exceeded on 4.3% of days year-round and on about 10% of days during the wet season when cloud cover and turbid terrestrial inputs are highest, which is the lowest exceedance days of all seagrass sites monitored in the GBR (Table 8), providing adequate light for growth.

**Table 8. Minimal light threshold exceedance for days seagrass are exposed to low light levels. (From McKenzie et al. 2014)**

| Region | Location | Site | Threshold exceedance (% days) | | Jan-Mar | |
|---|---|---|---|---|---|---|
| | | | Long-term | 2011-12 | Long-term | 2012 |
| Wet Tropics | Low Isles | subtidal | 37.4 | 26.5 | 51.5 | NA |
| | | intertidal | 5.1 | 0 | 12.7 | 0 |
| | Yule Point | intertidal | 16.3 | 2.3 | 32.8 | NA |
| | Green Island | subtidal | 9.8 | 3.5 | 14.6 | 0^ |
| | | intertidal | 13.4 | 1.0 | 7.7 | NA |
| | Dunk Island | subtidal | 30.0 | 19.6 | 34.3 | 22.8 |
| | | intertidal | 5.3 | 5.0 | 7.3 | 4.5 |
| Burdekin | Picnic Bay | subtidal | 43.1 | 24.5 | 55.4 | 28.2 |
| | | intertidal | 11.3 | 3.5 | 17.2 | 2.2 |
| | Bushland Beach | intertidal | 58.3 | 58.1 | 84.2 | 79.3 |
| | Cockle Bay | intertidal | 9.3 | 4.6 | 10.2 | 5.5 |
| Mackay Whitsunday | Pioneer Bay | intertidal | 32.4 | 30.0 | 56.0 | 60.7 |
| | Hamilton Island | intertidal | 15.0 | 20.5 | 9.7 | 8.2 |
| | Sarina Inlet | intertidal | 28.2 | 16.7 | 35.4* | NA |
| **Fitzroy** | **Shoalwater** | **intertidal** | **4.3** | **4.3** | **7.7** | **10.3** |
| Burnett Mary | Rodds Bay | intertidal | 1.4 | 0 | NA | NA |
| | Urangan | intertidal | 22.2 | 16.2 | 41.2 | 38.3 |

Threshold = 6 mol m-2 d-1 for intertidal *Zostera muelleri* communities in the southern GBR (Chartrand et al. 2012) including annual average, reporting year (2011–12) and wet season (January–March).
*2010 wet season data only

Despite this poor state of seagrass meadows in the region, recovery is possible. Areas that have supported seagrass communities in the past can, in theory, do so again, provided environmental conditions are suitable for colonisation and maintenance of meadows (Weston & Goosem 2004). Recent monitoring results indicate that recovery may have begun in some locations with a shift to the colonising species *H. ovalis* (McKenzie et al. 2014). Once re-established, seagrass meadows are expected to increase in abundance and distribution if environmental conditions remain favourable.

## 3.3. Species of conservation interest

The Fitzroy Basin marine region supports populations of species of conservation interest, including dugong (*Dugong dugon*), six marine turtle species (green, loggerhead, hawksbill, flatback, olive ridley and leatherback), humpback whales, three species of inshore dolphins, many species of shorebirds and seabirds, sawfish and sharks (see Table 4). The wetlands in this region provide important habitat and transport corridors for migratory bird (and other) species with the adjacent marine waters, many of which are listed under the Australian *Environment Protection and Biodiversity Conservation* Act *1999* (EPBC Act) and international agreements including:

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

There are 10 migratory marine bird species, two species of migratory mammals (dugong and humpback whale) and seven migratory reptiles (e.g. marine turtles and saltwater crocodiles) found within the Fitzroy region (GBRMPA 2013).

Many islands in the Fitzroy region are important marine turtle nesting sites — Peak Island, Curtis Island and the cays of the Capricorn-Bunker Group — as well as many offshore islands and cays that provide critical nesting habitat for seabirds (GBRMPA 2013). Globally important populations of loggerhead (*Caretta caretta*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*) and flatback (*Natator depressus*) turtles nest on the islands of the Fitzroy region and forage in nearby waters (Hamann et al. 2007).

### 3.3.1. Dugongs

Dugongs (*Dugong dugon*) are found throughout tropical and sub-tropical coastal waters of the western Pacific Ocean. Populations are reduced to relict groups over much of this range, and survival prospects are poor in most areas (Lucas et al. 1997). Northern Australia, from Moreton Bay, Queensland to Shark Bay, Western Australia is considered a significant stronghold of the species. While dugongs are found throughout the GBR, the most significant remaining populations are in the north, with populations depleted along the urban coast of the GBR, south of Cooktown (Coles et al. 2007; GBRMPA 2007). Large populations can also be found to the north and south of the GBR World Heritage Area, in the Torres Strait and Hervey Bay.

Dugongs are generally sparsely distributed in the Fitzroy region, although a small transient population exist around Port Curtis/Rodds Bay in the south and Shoalwater Bay in the north (Eberhard 2012) supported by the seagrass meadows in the region. Dugong Protection Areas (DPA) exist in the region, in Shoalwater Bay and Port Clinton (DPA ‘A’ Zone) and in marine waters adjacent to the Calliope basin (DPA ‘B’ Zone) (GBRMPA 2013) to protect these listed species and their habitat.

Recent monitoring has shown that the dugong population has experienced a significant decline over the previous decade, which is considered to be a direct response to seagrass declines as a result of extreme weather events and high rainfall wet seasons. Aerial surveys between 2005 and 2011 estimate the dugong population in waters between the Daintree River and the southern extent of the GBR Marine Park have declined from approximately 2,500 animals to 600 (Sobtzick et al. 2012). In addition, surveys conducted in November 2011 found that there were no calves in the remaining population, which is another indication that seagrasses were still recovering and that mature females were not able to maintain enough body condition to support offspring (Sobtzick et al. 2012).

3.3.2. Cetaceans (whales and dolphins)

Humpback whales migrate through the Fitzroy region in winter months, and three species of inshore dolphins are found in the Fitzroy estuary: the Australian snubfin dolphin (*Orcaella heinsohni*), the Indo-Pacific humpback dolphin (*Sousa chinensis*) and the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*). Under the EPBC Act, all species are listed as migratory, and also as species of conservation concern (Table 9). Relatively little is known about the status of inshore dolphins in Australia; however, there is evidence of historic and ongoing population declines from shark and gill netting and coastal development (Parra & Jedensjö 2009, Ross 2006).

3.3.3. Australian snubfin dolphins

The Fitzroy River estuary and Keppel Bay provide critical habitat for the Australian snubfin dolphin (*Orcaella heinsohni*) and are one of only three know areas where large aggregations (50-100 animals) have been recorded (Cagnazzi 2010; Cagnazzi et al. 2013; Parra et al. 2006). Current estimates are that a small group of around 80 snubfin dolphins live in the waters at the mouth of the Fitzroy River. In fact, this area is recognised as the southern-most extent for this species on the east coast of Australia (Cagnazzi 2010) and the population estimate for the entire central Queensland coast region is only 100 individuals. The closest neighbouring population is found in Repulse Bay, about 500 km north (Eberhard 2012).

The Australian snubfin dolphin (and the sympatric Indo-Pacific humpback dolphin) have small, localised populations, are exposed to high levels of human activity, and appear to be declining in number (GBRMPA 2012). The species is listed as ‘near threatened’ by the International Union for Conservation of Nature (IUCN), making them species of high conservation concern (GBRMPA 2013). They are generalist feeders, preying on a variety of fish and cephalopods (octopus, squid and cuttlefish) associated with shallow, inshore and estuarine habitats (Parra & Jedensjö 2009), and use the Fitzroy marine area for feeding and breeding.

The snubfin dolphin was only identified as a new species in 2005 (Beasley et al. 2005), and is Australia’s only endemic dolphin — found from the Fitzroy River in Queensland to Roebuck Bay in Western Australia, and possibly Papua New Guinea (Beasley et al. 2005; Gibson 2011; Robertson & Arnold 2009). It is listed as migratory under the EPBC Act; however, recent research has found this population to be isolated geographically and potentially genetically from other populations (Cagnazzi 2011). This rarely seen dolphin prefers waters close to land and in close proximity to river mouths

(Parra et al. 2002) and is only found in a small area of the Fitzroy estuary, in the same location as the previously proposed port developments and shipping channel.

Both snubfin and humpback dolphins found in the southern GBR, including in the Fitzroy region, have been found to accumulate significant levels of organic contaminants (Cagnazzi et al. 2013). Cagnazzi et al. (2013) measured these compounds in biopsy samples collected from free-ranging individuals and showed polyaromatic hydrocarbons (PAHs) levels comparable to those reported from highly industrialised countries. DDTs and HCB (pesticide residues) were found at low levels, while in some individuals, PCBs (industrial chemicals) were above thresholds that immunosuppression and reproductive anomalies occur.

### 3.3.4. Indo-Pacific bottlenose dolphins

Indo-Pacific bottlenose dolphins reach sexual maturity at 12-15 years, and nurse young for 3-5 years. Individuals can live to 40-50 years (Cockroft & Ross 1990). Conservative life history traits, small populations and movement patterns make these dolphins particularly vulnerable to impacts, including the risk of local extinction (Parra et al. 2006).

Bottlenose dolphins have a wider geographic distribution than other inshore dolphins, that includes most of the Indian and western Pacific oceans. Within this range, bottlenose dolphins have been recorded in various habitats from deep open water to rivers. In the GBR, bottlenose dolphins are found in large numbers, mainly offshore along the Reef, perhaps because of competition with humpback and snubfin dolphins. Further south, in southern Queensland, New South Wales, South Australia and Western Australia, bottlenose dolphins are found continuously along the coast. They are generalist feeders (GBRMPA 2011).

### 3.3.5. Indo-Pacific humpback dolphin

Found in tropical and subtropical waters in northern Australia and Asia (India to China), a recent genetic study (Frère et al. 2008) indicates that humpback dolphins in Australian waters may represent a different species from populations elsewhere. In Australia, they are found from northern New South Wales around to Exmouth in Western Australia, with a few sightings as far south as Shark Bay, Western Australia. In southern and central Queensland, Indo-Pacific humpback dolphins appear to be found in small, isolated populations in enclosed coastal/estuarine waters. Such distributions may become more continuous in northern Australia, although information is scarce. Similar to snubfin dolphins, humpback dolphins are generalists, feeding mainly on inshore and estuarine fish species (Parra & Jedensjö 2009).

### 3.3.6. Whales

Humpback whales (*Megaptera novaeangliae*) visit the Fitzroy region and broader GBR each winter/spring to calve and rear their young. Another species that visits the Fitzroy marine area during winter is the dwarf minke whale (*Balaenoptera acutorostrata*). While four species of mysticetes (baleen whales) are recorded with some regularity in the whole GBR, only the humpback whale is found routinely in large numbers in the area. Humpback whales migrate annually from summer feeding grounds in Antarctic waters to winter breeding grounds within the GBR (Sobtzick et al. 2012, Wenger et al. 2015). The first animals likely enter GBR waters in May with numbers increasing to a peak in August and then subsiding again with most gone by late October. During this time the whales calve, mate and fast (Cagnazzi 2010; Lawler et al. 2007).

3.3.7. Reptiles

The inshore coastal areas of the Fitzroy region provide important habitat for green, loggerhead, hawksbill and flatback turtles. Olive ridley and leatherback turtles have also been recorded but in much lower numbers. The region is a feeding and minor nesting area for green turtles and a major nesting area for flatback turtles, while other marine turtle species also use the area. All species of marine turtles found in Australian waters are listed under the EPBC Act (Table 9). The region also supports species of sea snakes and estuarine crocodiles.

3.3.8. Flatback turtles

Flatback turtles are found only in the tropical waters of Australia, New Guinea and Irian Jaya, and nesting is confined to Australia. While trends in population numbers of breeding flatback turtles are generally uncertain, their numbers are thought to be relatively stable on the Australian east coast including the GBR. Four genetic stocks are recognised, one of which is Eastern Queensland (Limpus 2008). In this group, nesting occurs between Bundaberg and Torres Strait. There is no evidence of a decline in the size of these rookeries over the past 30 years (Limpus 2008) although there is anecdotal evidence of earlier population decline.

All known breeding sites of the flatback turtle are in Australia. Breeding is centred in the southern GBR around Peak, Wild Duck, Curtis and Facing islandsIslands (Figure 6). It is estimated that about 10% of the global population of flatback turtles nest at rookeries on Peak and Wild Duck islands. Peak Island in Keppel Bay and several islands in Gladstone Harbour — Curtis, Facing and Hummock Hill — are very significant nesting sites for flatback turtles. Peak Island is a globally significant nesting site for flatback turtles, and forms one of the two largest nesting populations in eastern Australia. To protect this valuable nesting site the island and surrounding waters are located in a Preservation (Pink) Zone of the GBR Marine Park, with entry prohibited without written permission.

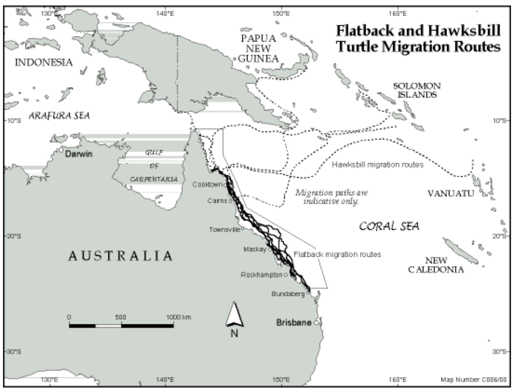

Figure 6. Indicative migration path of flatback and hawksbill turtles through the Great Barrier Reef (Source: www.gbrmpa.gov.au).

Unlike other turtles, flatback turtles do not have an oceanic phase, remaining within continental shelf waters, spending most of their time in sub-tidal soft bottom areas of the GBR, coming ashore to nest on sandy beaches. Flatback turtles feed primarily on soft-bodied invertebrates such as squid, soft corals and jellyfish.

3.3.9. Green turtles

Green turtles are found in tropical and subtropical waters throughout the world. Internationally the population is estimated to be large (about 2.2 million individuals) although there have been severe declines in some countries such as Indonesia. The total Australian population is estimated to be more than 70,000 animals in seven separate breeding aggregations (Limpus 2008). The southern GBR population is increasing (Limpus 2008). Key nesting sites in the southern GBR are found in the Capricorn-Bunker Group (e.g. Heron, Lady Musgrave and Wreck islands in the GBR Marine Park; Wreck Island is protected in a Preservation (Pink) Zone) with other nesting sites at Curtis Island, Facing Island and Mon Repos (on the mainland near Bundaberg). Green turtles spend their first five to 10 years drifting on ocean currents. Once they reach 30-40 cm carapace length they settle in foraging habitats such as coral and rocky reefs and inshore seagrass meadows. Green turtles mainly feed on seagrass and algae. Females reach sexual maturity between 25 and 50 years of age. They migrate from foraging to nesting grounds (on average 400 km), usually returning to the same island beach to nest, between October and March in the southern GBR (Limpus 2008).

3.3.10. Hawksbill turtles

Hawksbill turtles are found in tropical, subtropical and temperate waters around the world, but globally their numbers have been decimated, primarily through hunting for tortoiseshell. Australia has the largest breeding population of hawksbill turtle in the world, with two distinct populations in Western Australia and the GBR. Hawksbill turtles can be found throughout the GBR but primarily nest on islands in the northern GBR and Torres Strait. There is some evidence that the GBR population is in serious decline (Limpus & Miller 2008).

Hawksbill turtles spend their first five to 10 years drifting on ocean currents. Once they reach 30-40 cm carapace length they settle in foraging habitats such as coral and rocky reefs and inshore seagrass meadows. Hawksbill turtles feed almost exclusively on sponges. Females reach sexual maturity after about 30 years. Like green turtles, hawksbill turtles migrate long distances from foraging to nesting grounds (Limpus & Miller 2008).

3.3.11. Loggerhead turtles

Loggerhead turtles are found in tropical, subtropical and temperate waters around the globe. In Australia, loggerhead turtles are found in Western Australia and in the southern GBR, where major nesting areas are concentrated in coastal areas around Mon Repos, the Capricorn-Bunker Group, and islands and cays in the Swains Cays. The Australian population is estimated to be 2 to 4% of the global population (Limpus 2008). Like many other turtles, juvenile loggerheads drift in ocean current for about 15 years before returning to foraging sites. Loggerheads use a wide variety of habitats, feeding on benthic invertebrates such as molluscs. They nest on sandy beaches from November to March (Limpus 2008).

### 3.3.12. Leatherback turtles

Leatherback turtles are oceanic turtles rarely found close to shore, feeding primarily on jellyfish. They feed and occasionally nest within in the GBR, mostly in the southern GBR at Wreck Rock and adjacent beaches near Bundaberg, and only a few females nest in the GBR each year (Lucas et al. 1997). There is sporadic nesting at other widely scattered sites in Queensland. Leatherback turtles nesting in Queensland probably represent strays at the extremes of their ranges, with the survival of the foraging population in eastern Queensland dependent upon the larger, but declining, nesting populations in neighbouring Pacific countries (Limpus 2008).

### 3.3.13. Olive ridley turtles

Olive ridley turtles are the smallest of the marine turtles and live in tropical and subtropical regions of the Pacific and Indian oceans. In Australia, they are found in soft-bottomed, shallow, protected waters from southern Queensland, around northern Australia to Joseph Bonaparte Gulf in Western Australia. They feed in continental shelf waters on food that includes crabs, echinoderms, shellfish and gastropods. Olive ridley turtles do not breed in the GBR but some feed in the GBR lagoon (Limpus 2008).

### 3.3.14. Estuarine crocodiles

Estuarine crocodiles (*Crocodylus porosus*) also occur in mainland estuarine and freshwater environments and in low numbers on islands within the GBR and from inner-, mid- and outer-shelf locations. Estuarine crocodiles inhabit mangrove islands and low wooded islands and are an important part of the Fitzroy Basin region, with small populations known to inhabit the wetlands of the Fitzroy River coastal zone. In Queensland, they occur from Gladstone to Cape York and throughout the Gulf of Carpentaria. At the southern limit of breeding distribution, the Fitzroy estuarine crocodile populations are scarce and recruitment is minimal (Environmental Protection Agency 2007). Although it is generally perceived that the crocodile population has increased since they were protected from commercial hunting in 1974, there is no conclusive evidence to prove this. It is also thought that the proportion of larger crocodiles is increasing.

### 3.3.15. Sea snakes

Seventeen species of sea snakes have been reported in the GBR, and although 48% of the 31 species found in northern Australian waters are endemic, there are no species endemic to the GBR (Weston & Goosem 2004).

**Table 9. Conservation status of marine fauna found in the Fitzroy Basin marine region. (from EPBC website[17] and NCA website[18]).**

| Common name | Conservation status | |
|---|---|---|
| | EPBC | NCA |
| *Marine mammals* | | |
| Dugong | Migratory | Vulnerable |
| Humpback whale | Vulnerable; migratory | Vulnerable |
| Irrawaddy dolphin | Migratory | Near threatened |
| Indo-Pacific humpback dolphin | Migratory | Near threatened |
| Australian snubfin dolphin | Migratory | Near threatened |
| *Marine reptiles* | | |
| Flatback turtle | Vulnerable; migratory | Vulnerable |
| Green turtle | Vulnerable; migratory | Vulnerable |
| Hawksbill turtle | Vulnerable; migratory | Vulnerable |
| Leatherback turtle | Vulnerable; migratory | Endangered |
| Loggerhead turtle | Endangered; migratory | Endangered |
| Olive ridley turtle | Endangered; migratory | Endangered |
| Estuarine crocodile | Migratory | Vulnerable |
| *Seabirds* | | |
| Red-tailed tropicbird | No status | Vulnerable |
| Little tern | Migratory (CAMBA, JAMBA) | Endangered |
| Common, Black-naped and Roseate terns | Migratory (CAMBA, JAMBA) | No status |
| Australian fairy tern | Vulnerable | No status |

[17] http://www.environment.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl?wanted=fauna#mammals_extinct Accessed 2015
[18] http://www.ehp.qld.gov.au/wildlife Accessed 2015

| | | |
|---|---|---|
| Herald petrel | Critically endangered | Endangered |
| *Fishes* | | |
| Sawfish (various species) | Vulnerable | No status |
| Sharks (various species, e.g. speartooth, grey nurse) | Critically endangered | Endangered |

EPBC – *Environment Protection and Biodiversity Conservation Act 1999*; NCA – *Queensland Nature Conservation Act 1992*

3.3.16. Sawfish

Sawfish are inshore specialists with a long, blade-like snout covered with lateral teeth. The restricted habitat range of sawfish and their high vulnerability to net fisheries has resulted in significant population declines for most species over the past 50 years (Pogonoski et al. 2002). Green sawfish (*Pristis zijsron*) were previously found in the Fitzroy estuary but none have been reported as caught in recent years (Eberhard 2012).

3.3.17. Seabirds

The GBR World Heritage Area supports between 1.4 and 1.7 million tropical seabirds that visit the region to feed and roost (Turner et al. 2006; GBRMPA 2008), including 22 species that use the islands and cays to breed (King 1993). Many of these seabird species are resident in the Fitzroy region, while others visit as part of their annual migrations, such as the common tern. Wedge-tailed shearwaters and black noddies nest on all 15 vegetated islands in the Capricornia Cays as well as Lady Elliot Island to the south from October until March (Hemson & McDougall 2013;Figure 7).

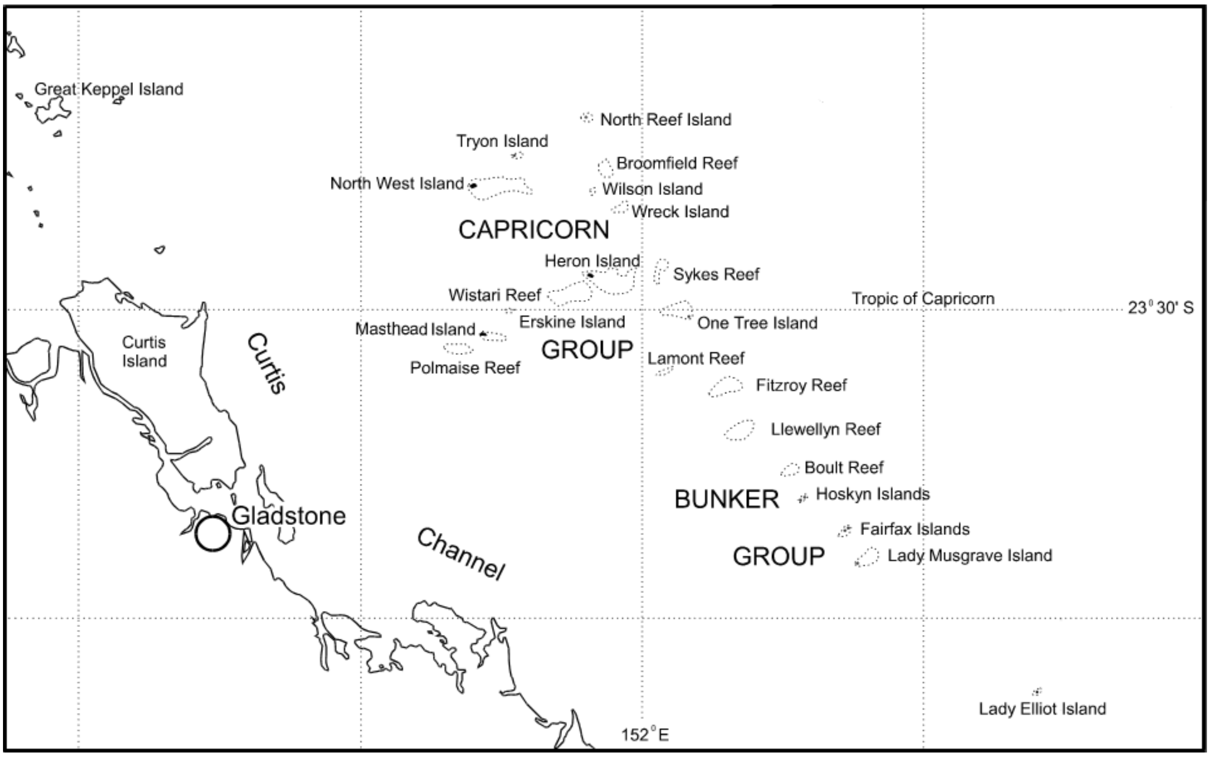


*Figure 7. Seabird nesting islands and cays in the Capricorn-Bunker Group. (From Hemson & McDougall 2013)*

Coral cay vegetation, particularly pisonia forest, provides important nesting sites in the region; however, some changes in nesting numbers and species have been noted in the Fitzroy region, including both declines and shifts in nesting (Table 10). For example, Frigate Cay in the Swains Cays lost vegetation cover in 2009–10 due to tropical cyclone Hamish and did not recover, resulting in a loss of seabird nesting habitat for tern species and more exposed nesting sites for other seabirds, such as boobies. Thomas and Bylund cays (Swains Cays) were also swamped by the storm surge of tropical cyclone Hamish, terminating nesting effort for that year (Driscoll 2013).

**Table 10. Significant seabird nesting sites in the Fitzroy region and noted changes to sites. (From Weeton & Goosem 2004; Turner et al. 2006)**

| Seabirds utilising site | Nesting site | Status change |
|---|---|---|
| Wedge-tailed shearwaters; Black noddy | Capricorn-Bunker islands; Heron Island | • Compromised tree habitats |
| Black-naped tern | Capricorn-Bunker islands | • Nesting failures due to inability to find sufficient food |
| Masked and brown boobies; Tern species (Common, Black-naped, Little, Roseate, Fairy) | Swains Cays (Baron Island, Frigate Cay, Thomas Cay, Bylund Cay) | • Loss of vegetation on all cays except Price and Bell cays<br>• Unvegetated cays support an altered and reduced range of nesting species |
| Little tern | Islands in Shoalwater Bay and Broad Sound area (secondary sites) | • Recent surveys documented increased nesting |
| Australian pelican | Pelican Rock and Akens Island (Shoalwater Bay) (primary sites) | • Vegetation status stable |
| Opportunistic individuals | Riptide Cay (secondary site) | • Sand cay now supports some opportunistic nesting (success unknown) |

Studies of long-term monitoring data of breeding seabirds documented breeding and non-breeding populations of seabirds in the Fitzroy region, as well as some population trends (Driscoll 2013). At Heron Island, wedge-tailed shearwaters use seasonally available prey that decline both seasonally and annually due to changes in productivity at lower trophic levels (Smithers et al. 2003; Peck et al. 2004; Weeks et al. 2013). The Capricorn-Bunker group  has breeding tern and booby species that are also typical of the offshore Swains Cays, as well as the roseate tern and red-tailed tropicbird. In contrast, the common noddy and masked booby are less common. Winter breeding is more common in the Capricorn-Bunker group and total breeding activity has declined in recent years (Driscoll 2013).

The Swains Cays and Bell Cay have generally high levels of breeding activity for many species of seabirds. The species that typically breed in the area are the lesser frigatebird, masked booby, brown booby, common noddy, bridled, black-naped and crested terns (Driscoll 2013). Fairy terns (*Sternula nereis exsul*) nesting in New Caledonia have recently been found to visit the Swains Cays during the non-breeding season (McDougall 2009). Little terns (*Sternula albifrons*) and roseate terns (*Sterna dougallii*) have a breeding population on the GBR that is supplemented by a larger summer non-breeding population that nests elsewhere during the southern hemisphere winter (Higgins & Davies 1996). Roseate terns are relatively common in the Swains Cays but only about 40% breed in the GBR

(O'Neill et al. 1996). Decreases were noted in brown booby and silver gull populations, attributed to reductions in food availability (Heatwole et al. 1996).

Seabirds are relevant to a number of matters of national environmental significance, and many of the region's breeding and non-breeding seabirds are listed threatened species and 23 are listed migratory species under the EPBC Act (Table 10). In addition, the number of breeding seabird species is included in the Statement of Outstanding Universal Value for the GBR World Heritage Area (GBRMPA 2014).

In this time of a changing climate, there is growing concern about seabird species with foraging strategies and prey species that are strongly influenced by climatic conditions, particularly the offshore and pelagic foraging seabirds. In the southern part of the Fitzroy region, there have already been incidences of serious nesting failure of wedge-tailed shearwaters. These failures are closely correlated with reduced availability of their pelagic prey as a result of the El Niño Southern Oscillation cycles and higher than average increases in sea surface temperatures and the interaction between the two (Congdon et al. 2005; Devney et al. 2009b).

Shorebirds feed on the mudflats and beaches of GBR islands and the adjacent mainland. Several species are resident all year and breed on remote island and mainland beaches. Hundreds of thousands of migratory shorebirds from the northern hemisphere use the GBR as a wintering ground, or on passage to and from wintering grounds further south. Many of the shorebirds and seabirds of the GBR are listed under international treaties for the protection of migratory birds (Congdon et al. 2007).

# 4. Pressures and threats to coastal and marine assets

## 4.1. Terrestrial pollutants: declining water quality

The Fitzroy region is a large area that includes six basins (Water Park, Styx, Calliope, Fitzroy, Boyne, Shoalwater and Byfield) with a strong rainfall gradient of low and highly variable annual rainfall. Rivers, particularly the large Fitzroy River, tend to experience irregular flooding (high magnitude but historically low frequency) (Figure 8), and coastal and marine assets are therefore only exposed to flood waters approximately once every 10 years. In the summer of 2010–11 after a long period of low flow conditions in the region essentially dating back to 1991, discharge from many rivers in the central and southern areas of the GBR catchment was more than three times above the median discharge associated with ex-tropical cyclone Tasha (Devlin et al. 2012c). The largest discharges were from the Burdekin, Burnett and Fitzroy rivers (State of Queensland 2013). In 2013, the western part of the region was drought declared, with below average rainfall (State of Queensland 2013), despite the high rainfall in eastern coastal areas following ex-tropical cyclone Oswald.

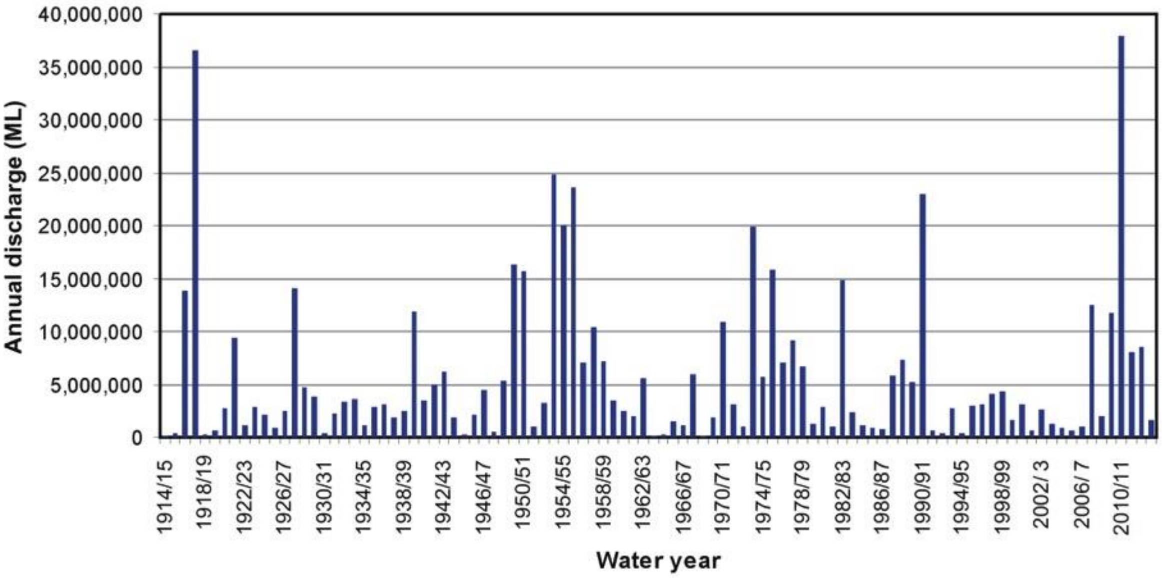


*Figure 8. Annual discharge (ML) for the Fitzroy River at Rockhampton. (From Australian Bureau of Meteorology)*

Changes in inshore water quality have been driven by relatively large fluctuations in chlorophyll *a* compared to total suspended solids (TSS). Chlorophyll *a* was rated as 'very poor' in both 2011–12 and 2012–13 and exceeded the Water Quality Guidelines for a significant period in both the dry and wet seasons. TSS was rated as 'moderate' in 2011–12 and 2012–13 though concentrations exceeded the Water Quality Guidelines for periods during both the 2012–13 dry and wet seasons in 2012–13 (State of Queensland 2013). However, it is now clearly understood that chlorophyll and TSS concentrations derived from the remote sensing algorithms used in the MMP are highly unreliable based on the joint remote sensing evaluation funded by the combined Fitzroy, Burdekin and Cape York WQIPs (Waterhouse et al. 2015), and these assessments for chlorophyll and TSS therefore have low confidence (Maynard et al. 2015; Petus et al. 2015; Waterhouse et al. 2015).

Due to catchment geomorphology and activities, pollutant loads of the Fitzroy Basin rivers are one of the largest sources of suspended sediment to the GBR, as well as delivering significant loads of pesticides and nutrients (Brodie et al. 2013a). Concentrations of particulate water quality variables such as TSS, nitrogen and phosphorous, chlorphyll *a* as well as Secchi depth (a measure of water clarity) have increased in the coastal and inshore areas compared to the offshore lagoon (Brodie et al. 2007; De'ath & Fabricius 2008, 2010; Fabricius et al. 2013, 2014; Logan et al. 2014). This decreased water quality is linked to greatly increased discharges of fine suspended sediment, nutrients and pesticides in the period since about 1830 following agricultural development and associated land clearing in the catchments. It is estimated that TSS loads from the Fitzroy Basin region are now about 3-times higher than pre-1830 (depending on estimation methodology) (Kroon et al. 2012; Carroll et al. 2012; Dougall et al. 2014; Waters et al. 2013, 2014). Dissolved inorganic nitrogen (DIN) is estimated to be twice as high, dissolved inorganic phosphorus (DIP) also twice as high, particulate phosphorus (PP) 3-times higher, and particulate nitrogen (PN) twice as high. Large uncertainties remain in the estimates of increases in current loading compared to pre-European loads due to the uncertainty with estimating pre-European loads. However, more recent results from Source Catchments modelling within the Paddock to Reef Program (Carroll et al. 2012; Dougall et al. 2014; Waters et al. 2013, 2014) are considered robust.

Suspended sediment and nutrient discharges from the Fitzroy Basin originating from agricultural activities (Packett et al. 2009) have been shown to extend for hundreds of kilometres from the river mouth, generally to the north (Figure 9) but also less frequently offshore to the Capricorn-Bunker Group (Byron & O'Neill 1992; O'Neill & Byron 1992; Brodie & Mitchell 1992). The plumes impact directly on the reefs of the Keppel Islands (Packett 2007) with severe effects. The plumes in extreme flow years such as 1991 and 2011, with their low salinity water, fine sediment and nutrient content caused massive mortality in shallow reef biota, including mortality to corals (Tan et al. 2012) but also much of the benthic biota such as molluscs, algae, soft corals, sponges and bryozoans (Coates 1992; van Woesik et al. 1995; Jones & Berkelmans 2014).

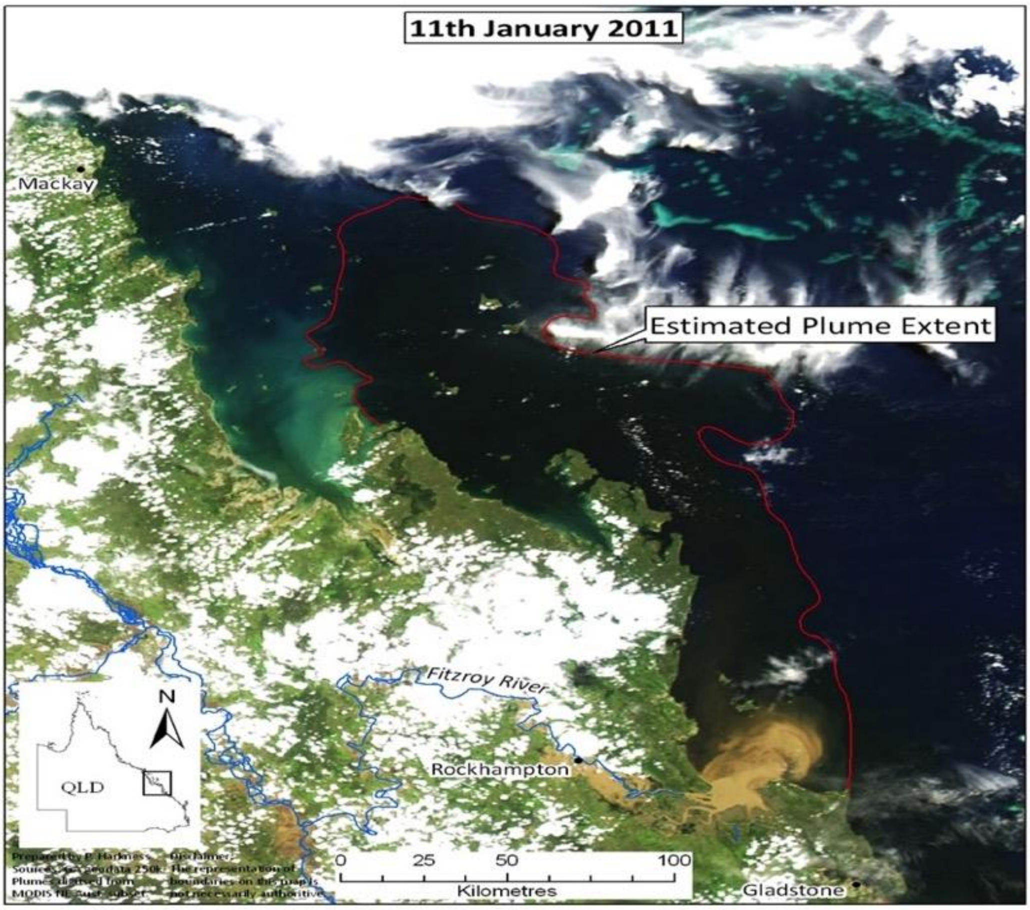


*Figure 9. Estimated plume extent for the Fitzroy River in early 2011. (From M. Devlin supplied 2015)*

The catchment sources of fine sediment, nutrients and pesticides in the Fitzroy region are comparatively well known (see Sources Chapter). The ranking of the relative risk of degraded water quality between NRM regions in the GBR determined the Fitzroy region to be at highest risk with respect to sediment loads and a priority area for water quality management. The region was ranked against other GBR regions as posing the second highest risk to coral reefs from degraded water quality, and the marine area is exposed to very high ecological risk from degraded water quality (Waterhouse et al. 2013).

Pesticide monitoring identified tebuthiuron was the only pesticide that exceeded the Water Quality Guidelines at a routine monitoring site at North Keppel Island, which also exceeded the ANZECC and ARMCANZ Interim Working Level for marine waters. Tebuthiuron is used by the grazing industry and is typically found at elevated concentrations in the Fitzroy region due to the high proportion of land used for grazing activities. A range of other pesticides detected in the Fitzroy region included atrazine and its breakdown products diuron, hexazinone, simazine, ametryn, prometryn and metolachlor (State of Queensland 2013).

The impacts of poor water quality on coral reefs and seagrass beds can manifest as either acute, short-term changes associated with high-nutrient, high-sediment, low salinity flood plumes, or more chronic impacts associated with changes in long-term water quality conditions (Devlin et al. 2012b). Large-scale mortality events associated with flooding have been documented for coral reefs in the Fitzroy region (van Woesik et al. 1995; Berkelmans 2009; Berkelmans et al. 2012; Jones and Berkelmans 2014) and seagrass meadows (McKenzie et al. 2010; McKenzie et al. 2014). Chronic exposure to increased concentrations of nutrients, turbidity and sedimentation can affect the recovery potential and resilience of some species (Fabricius 2011; Thompson et al. 2013). Reduced water quality, including decreased clarity, increased nutrient status (nitrification) and increased pesticide concentrations, is therefore likely to lower reef resilience through three mechanisms.

1. bottom-up enhancement of macroalgal growth (Schaffelke 1999; De'ath & Fabricius 2010)

2. negative impacts on coral physiology (Fabricius et al. 2013; Flores et al. 2012)

3. loss of top-down control of macroalgal abundance through loss or displacement of herbivores.

In summary, the 'very poor' assessment of the coral health index comes after a period of repeated flooding and contrasts recovery of coral cover following previous bleaching events during periods with low river flows. Light reduction as a result of turbidity, increased nutrient supply, along with lower salinity, are all mechanisms that reduce coral fitness or contribute to higher rates of disease in corals (e.g. Fabricius 2005; Voss and Richardson 2006; Haapkylä et al. 2011). In the event of a return to lower flows, the rate at which the current suppression of resilience is reversed will help to assess the longer term impacts of run-off on the ecology of the reefs in this region. However, given the highly variable flow of the Fitzroy River, periods of low rainfall, which in this catchment may reduce vegetation cover and so increase the potential for erosion and mobilisation of catchment soils, will inevitably be followed by large flood events carrying this available material into coastal waters.

The major threats to seagrass have been identified as agricultural run-off, urban/industrial run-off, urban/port infrastructure development, dredging and shipping accidents (e.g. oil spills) (Grech et al. 2011, 2012; Coles et al. 2012). Changes to nutrient dynamics and light penetration in coastal waters have been documented to impact on seagrass extent and condition with continued declines recorded since 2005 (McKenzie et al. 2014). Chronic elevated nutrients lower the availability of light to seagrasses due to increased growth of algae and epiphytes on the plants (Burkholder et al. 2007). Pulsed increases in suspended sediments delivered in river discharge and re-suspension by tides and wind of this sediment throughout the dry season increase turbidity and can reduce light and result in reduced productivity and potential seagrass loss (Waycott & McKenzie 2010; Collier et al. 2015).

## 4.2. Crown-of-thorns starfish outbreaks

The crown-of-thorns starfish (COTS) is a major predator of hard corals and repeated COTS outbreaks on the GBR have been responsible for greater declines in coral cover, particularly on mid-shelf reefs than any other type of disturbance, including cyclones, disease and coral bleaching (De'ath et al. 2012). Present day outbreaks can be influenced by anthropogenic changes (Brodie et al. 2005; Fabricius et al. 2010), including removal of adult predators (Endean 1982), loss of predators of adult COTS (Sweatman et al. 1995) and larval food supply enhancement (Birkeland 1982; Brodie 1992; Brodie et al. 2005; Fabricius et al. 2010; Uthicke et al. 2014; Wolfe et al. 2015).

The Swain Cays in the Fitzroy region have had low-level chronic COTS infestations throughout most of the past three decades, which may be explained by the high density of available coral and upwelling of nutrients through regional oceanography (Thompson et al. 2013). COTS have been recorded in high numbers in the Swain Cays since monitoring began in 1986, with active outbreak levels recorded on one or more reefs in the group nearly every year (Miller et al. 2015). In particular, from 1999 to 2003 COTS activity was high and greatly exceeded outbreak levels across the region. After 2004, COTS activity declined in the Swain Cays and by 2007 no outbreaks were recorded. COTS activity has remained low (below outbreak densities) on Swains Cays since 2007 (Miller et al. 2015). It is considered that COTS outbreaks in the Swains Cays are not driven by anthropogenic terrestrial run-off or secondary outbreaks linked to the COTS outbreak waves that originate offshore from Cairns (Brodie et al. 2005; Fabricius et al. 2010).

A primary outbreak of COTS in the southern Capricorn-Bunker group that was first observed in 2008 and peaked in 2014 does not appear to be correlated with flooding (Miller et al. 2015). Assuming that COTS spawn in December and January in the southern GBR (Babcock & Mundy 1992) there have been a number of occasions over the past 30 years where floods, particularly early season floods, from the Fitzroy River have reached Capricorn-Bunker reefs. These include major early season floods in 1991 and 2011 and minor flood events in 1996, 1999 and 2008. Despite this history of floods, COTS outbreaks have not been recorded from this sector until recently. Capricorn-Bunker reefs may be far enough offshore that they are not exposed to regular flooding.

Instead, the recent COTS outbreak appears to be the result of a combination of life history traits of COTS and prevailing oceanographic conditions (Miller et al. 2015). The hydrodynamics of the area are such that larvae could be dispersed to other reefs in the region, since the Capricorn Eddy contributes to a north-west flow within the region (Griffin et al. 1987). This flow is greater during the summer months when the East Australian Current is stronger and the south-east trade winds are weak (Weeks et al. 2010) and COTS spawning occurs. This effectively puts other reefs in the region "downstream" to those reefs with outbreaks at risk of experiencing a secondary COTS outbreak (Miller et al. 2015). This recent COTS outbreak appears to have declined, with AIMS LTMP surveys in January 2015 recording small numbers of COTS during manta tow surveys of the Capricorn-Bunker or Swain Cays (AIMS online report[19]).

Three decades of monitoring of mid-shelf and offshore reefs in the Fitzroy region shows limited long-term impacts of COTS outbreaks on coral cover or diversity with increasing coral cover observed during 2015 surveys as reefs recover from the effects of COTS outbreaks (AIMS online report[16]). This indicates that these are likely to be naturally-occurring population peaks that have been a part of the ecosystem in the southern GBR for decades. Therefore, any control or management program for COTS is likely to be unnecessary, particularly given the remote nature of these reefs.

## 4.3. Coastal development, ports and shipping

Ongoing and future coastal developments also represent a pressure on Fitzroy marine and coastal assets. While coastal development can directly remove or damage coastal wetlands and inshore seagrasses, changes to environmental planning legislation suggest this is now only likely to occur in conjunction with the construction of major infrastructure projects and/or port expansions. Without planned intervention, coastal development in general can exacerbate the impacts of other pressures on water quality, e.g. sediment movement during the construction phase. In addition, development in low lying coastal areas and/or areas subject to increasing exposure to extreme weather events may also pose a risk to coastal and marine assets.

In the Fitzroy region urban expansion is occurring along the Capricorn Coast from Yeppoon to the south of Emu Park and around the main regional centres of Rockhampton and Gladstone. Further inland towns and regional centres such as Emerald continue to expand cyclically at a rate driven principally by coal mining and gas extraction activities. The Urban Water Quality Improvement Study prepared through the Fitzroy WQIP process includes details on projected population growth and urban expansion with reference to relevant Queensland legislation influencing water quality in urban areas (Gunn 2015).

Port developments can have implications for marine and coastal assets in terms of direct loss of inshore habitats (e.g. seagrasses), and sediment and pollutant inputs to the marine environment. Dredging and dredge spoil disposal produce high levels of turbidity (suspended sediments) in localised areas and in some instances can result in the re-suspension of nutrients and toxicants (Erftemeijer et al. 2012). Acute and chronic sediment exposure may lead to loss of sensitive species, poor coral recruitment, increases in coral disease prevalence and a phase shift from corals to macroalgal communities (Erftemeijer & Lewis 2006; Erftemeijer et al. 2012). Impacts of dredging depend on the proximity of disposal areas to sensitive ecosystems, the potential for dispersal of sediments and sediment qualities. Sensitivity of ecosystems is dependent on their initial condition, resilience and the conditions that they normally experience (Erftemeijer et al. 2012).

[19] http://www.aims.gov.au/docs/research/monitoring/reef/ltm2010-11-12.html Accessed 2015

The Port of Gladstone is a significant coastal facility; it is one of the largest coal export ports in Australia and in 2011 approval was granted for development on Curtis Island of three liquefied natural gas (LNG) processing facilities. Both the Port of Gladstone and the smaller Port of Rockhampton (situated in the Fitzroy River delta at Port Alma) are within the Fitzroy Basin region. The Port of Gladstone was recently expanded to facilitate the new LNG facilities and increase port access by deepening, widening and creating new shipping channels to the Western Basin[20]. Future developments are proposed for the Port of Gladstone including a Channel Duplication Project to allow for two-way passage for ships[21] and land reclamation for a Fisherman's Landing expansion project[22]. Proposals for large-scale development of the Port of Rockhampton to accommodate increased coal exports have recently been suspended[23, 24].

A variety of port and shipping activities, as well as portside industries, can influence port water quality. These activities include capital and maintenance dredging, shipping movements and incidents, construction and maintenance of wharves and in-water structures, and emissions from industries. A separate Ports Synthesis study undertaken as part of the Fitzroy WQIP provides further information on factors specifically influencing water quality in the Ports of Gladstone and Rockhampton as well as describing current water quality monitoring, reporting and management (Flint et al. 2015).

## 4.4. Extreme events: floods and cyclones

Marine assets in the Fitzroy marine region have been exposed to a range of extreme events, including thermal bleaching (Keppel Island reefs 2006), cyclones and storms causing physical damage (2008, tropical cyclone Hamish 2009, ex-tropical cyclone Oswald 2013, tropical cyclone Marcia 2015), and extreme rainfall events (2010, ex-tropical cyclone Tasha 2010–11, ex-tropical cyclone Oswald 2012–13). Direct exposure to low salinity floodwaters due to extreme rainfall associated with ex-tropical cyclone Tasha also reduced coral cover at some reefs to 2 m depth in the Fitzroy region in 2011 (Thompson et al. 2013; Jones & Berkelmans 2014).

Although a relatively weak storm, ex-tropical cyclone Tasha produced widespread torrential rains in Queensland, amounting to more than 250 mm in some areas. Thousands of hectares of cropland were inundated by floods and many towns and cities were underwater including Rockhampton (Figure 10) and Theodore. Much of the area was flooded after the Dawson River reached its highest level in 50 years, cresting at about 14 m. By late December 2010, nearly half of Queensland was flooded with significant environmental as well as infrastructure damage. The Fitzroy River flooded during this period, inundating inshore habitats — coral reefs and seagrass meadows — with low

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[20] http://www.westernbasinportdevelopment.com.au/. Accessed May 2015.
[21] http://www.gpcl.com.au/OperationsDevelopment/ChannelDuplicationProject.aspx. Accessed May 2015.
[22] http://www.gpcl.com.au/OperationsDevelopment/FishermansLandingExpansion.aspx. Accessed May 2015.
[23] http://www.statedevelopment.qld.gov.au/assessments-and-approvals/balaclava-island-coal-export-terminal.html. Accessed May 2015.
[24] http://www.statedevelopment.qld.gov.au/assessments-and-approvals/fitzroy-terminal-project.html. Accessed May 2015.

salinity, high turbidity and pesticides. Impacts in the marine environment were extreme with high coral mortality in the Keppel Island area (Tan et al. 2012; Jones & Berkelmans 2014).

*Figure 10. Rockhampton 2011 flood following ex-tropical cyclone Tasha rainfall (Source: TropWater).*

Significant impacts were also associated with the Category 1 tropical cyclone Oswald in 2013, largely after it was downgraded to a significant rain depression. Awoonga Dam at the top of the Boyne River was measured at 193% capacity and spilled over for about five months following the rainfall associated with ex-tropical cyclone Oswald (GAWB 2013). GBRMPA's Integrated Eye on the Reef monitoring network recorded some damage to reefs from Cairns to the Capricorn-Bunker Group following ex-tropical cyclone Oswald, which traversed down the reef from north to south between 23 and 29 January 2013. The high winds and heavy rainfall associated with this event had the greatest effect on coral reefs and seagrass meadows in southern areas. These effects were primarily due to physical damage from wind and waves. Flooding of the Burnett and Mary rivers to the south as a result of ex-tropical cyclone Oswald influenced the Fitzroy marine area as flood plumes reached inshore reefs (Figure 11).

*Figure 11.Burnett flood plume at river mouth 2013 (Source: M. Devlin)*

In addition to potentially facilitating the persistence of macroalgae within reefs of the Keppel Islands, flooding of the Fitzroy River also appears to have directly stressed the corals across the region. The incidence of coral disease has shown distinct peaks; the first associated with the coral bleaching event in 2006, and subsequent high levels of disease were observed in 2008, 2010, 2011 and 2013 followed extreme flood events (Thompson et al. 2013). The consistent pattern of high incidence of disease among coral communities following each of the recent floods supports the hypothesis that increased availability of organic matter, reduced salinity (Haapkylä et al. 2011), and increased nutrient enrichment (Vega Thurber et al. 2013) facilitate certain types of coral disease. Reductions in light levels over extended periods of time as a result of higher turbidity from increasing concentrations of suspended sediments as well as dense plankton blooms is another plausible explanation for reduced coral fitness (Cooper et al. 2008).

Tropical cyclone Marcia in February 2015 — a category 5 cyclone — passed inland of the Keppel Island Group and is likely to have physically impacted on fringing reefs in those inshore areas. Flooding in the Fitzroy River was significant and the reduced return interval of these events is unprecedented in the past 100 years.

The contrast in the rapid recovery of coral communities in the Keppel Islands after the 2006 bleaching event over a period of two years of negligible river flow compared to the recent lack of recovery highlights the significant role of terrestrial run-off and water quality parameters in the ecology and recovery potential of these reefs. Since the start of the high discharge period in 2008, the compounding effects of additional disturbances such as storms, continued slow rates of cover increase as a result of disease, and competition with the high cover of macroalgae, have led to the decrease in coral health to 'very poor' (Thompson et al. 2013).

Some species however benefit from increased rainfall, particularly those that use estuaries during part of their life cycle, such as barramundi, banana prawns and king threadfin, also important fisheries species in the Fitzroy region. Successful barramundi recruitment depends on the ability of post-larvae, juveniles and adults to migrate between wetland, freshwater and marine environments necessary for each life cycle stage (Moore and Reynolds 1982) and rainfall is a critical influence on the availability of 'swamp habitat' particularly during the early part of the spawning season (Griffin and Kelly 2001). Significant positive relationships have been reported between seasonal freshwater flows and the year-class strength of barramundi in five GBR catchments including the Fitzroy River (Staunton-Smith et al. 2004, Halliday et al. 2012). Sawynok and Platten (2011) reported positive relationships between catch rates of recreationally caught barramundi in the Fitzroy River region and rainfall and riverflow variables, with January rain having the greatest influence. Increases in barramundi commercial catch have been significantly correlated to variations in both river height and rainfall with a one-year lag, suggesting that the previous year's productivity on the flood plain has increased growth of barramundi (Robins et al. 2005, Meynecke and Lee 2011, Halliday et al. 2012).

Biological studies show that banana prawn migration from estuaries is highly correlated with rainfall events (Staples and Vance 1986, Vance et al. 1998), and variations in rainfall can have significant effects on the abundance of adult banana prawns in offshore waters. King threadfin populations are also strongly influenced by rainfall and freshwater river flows (Halliday et al. 2008). Overall recruitment and survival of juvenile king threadfin was consistently and positively correlated to the amount of freshwater flowing or coastal rainfall delivered into the Fitzroy River estuary during spring and summer. This is most likely due to increased biological productivity of the estuary system increasing the availability of food and enhancing growth, decreased salinity resulting in lowered energy budgets, and increased turbidity increasing juvenile survival through reduced predation (Halliday et al. 2008). Possible correlations have also been identified between Spanish mackerel catch and increased chlorophyll-*a* concentrations during the spring spawning season but remain inconclusive (Welch et al. 2014).

Although marine habitats in the Fitzroy region have been naturally influenced by storms, cyclones and flood events for hundreds of years, the projected increase in intensity of these events (Climate Commission 2013) is particularly concerning. Greater impacts coupled with shortened return intervals are likely to hinder the natural recovery cycle, particularly since reefs in the Keppel Islands are genetically isolated (van Oppen et al. 2015) and have been shown to recover from disturbance through robust tissue regeneration (Diaz-Pulido et al. 2009). Cyclone damage is likely to remain a key driving force of change in the GBR in the future (Osborne et al. 2011; De'ath et al. 2012).

Flow-on effects to the marine animals that depend on coral reef and seagrass habitats have also been documented as a result of declining water quality and extreme events. Fish assemblages have been shown to change across water quality gradients (Fabricius et al. 2005) and in response to loss of coral habitat (Halford et al. 2004; Yahya et al. 2011; Wilson et al. 2009; Williamson et al. 2014). High dugong mortality was recorded along the urban coast of the Fitzroy region during the 2011 and 2012 events with 15 and 12 reported deaths, respectively, compared to only three in 2010, and four in 2009 and 2013 (Queensland StrandNet Data 2015). In this same period, 304 turtles (mostly green turtles) were reported as stranded in 2011 and 155 in 2012, compared with 63 in 2010, 39 in 2009 (Figure 12; Queensland StrandNet Data 2015). This increase is believed to be due mainly to starvation associated with extreme events that resulted in the loss of seagrass meadows (Bell & Ariel 2011; Devlin et al. 2012c). Any future declines in seagrass meadows are expected to threaten the viability of turtles and dugong populations (Sobtzick et al. 2012).

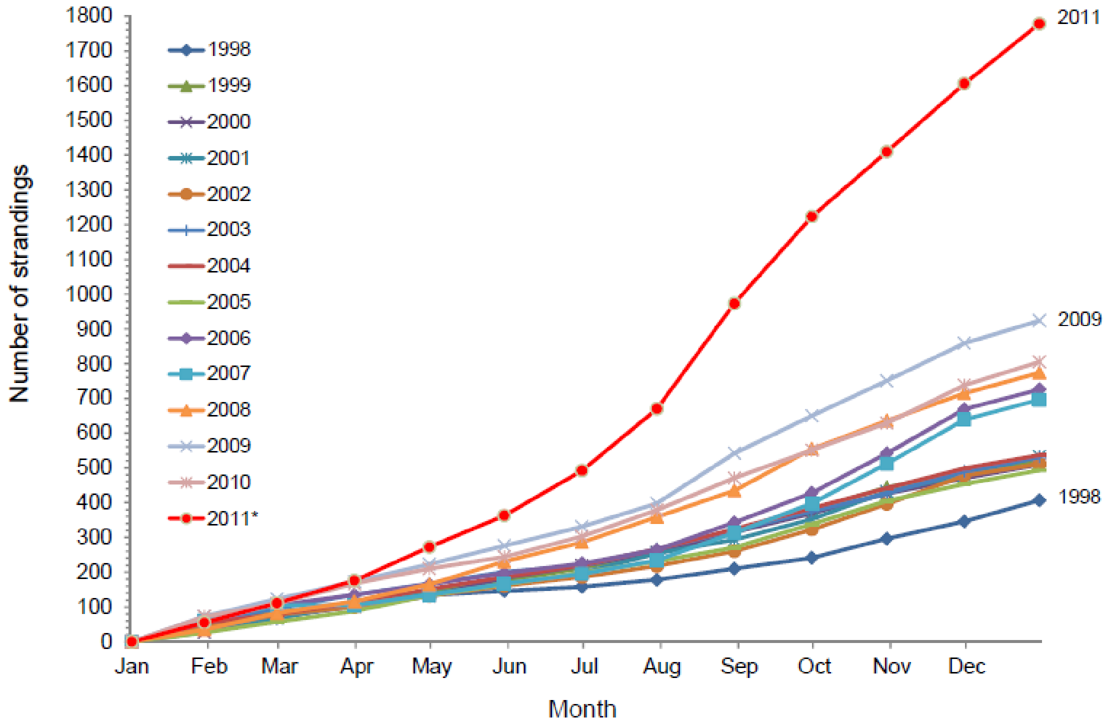


*Figure 12. Monthly cumulative marine turtle strandings in Queensland between 1998-2012 inclusive. (From Meager & Limpus 2012)*

Coastal wetlands are at the land-sea interface and as a result, are at risk from extreme events and sea-level rise. As sea level rises, storm surges will inundate low lying coastal areas impacting on wetlands that are in integral part of the Fitzroy coast (Low 2011). Mangroves have evolved to tolerate and depend on tidal inundation by saltwater. However, they are unable to tolerate complete submersion, and as the frequency and duration of inundation increases with sea-level rise and more intense storms, growth of trees will decline and forests may migrate landward or to higher ground (Waycott et al. 2011). Thus mangrove areas in the Fitzroy region with low tidal ranges, low rainfall and limited sediment supply are more likely to experience retreat of seaward fringing mangroves as sea levels rise (Lovelock et al. 2007; Waycott et al. 2011). This has already been observed in other tropical regions, with the gradual retreat of mangroves in southern Papua New Guinea (PNG) in response to rates of sea-level rise similar to those projected (Valiela et al. 2001), and in Micronesia, where mangrove sediments are not keeping pace with current sea-level rise (Wolanksi et al. 2001).

Landward migration of mangroves is possible in areas with high tidal ranges, high rainfall and high sediment supply providing landward barriers, such as roads, levee banks and developments do not inhibit movement (Sheaves et al. 2007; Waycott et al. 2011). Therefore, landward migration may be inhibited in urbanised and industrial coastal areas around Port Curtis, Port Alma, Yeppoon and Rockhampton.

## 4.5. Climate change: elevated sea temperatures

Periods of higher-than-normal sea surface temperature are stressful to corals and have caused severe and spatially-extensive coral bleaching events in the GBR since the 1980s (Hoegh-Guldberg et al. 2007). Previous mass bleaching events in 1998 and 2002 impacted reefs over broad areas of the GBR but had little impact on reefs in the Keppel Islands in terms of mortality (Berkelmans et al. 2004; Diaz-Pulido et al. 2009). However, reefs in the Keppel Islands experienced significant local thermal bleaching in 2006 that affected 95% of Scleractinian corals and resulted in 15% mortality (Diaz-Pulido et al. 2009). Initial MMP surveys in 2005 documented moderate to high hard coral cover on all the *Acropora*-dominated reefs. In the 2005–06 summer, increased sea surface temperatures led to a severe bleaching event localised to the Keppel Islands resulting in marked reductions in coral cover, in particular Acroporidae, and a resultant bloom of the brown macroalgae *Lobophora variegata* (Diaz-Pulido et al. 2009). Subsequent surveys recorded coral cover increasing post-bleaching, demonstrating the resilience of hard corals in this region to these events (Sweatman et al. 2007).

Modelling of sea temperatures using the IPCC AR5 Representative Concentration Pathways (RCP) predicts that severe effects of increasing sea temperatures will be evident by 2030, with annual bleaching conditions occurring, associated with atmospheric carbon dioxide equivalent concentrations of 510 ppm (under RCP6.0) (van Hooidonk et al. 2013). For the Fitzroy region this means that the reduced return interval of disturbances, particularly coral bleaching, will undermine recovery of reefs.

Thermal stress has also been linked to increased frequency of coral diseases (Selig et al. 2006; Bruno et al. 2007) as well as elevated nutrients (Bruno et al. 2003; Haapkyla et al. 2011). The incidence of coral disease on inshore reefs in the Fitzroy region has shown distinct peaks; the first associated with the coral bleaching event in 2006, while subsequent high levels of disease followed extreme flood events in 2010 and 2011 (Thompson et al. 2013).

Tropical seagrasses can also be impacted by prolonged periods of above-average sea temperatures, as they prefer water temperatures of 25–35 °C. When sea temperatures rise to 35–40 °C, photosynthesis declines due to the breakdown of photosynthetic enzymes (Ralph 1998) and can result in reduced growth rates (Waycott et al. 2011). Although temperature tolerance varies between species and seasons (Perez & Romero 1992; Campbell et al. 2006), overall seagrass can only survive temperatures greater than 40 °C for short periods, and prolonged exposure leads to the 'burning' of leaves or plant mortality (Waycott et al. 2011). Extreme water temperatures (>38 °C) were recorded within the seagrass canopy in 2011–12 across the Fitzroy region, with the highest in March 2012; however, temperatures were on average cooler in 2011–12 than in previous years (McKenzie et al. 2014).

Marine turtles are also affected by increasing sand temperatures on nesting beaches, with successful egg incubation only occurring between 25 and 33 °C (Miller 1985; Spotila & Standora 1985). Incubation near 33 °C results in a high occurrence of hatchling abnormalities, and prolonged exposure above 33 °C typically results in hatchling mortality (Miller 1985). Also, sex determination in turtles is temperature-dependent with a 50:50 male:female sex ratio produced in eggs incubated at about 29 °C, although this differs slightly between species (Mrosovsky 1994; Ackerman 1997). Nests exposed to temperatures above 29 °C produce more female hatchlings, while nests kept below 29°C produce more males (Davenport 1997). There are many important turtle nesting islands and cays in the Fitzroy region, and increasing temperatures due to climate change will have serious implications for their nesting success and population dynamics.

Studies in the Capricorn-Bunker group (Heron Island) and Swains Cays have linked poor seabird foraging and breeding success to localised increases in sea surface temperatures and intense El Niño Southern Oscillation conditions (Smithers et al. 2003; Peck et al. 2004; Devney et al. 2009a; Devney et al. 2010). In addition, long-term increases in air temperature coupled with drought periods are known to contribute to dieback of *Pisonia grandis* on GBR islands, a tree species that is crucial nesting habitat for black noddies and wedge-tailed shearwaters (Batianoff et al. 2010). Collectively this evidence has generated concern regarding the conservation of seabirds in the GBR under a changing climate (GBRMPA 2006).

## 4.6. Cumulative pressures

Analysis of cumulative pressures in the GBR — tropical cyclones, COTS outbreaks and thermal stress — between 2001 and 2011 found some areas of highest relative exposure in the inshore Fitzroy region — Gladstone Harbour (Figure 13; Maynard et al. 2013) — mainly due to thermal stress. There were no areas of lowest relative exposure in the Fitzroy marine region. The Swains Cays were identified as having moderate relative exposure to the cumulative pressures of tropical cyclones, COTS outbreaks and thermal stress (Figure 13), however, the main driver behind this exposure is thermal stress (Maynard et al. 2013).

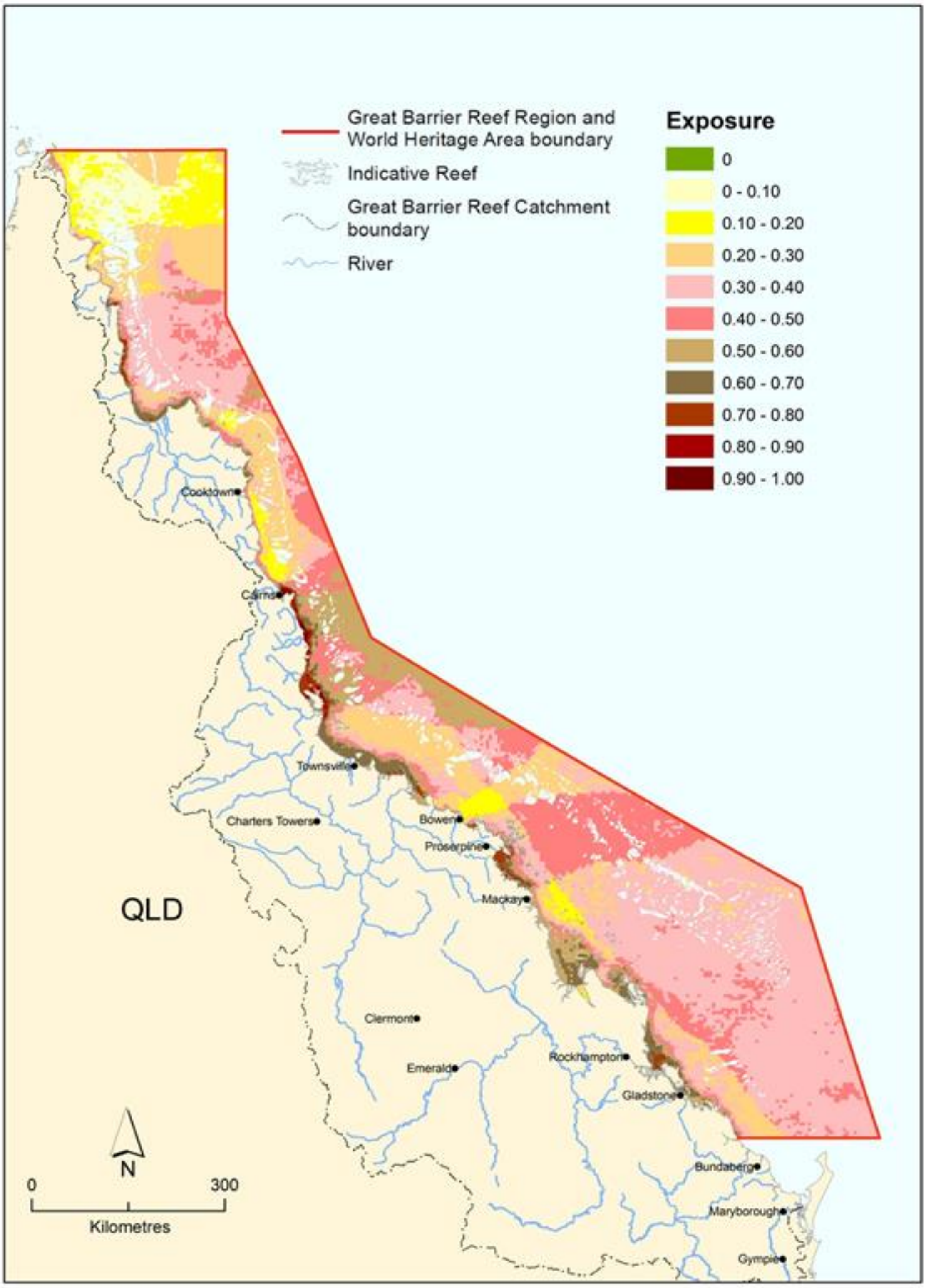


*Figure 13. Exposure of the GBR Marine Park to tropical cyclones, COTS and thermal stress between 2001 and 2011. (from Maynard et al. 2013)*

Assessing the resilience of reefs to cumulative pressures, such as poor water quality, thermal stress and cyclones has been used to target management actions in the Keppel Islands (Maynard et al. 2010). An assessment of 31 sites in the Keppel Islands, with its long history of disturbance and recovery, identified sites that were inherently resilient. North Humpy Island, Pumpkin Passage, West Halfway Island, West Outer Rocks — and sites where resilience could be enhanced through management influence using local resilience-based management strategies — Pelican Island, north-west Barren Island, Forty Acre Paddock, North Humpy Island and Monkey Beach Reef (Maynard et al. 2010). Management strategies initially focused on no-anchoring areas to reduce physical damage with surveys showing reduced anchor damage inside all no-anchoring areas from about 80 instances per 1,000 $m^2$ in 2008 to less than 10 in 2012 (Beeden et al. 2014). As disturbance regimes increase and cumulative pressures impact on marine ecosystems, management of reef refugia will be an important strategy in the region.

Overall, the changing climate as observed and predicted within the GBR will increase the frequency with which coral reefs, seagrass meadows, and coastal wetlands are being disturbed by extreme events such as floods, tropical cyclones and thermal stress. Response to and recovery after these acute events will be exacerbated by chronic poor water quality, which also influences other drivers of ecosystem condition such as COTS outbreaks and disease. The magnitude of impacts and the ability of ecosystems to recover from these events or transition to an alternative state, will depend on: (i) their condition prior to the disturbance, (ii) chronic environmental pressures, such as water quality, and (iii) the return period between events compared with recovery time (Johnson et al. 2013).

# 5. Knowledge gaps and recommendations

The relatively rapid recovery of fringing reefs in the Keppel Islands after the 2006 bleaching event led to the conclusion that frequent, large-scale disturbances may have conferred reefs with the ability to rapidly recover. It was postulated that the region's abundant corals may serve as key refugia or sources of larvae for reef recovery at broader scales. In addition, robust tissue regeneration, high competitive ability of corals, and a seasonal dieback in the monospecific macroalgal bloom was observed to facilitate this recovery (Diaz-Pulido et al. 2009). However, more recent and frequent disturbances by storms and flooding have caused a significant decline in coral cover and condition in the Keppel Island group, highlighting the influence of short return intervals and poor water quality in this decline.

Therefore a better understanding of the actual influence of poor water quality on marine ecosystem condition relative to other threats, such as changing climate drivers and coastal development, and in influencing recovery is needed. It is often difficult to tease out the relative contribution of different pressures on declining habitat condition, and while the De'ath et al. (2012) study made significant progress in this area, it did not explicitly consider poor water quality as a driver of reef change. Without this information, any gains in ecosystem condition as a result of water quality improvements cannot be accurately measured.

To support such an approach, a comparison of the various long-term monitoring data is needed. Currently different methods are used by different groups to undertake reef monitoring, including by the AIMS LTMP, Reef Rescue MMP, Reef Check Australia and the GBRMPA Eye on the Reef Program. The data are collected using different methods — manta tow, video transects, point sampling and rapid assessments — over different time periods and seasons, and at different sites. It is not surprising therefore, that results do not provide a consistent message. To determine the relative contribution of water quality and other drivers of change on ecosystem condition, it is essential that the condition of the GBR ecosystem be consistently monitored and reported.

The health of freshwater and estuarine ecosystems in catchments adjacent to the GBR lagoon also need to be consistently monitored and understood. Improvements in knowledge of the impaired functioning of these systems would help to direct effective on-ground restoration work aimed at maximising improvements in the quality of water entering the reef. Similarly, it is important to better understand the relative contributions to the inshore marine environment of the different sources of pollutants, to best direct management actions and restoration activities. This issue is discussed further in the Ports Synthesis study being undertaken for the Fitzroy WQIP (Flint et al. 2015).

Understanding the environmental conditions that compromise resilience and identifying specific communities or habitats that are on the brink of crossing an ecological threshold are critical for being able to successfully manage pressures on marine ecosystems, including degraded water quality. When such an ecological threshold has been passed, the ecosystem may no longer be able to return to a stable state and this can lead to rapid declines in ecosystem health (Groffman et al. 2006). Identifying thresholds of response when marine and coastal ecosystems decline irreversibly and no amount of water quality improvement will result in ecological benefits will provide valuable information to catchment management.

Addressing water quality will result in improvements to the status and trends of marine and coastal ecosystems in the Fitzroy region, and facilitate enhanced resilience to other threats, such as climate change. The WQIP provides a targeted mechanism for addressing agricultural sediment, nutrient and pesticide inputs to the marine environment. However, it should be recognised that some pressures on marine and coastal assets are beyond the scope of the WQIP and will continue to drive declines in ecosystem condition. Such pressures, for example climate change, need to be addressed through other coordinated inter-governmental initiatives.

# 6. Conclusions

Marine and coastal ecosystems in the Fitzroy region have always been dynamic with periods of recovery and maintenance punctuated by disturbances. Disturbance frequencies have been increasing recently (Climate Commission 2013) and are projected to escalate further in coming decades. Synthesising recent monitoring results for marine and coastal ecosystems in the region provides a snapshot of their current status and trends, and the pressures that will impact on them into the future (Table 11). The assessment is based on currently available information and in cases where information is limited, relies on expert judgement. Table 12 provides a spatial representation of this information for key assets relative to the results of the risk assessment (see Risk Assessment; Waterhouse et al. 2015).

**Table 11. Assessment matrix summarising the current status of and threats to coastal and marine assets in the Fitzroy region.**

| Asset | Value/service | Status* | Trends | Pressures/threats |
|---|---|---|---|---|
| Inshore coral reefs | Tourism, critical habitat, coastal protection & stabilisation | Very poor | Declines due to TC Hamish & flooding in 2010/11, 2013; Coral cover 20%; Limited recovery | Elevated sediment and pesticides, turbidity, freshwater inputs, coastal development/ports, extreme weather (i.e. tropical cyclones, floods), increasing sea surface temperatures (SST) (coral bleaching), ocean acidification |
| Mid-shelf and offshore coral reefs | Reef tourism, critical habitat, coastal protection | Poor | Declines due to tropical cyclone Hamish; Coral cover 10-30%; Signs of recovery | COTS, extreme weather (i.e. tropical cyclones), increasing SST (coral bleaching), ocean acidification |
| Inshore seagrass meadows | Critical habitat (esp. dugong), coastal stabilization, nutrient cycling | Very poor | Declines due to high turbidity and flooding in 2010–11, 2013; Signs of recovery | Elevated sediment, turbidity, low tide exposure, coastal development/ports, extreme weather (floods, cyclones) |
| Mid-shelf and offshore (reef) seagrasses | Critical habitat, nutrient cycling, part of reef matrix | Poor | Recent declines due to low tide exposure; Signs of recovery | Extreme weather (cyclones) |
| Coastal wetlands | Critical habitat, coastal protection & stabilisation, nutrient cycling, aquatic ecosystem protection | Very good to poor (Wetland dependent) | Localised declines in wetland extent; Impacts of catchment activities on water quality | Elevated sediment, nutrients and pesticides, introduced pests and weeds, coastal development, extreme weather (i.e. tropical cyclones, floods, storm surges), sea-level rise |
| Island environments | Tourism income, critical habitat (especially. for seabirds and turtle nesting) | Moderate | Changes to island vegetation and area | Human disturbance, introduced pests, extreme weather (i.e. tropical cyclones), sea-level rise, changing rainfall patterns |
| Dugong | Tourism income, cultural importance, ecosystem role | Very poor | Significant declines due to flooding events in 2010–11, 2013 | Declining seagrass condition, human disturbance/interactions, vessel strikes |
| Marine turtles | Tourism income, cultural importance, ecosystem role | Moderate (Poor for some species that nest on low-lying cays) | Stable | Human disturbance/interactions, declining nesting island condition, increasing air/sand temperatures |

| | | | | |
|---|---|---|---|---|
| Fish/sharks | Commercial and recreational fisheries, herbivore grazing macroalgae, apex predators | Species dependent | Species dependent | Declining habitat condition, unsustainable fishing practices, increasing SST |
| Cetaceans | Tourism income, iconic megafauna, apex predators | Species dependent (consider conservation status) | Stable | Human disturbance/interactions, reduced prey availability, declining habitat condition |
| Seabirds | Tourism income, iconic fauna, apex predators | Species dependent (consider conservation status) | Stable or some species in decline (e.g. common noddy) | Human disturbance/interactions, reduced prey availability, declining habitat condition |

** Status assessment, e.g. RWQPP report card five-point scoring system or expert judgement where not available.*

*Pressures in blue are those that are beyond the scope of the WQIP.*

**Table 12. Spatial assessment of water quality risk to key coastal and marine assets in the Fitzroy region.**

| Marine/coastal asset | Habitat features | Relative risk | Current status* |
|---|---|---|---|
| Shoalwater and Corio bays | Estuarine seagrass; Ramsar wetland; DPA; highly turbid | Very high# | Moderate – Good |
| Keppel Bay (Balaclava Island) | Highly turbid; coastal wetlands | High – Very high | Moderate |
| Curtis Island | Coastal wetlands; inshore seagrass and reefs | High – Very high | Poor |
| Keppel Islands | Inshore fringing reefs; intertidal seagrass | High | Very poor |
| Northumberland Islands (Mackay-Whitsunday region) | Fringing reefs and shoals | Moderate | Moderate |
| Broad Sound | Highly turbid; limited reefs and seagrass | Low – Moderate | Poor – Moderate |
| Percy Islands | Island group with fringing coral reefs | Low | Poor – Moderate |
| Capricorn-Bunker Group | Mid-shelf coral reefs; deep-water modeled seagrass | Low – Very low | Poor |

**Status based on semi-quantitative assessment, e.g. RWQPP report card five-point scoring system or expert judgement where not available.*

*#Very high risk not anthropogenically driven and due to natural high turbidity.*

The threats identified in Table 11 indicate that declines are likely to continue for some marine and coastal ecosystems due to the cumulative pressures of poor water quality, COTS outbreaks, climate change and coastal development. It is for this reason that addressing chronic stressors caused by human activities, such as degraded water quality, are important for maintaining and improving ecosystem condition. Improving water quality can decrease the sensitivity of corals and seagrasses to episodic disturbances when they occur, and improve recovery post-disturbance (Wiedenmann et al. 2012; Thompson et al. 2013). The events of recent years have shown that disturbances can occur in some areas every year for consecutive years and can even occur during the same year. As the return period between disturbances decreases, recovery will depend on maintaining ecological resilience and minimising chronic pressures such as poor water quality.

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# Appendix A: Freshwater, estuarine and coastal marine wetlands

**Table A1: Freshwater, estuarine and coastal marine wetlands of National Importance within the Fitzroy Basin region.** Wetlands marked with an asterix (*) are coastal wetlands, others are freshwater wetlands in inland catchments. The internationally important wetland of the Great Barrier Reef Marine Park is not discussed in this section. (Modified from Directory of Important Wetlands in Australia (DIWA) available at: http://www.environment.gov.au/topics/water/water-our-environment/wetlands/australian-wetlands-database Accessed March 2015).

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| **Boggomoss Springs — wetland area is several hectares, scattered over an area of 400 hectares** | |
| Description | The Boggamoss Springs arise from the Great Artesian Basin where the Dawson River has cut through to the aquifer. Soil types are grey clays and sandy clays, and it is associated with alluvial deposits in the Dawson River alluvial plain. The springs are a source of permanent fresh water (5–10 cm depth) with constant flows that are variable by season and other unquantified factors. The springs have been an important source of water for livestock since settlement of the area. |
| Ecological features | The springs are a good example of active artesian spring wetlands, which are a rare habitat type. They are permanently saturated and provide a habitat type distinct from surrounding regions and also markedly different in terms of floristics and structural features to those associated with other artesian springs. Important plant communities include mixed grassland (*Phragmites* sp., *Paspalum* spp.), sedgeland (*Fimbristylis* spp., *Juncus* spp., *Schoenoplectus* spp.) and forbland (*Utricularia* spp., *Eriocaulon* spp.) and several fern species. The springs represent a rare plant community type. The vulnerable hairy-joint grass (*Arthraxon hispidus*) and several other species of uncertain taxonomic status occur. Notable fauna include undescribed snail species and the Boggomoss snail (*Adclarkia dawsonensis*) which is found only here and is listed as Critically Endangered under the EPBC Act. |
| **Fairbairn Dam — wetland area is 15,406 hectares** | |
| Description | The site is described as Fairbairn Dam to the maximum water level of the impoundment; created by damming a valley of the Nogoa River in 1972. The capacity of the impoundment is 1,440,000 megalitres. The catchment comprises Gindie, Sawyer, Jeffries, Six Mile, Dead Horse and Ram Gully creeks, and the Nogoa River to the south, Borilla Creek to the west, and Anakie, Skeleton and several unnamed streams to the north. Surrounding uplands are gently sloping flats and low hills and the dominant lithology is Tertiary olivine basalt overlying Upper Permian sandstone, with the main area of impoundment comprising Quaternary alluvium. Soils are described as siliceous sands and dark cracking clays. |
| Ecological features | Fairbairn Dam includes deep water habitats and lacustrine wetlands, and in the largely ephemeral environment of the Fitzroy Basin it is an important refuge for waterbirds and aquatic biota. Although artificial it provides the equivalent of a natural lake and swamp habitat. No known notable flora, but the dam is a notable refuge for a wide variety of waterbirds (recorded species list available on the DIWA website). |
| *** Fitzroy River Delta — wetland area is 72,220 hectares** | |
| Description | The delta and coastal floodplain of the Fitzroy River includes marine plain (mostly freshwater) wetlands on the north side of the river, Serpentine Creek, inter-tidal wetlands of Casuarina Island and the estuary mouth, and a ponded salt-field complex. The delta is the culmination of a long (65 km) estuary and consists of an extensive floodplain with oxbows and swamps; supra and intertidal flats and estuary landforms; and chenier deposits. Permanent, shallow, saline marine and estuarine waters subject to tidal influence; shallow, seasonal and permanent freshwater floodplain swamps and lagoons. The chenier deposits occurring in small parts of the lower delta are a rare landform feature and are of significant heritage value and scientific interest. Important for recreational fishing/crabbing, salt production, rail transport, shipping, commercial fishing/crabbing and grazing. |
| Ecological features | Habitat types include freshwater lagoons, woodland and sedgelands, saline coastal flats, mangrove forests, intertidal sand and mud flats, seagrass beds and open marine and estuarine waters, supra-tidal flats. Casuarina Island and the adjacent marine plain comprise networks of flats, channels and marine swamps and patches of semi-evergreen vine thicket (beach scrub) occur on the chenier ridges. At least two mangrove species (*Bruguiera exaristata* and *Xylocarpus australasicus*) are near the southern limit of their distribution. Seagrass beds and mangrove communities are an important habitat for a variety of marine fauna species. Some areas of slightly higher ground (subject to inundation) have remnant woodland of old-growth coolabah *Eucalyptus coolabah* and forest red gum *E. tereticornis,* which have |

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| | been extensively cleared from floodplain systems in the bioregion. Basins on the serpentine plain component of the site support beds of sedge. Despite hydrological changes due to river regulation and local ponding, much of the deltaic wetland complex of the Fitzroy River has, to date, escaped the major impacts of agricultural and industrial development and provides a good example of a major estuarine system. Use of low-salinity and freshwater wetlands in the site by waterbirds includes some breeding (including small colonies). Migratory shorebirds use these wetlands as well as intertidal mudflats in seaward sectors of the estuary. Seagrass beds and mangrove communities provide important habitat for marine fauna. The channel provides habitat for several species of inshore dolphins, marine turtles and estuarine crocodiles. It is likely that the area is an important nursery habitat for a variety of fish, including barramundi *Lates calcarifer*, as well as crustaceans and includes the Fitzroy River Fish Habitat Area. Surveys of waterbirds in 1994 recorded over 7600 waterbirds of 49 species including a number of species protected under the EPBC Act 1999 and listed under JAMBA/CAMBA (e.g. Latham's snipe *Gallinago hardwickii* and marsh sandpiper *Tringa stagnatilis* at freshwater sites). Magpie geese *Anseranas semipalmata*, grey teal *Anas gracilis*, plumed whistling-duck *Dendrocygna eytoni* and black-winged stilt *Himantopus himantopus* are the most abundant species. The largest concentrations (hundreds) of red-necked avocet *Recurvirostra novaehollandiae* in the lower Fitzroy River district tend to be in saline ponds of the delta, in the late dry season. The beach stone-curlew *Esacus neglectus* also occurs, as does the Critically Endangered (EPBC Act) Capricorn yellow chat *Epthianura crocea macgregori,* in sedge or other saline swamps of the site floodplain. Large colonies (> one million) of flying foxes, including the little red flying-fox *Pteropus scapulatus*, black flying-fox *P. alecto* and the vulnerable grey-headed flying-fox *P. poliocephalus* occur in the mangroves. |
| **Fitzroy River Floodplain — total wetland area is a few hundred hectares and the ephemeral floodplain covers 19,485 hectares** | |
| Description | The site comprises the Fitzroy River and associated floodplain wetlands, bounded by Gracemere and Gavial Creek in the south and Yaamba in the north. It includes 81 identified water bodies including permanent, seasonal and intermittent oxbows, waterholes and swamps, as well as the Fitzroy River channel and its backwaters. The Fitzroy is a large, permanent, freshwater river; its lower non-tidal reaches are maintained at a high level by a barrage forming prominent backwater wetlands. The dominant landform is a broad floodplain with a meandering main channel, numerous oxbows, billabongs and floodplain swamps. A feature of the floodplain is numerous natural levees/scrolls, often in parallel series, which trap water from wet season floods to form elongated wetlands. Major floods of the Fitzroy River may inundate the entire floodplain. Most of the floodplain is very highly valued grazing land for beef cattle. The main Fitzroy River channel is valued for water-skiing and fishing; the conservation and research values of the remnant vegetation of parts of the floodplain, notably the Long Island Bend forests, is very high due to the disturbed nature of the majority of the floodplain. |
| Ecological features | Heavily modified (cleared and grazed) floodplain, up to the stream banks in most situations, with riparian zone and original vegetation severely depleted. Main vegetation communities on the river banks and floodplain are *Eucalyptus coolabah* open woodlands, E. *tereticornis, Corymbia tessellaris* and open forest, *Melaleuca leucadendra* fringing forest, and various combinations. Some sedgeland and aquatic macrophytes associated with lagoons, but most are heavily disturbed. Weeds are present but riverine forest persists in backwaters of the Fitzroy River itself. Though impacted by urban development, agricultural and water use practices and invasive species, the site retains a functional, extensive and diverse system of wetlands that is representative, and arguably the best example, of floodplain wetlands in the bioregion. It supports a high number of waterbird species (61 species recorded and 21 species breeding), including threatened species. Endangered (EPBC Act) Australian painted snipe (*Rostratula australis*) have been recorded, as have some of the largest concentrations (well over 1% of the total population) of cotton pygmy-goose (*Nettapus coromandelianus*) in Australia. Small numbers of freckled duck *Stictonetta naevosa* have been recorded at times of widespread inland drought. Probably an important nursery area for fishes and the channel has a small population of estuarine crocodiles. |
| **Hedlow Wetlands — wetland area is 11,093 hectares** | |
| Description | The wetlands extend from Black Mountain-Mount Hedlow in the south to the floodplain beyond Mount Atherton in the north and include creeks, lakes, waterholes and an extensive area of ephemeral floodplain. The southern section is associated with a cluster of prominent volcanic plugs. The wetlands include several small, deep, permanent, freshwater lakes and lagoons and some semi-permanent freshwater swamps and marshes. Most of the area is low lying and becomes inundated for short periods in most years and in very wet years inundation may be prolonged for several months. Hedlow Creek may meet floodwaters of Limestone Creek, Werribee Creek and other creeks before spreading westward in a poorly defined watercourse to eventually join Alligator Creek, and the Fitzroy River at South Yaamba. Most of the area is regarded as an important cattle grazing resource and there is significant scientific and conservation interest in waterbird populations in the area. |
| Ecological features | The Hedlow Wetlands provide a good and rare example of a floodplain complex in the middle reaches of a small river system. The wetlands are similar to the Fitzroy River Floodplain in that they provide significant habitat for waterbirds (40 species recorded). The area may be a major source for southward dispersal of species such as the cotton pygmy-goose *Nettapus coromandelianus*: the population in the Hedlow-Fitzroy-Capricorn Coast wetlands may represent up to one third of the total Australian population. Most of the (formerly extensive) *Melaleuca* spp. woodlands and *Eucalyptus tereticornis* open forests and woodlands have been cleared. *Eleocharis* spp. sedgelands form the dominant community and are an important habitat for some fauna; mixed species grasslands occur on ephemerally flooded areas; many exotic plant species are encroaching, or have been deliberately planted (some weeds, others forage species). |

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| **Lake Elphinstone — wetland area is 300 hectares** | |
| Description | Lake Elphinstone is formed in a depression on a sandstone surface. The lake is partially dammed at its overflow on the southern end and the overflow creek drains through a gorge cut through the sandstone of the Carborough Ranges to join the Isaac River. The catchment is localised and is drained by several unnamed streams. Lake Elphinstone is a source of the Isaac River and itself sources water from run-off and stream flow from the local catchment; however, it is possible that there may also be an underground supply to the lake. Most of the lake is shallow (less than 2m deep) but water levels fluctuate seasonally. The lake has been a source of water for some local requirements and for coal mines. The south-western section of the lake is used for camping, recreational boating and water-skiing when there are no toxic algal blooms. |
| Ecological features | Lake Elphinstone includes lacustrine and palustrine habitats, forested wetlands with emergent and aquatic beds. The lake provides an outstanding and easily accessible example of the geomorphological effects of changes in stream competence on a landscape. Extensive aquatic and emergent beds provide a food source for a wide range of water birds. The lake is the largest natural freshwater body in central Queensland and provides drought refuge and probably breeding sites for a range of fauna. The majority of the lake's margins are occupied by emergent wetlands dominated by sedges or grasses. Notable flora species recorded in these areas include *Diplachne parviflora*, *Leptochloa fusca*, *Paspalum distichum, Bothriochloa decipiens, Cyperus scariosa, C. alopecuroides, C. difformis, C. polystachyos, Ludwidgea octovalvis, Phyla nodiflora, Pomax umbellata, Eclipta prostrata* and *Pterocaulon sphacelatum*, as well as *Melaleuca leucadendra* and *Lophostemon grandiflorus*. In drier areas *Eucalyptus platyphylla, E. tereticornis Corymbia trachyphloia, M. nervosa* and *Pleiogynium timoriense* become prominent. The understorey of these wooded areas is similar to the emergent wetlands described above. Aquatic beds dominate the shallow, rarely exposed portions of the lake. Species recorded in these beds include *Potamogeton crispus*, *Myriophyllum verrucosum*, *Charas* sp. and *Hydrilla verticillata*. The site is known to be a breeding area for the black swan (*Cygnus atratus*) and the brolga (*Grus rubicundus*). A list of the bird species recorded at Lake Elphinstone can be found on the DIWA website. |
| **Lake Nuga Nuga — wetland area is 2070 hectares** | |
| Description | Lake Nuga Nuga is a large water body in an otherwise semi-arid area. It lies in the broad valley between the Expedition and Carnarvon ranges with Mount Warrinilla at its northern end, in the catchment of Brown River together with a number of streams that drain north-east out of the Carnarvon Range, and streams draining south-west out of the Expedition Range. Landform is levee, drainage depression, stream channel, stream bed, flood-out, back-plain, lake and swamp. The lake is supplied principally by run-off, flood-out and stream flow from the catchment. Water depth is mostly below 2 m with a maximum of 9 m. Cultural values include some Aboriginal sites in the area. |
| Ecological features | The following habitats are recognised at Lake Nuga Nuga: open water supporting extensive aquatic bed; some saline shrubland; and lake margin. Aquatic bed communities are dominated by *Nymphaea* sp. and species such as *Acacia harpophylla* and *Casuarina cunninghamiana* occur on the margins. Significant use of the lake is made by waterbirds such as pelicans and cormorants and the lake is an important refuge in a dry landscape. |
| **Palm Tree and Robinson Creeks — wetland area is 50,223 hectares** | |
| Description | The Palm Tree and Robinson creeks wetland (in the Dawson catchments of the Fitzroy Basin) is characterised by a series of shallow lakes and seasonal streams at a creek junction. The catchment includes Robinson Creek and a number of other minor streams that drain out of the Murphy and Lynd ranges to the south and west of the site, and Palm, Box, Champagne, Punchbowl and Little Tualka creeks that drain out of the Gilbert Range to the south and east of the site. Landforms include flood-out, drainage depression, stream channel, stream bed, swamp and lake. The water supply is principally run-off and stream flow from the catchment. Water depth is shallow, seasonally variable and semi-permanent. Social values include a water resource for stock, recreational and scenic values. |
| Ecological features | The wetland habitats comprise seasonal and semi-permanent pools and provide a good example of a type of seasonal and semi-permanent wetland. Notable species include groves of *Livistona* sp. (unnamed) and the wetland is a breeding area for water birds. |
| *** Shoalwater Bay Training Area (SBTA) Overview — wetland area is 270,451 hectares** | |
| Description | The SWBTA encompasses the Shoalwater Bay and the Dismal Swamp-Water Park Creek area, in addition to other areas. It is bisected by steep mountain ranges, which divide the coastal plains into western, central and eastern sections. A large part of SWBTA drains directly to the sea in Shoalwater Bay, Port Clinton or Island Head Creek. Also drains to Broad Sound, the Fitzroy River, and freshwater stored in the sand mass drains into Water Park Creek (part of the Capricorn Coast's water supply). Peak flows occur in the wet season. Within the marine area there are two large islands, Townshend and Leicester as well as several small islands, numerous shoals and sand bars. Parabolic dunes and parallel beach ridges cover an area of 16,700 hectares and act as a reservoir for fresh water draining from springs within and on the perimeter of the sand mass. There is an unusually high tidal range (approaching 7 m) and strong currents create a high sediment load and result in constantly changing sand and mud shoals. Tidal races can occur in Canoe Passage and Strong Tide Passage. The freshwater wetlands of SWBTA are associated with these coastal sand dunes and cover an area of 2000 ha. Swamps include the low-lying inter-dune areas replenished by rainfall and local run-off and a few small perched lakes, located in the Dismal Swamp sector. Apart from the perched lakes, the swamps of the area are found in low-lying areas, generally in inaccessible locations, close to the coast. There are also spring-fed swamps fed by perennial steams draining from the sand mass. These can be divided into those on the coastal side of the dunes |

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| | (e.g. Freshwater Swamp) and those located on the inland side (e.g. Dismal Swamp). The area has significant cultural importance and members of the Darumbal Noolar-Murree Aboriginal Corporation regularly visit the site to renew their cultural affiliations, under an arrangement with the Department of Defence. An archaeological survey of SWBTA located aboriginal heritage sites throughout the area and identified the coastline and creek and swamp margins as Core Habitation Zones, where the highest densities of aboriginal archaeological sites were recorded. |
| Ecological features | The SWBTA is one of the few large estuarine systems with a largely undisturbed catchment. Consequently the creeks, streams, estuaries and bays have very low levels of pollution and the swamps and dunes of the SWBTA form part of a coastal wilderness area that remains in a relatively undisturbed state. The marine areas represent a valuable reference site for comparison with other sections of the Queensland coast, which may be affected by urban and agricultural development. The low levels of nutrients present in the spring water and the generally low fertility of the sand dunes results in the freshwater swamps supporting low numbers of birds, fish and other freshwater fauna. Vegetation also consists of species well adapted to the low fertility of the dunes. The marine areas of SWBTA are composed of a wide range of marine habitats that include very significant areas of seagrass and mangroves. The coastal and marine sections are Wetlands of International Significance under the Ramsar Convention. The terrestrial areas of the SWBTA are listed on the Australian Register of the National Estate. The marine area supports 23 species of mangroves and 10 species of seagrass. A feature of, and the dominant species in, the coastal freshwater swamps is the peat-forming sedge *Empodisma minor*. In closed sedgelands it forms a dense wall over 2 metres tall, in association with *Gahnia sieberana*. In open water bodies the sedge *Lepiporonia articulata* forms the dominant species with *Restio pallens* on the shoreline. Species that occur in the closed sedgeland communities include *Sowerbaea subtilis*, *Lycopodiella serpentina* and *Schizaea malaccana*. The marine area contains a high diversity of marine and estuarine fish species with 445 species (16% of Australia's known species) recorded. EPBC Act listed species include marine turtles and dugong. The area supports shorebird numbers in excess of 20,000 in summer, and about 16,000 during winter. The mangrove, tidal mudflats and salt flats are important habitats for local and migratory shorebirds with substantial numbers of 16 species of holarctic breeding, migratory waders, and 26 and 27 species protected under the JAMBA and CAMBA treaties respectively being recorded from the area. The area has been identified as being of particular international importance to the eastern curlew (*Numenius madagascariensis*), the whimbrel (*Numenius phaeopus*) and the great knot (*Calidris tenuirostris*), all of which occur at numbers exceeding 1% of their population in the East Asian-Australasian Flyway. Sandy beaches support significant numbers of the beach stone-curlew (*Esacus neglectus*), listed in Queensland as vulnerable. |
| *** Shoalwater Bay — wetland area is 122,561 hectares** | |
| Description | The Shoalwater Bay site comprises a complex, continuous wetland aggregation formed in a large shallow marine embayment and includes associated coastal islands. The catchment is that of Ross, Rocky, Mooly, Rasberry and Louisa creeks and a number of unnamed streams. Landforms include: tidal flat, intertidal flat, supratidal flat, bar, beach, tidal creek, estuary, drainage depression, stream channel and swamp; uplands are flats, beach ridges and hills with high relief. Shoalwater Bay is a large shallow embayment. The shore is lined mostly with recently emerged (c. 3 m, Holocene) coastal deposits. Most are modern and superficial and overlie largely metamorphic rocks of the Shoalwater Formation. Areas of older sands (Tertiary to Quaternary) occur on the southern and western sides of Shoalwater Bay. The islands are predominantly quartz, greywacke, mudstone and rare chert of the Paleozoic Shoalwater Formation. The dune areas are composed of siliceous sands (quartzipsamments), while the soils of the intertidal areas and the mangroves are largely undescribed. Water is supplied by marine and estuarine waters that flood the bay, intertidal flats and channels. During wet season events the tidal creeks are diluted by freshwater flooding and stream flow from the catchments. The maximum depth in the bay is about 20 m but is mostly less than 11 m. The area is part of the traditional lands of the Darumbal Aboriginal people. The area contributes to the production of important regional commercial fisheries and the low level of disturbance and natural richness of the site makes it particularly important as a benchmark for scientific research. The area was acquired by the Department of Defence in 1965 for military training purposes and access to non-military personnel is restricted. A State marine park occurs on the site, which also includes portions of the Shoalwater and Corio Bays Area Ramsar Site and two Dugong Protection Areas. |
| Ecological features | Five wetland habitats occur within the bay, or adjacent to it: (i) shallow open water systems including seagrass beds; (ii) rocky marine shores, beaches, bars, etc; (iii) lower intertidal mudflats; (iv) mangrove communities; and (v) supratidal flats. The Shoalwater Bay site is a particularly good example of a shallow marine and estuarine wetland type within the Central Queensland Coast bioregion. It is particularly significant because of the extent and richness of the marine and estuarine habitats due to the extreme tidal range (7.24 m), the sheltered environment of these habitats and the relatively undisturbed nature of the area. The site is also a part of the greater Shoalwater Bay Training Area, which is the largest coastal wilderness area between southern New South Wales and the Cape York Peninsula. The area is distant from the effects of large rivers with highly disturbed catchments and the local catchment is well protected. Rich aquatic beds of seagrass extend to depths of c. 20 m because of the clarity of the water and eight species of seagrass have been recorded: *Halodule uninervis, Halophila ovalis, H. spinulosa, H. ovata, H. decipiens, Zostera capricorni, Halodule pinifolia* and *Cymodocea serrulata*. In addition, 43% (18 of 39 species) of all mangrove species recorded in Australia are noted as occurring in the area including golden mangrove fern (*Acrostichum speciosum*), *Acanthus ilicifolius*, black mangrove (*Lumnitzera racemosa*), milky mangrove (*Excoecaria agallocha*), *Xylocarpus granatum*, river mangrove (*Aegiceras corniculatum*), myrtle mangrove (*Osbornia octodonta*), club mangrove (*Aegialitis annulata*), |

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| | *Bruguiera exaristata*, *B. gymnorhiza, Ceriops australis, C. tagal, Rhizophora apiculata, R. stylosa, Scyphiphora hydrophyllacea*, *Sonneratia alba* and grey mangrove (*Avicennia marina*). The Shoalwater Bay site contains a high diversity of marine and estuarine fish (428 species). 16 species of holarctic breeding, migratory waders have been recorded with numbers for six species exceeding 1% of their population in the Asian-Australian flyway. The area is internationally identified as important to the eastern curlew (*Numenius madagascariensis*), whimbrel (*N. phaeopus*) and great knot (*Calidris tenuirostris*). Significant numbers of the beach stone-curlew (*Esacus neglectus*) occur in the area. A total of 26 bird species listed under JAMBA, and 27 species under CAMBA occur. Populations of green turtle (*Chelonia mydas*), loggerhead turtle (*Caretta caretta*), hawksbill turtle (*Eretmochelys imbricata*) and flatback turtle (*Natator depressus*) occur. The area supports the largest feeding population of green turtles on the east coast of Australia. It also contains the most extensive area of dugong (*Dugong dugon*) habitat in the Mackay-Capricorn section of the Great Barrier Reef. The estuarine crocodile (*Crocodylus porosus*) is reported to occur in low numbers. |
| *** Corio Bay Wetlands — wetland area is 6,914 hectares** | |
| Description | Corio Bay is a complex, continuous aggregation of marine, estuarine and freshwater wetlands, formed in a shallow embayment with shallow marine waters and a large intertidal zone, fringed by freshwater swamp and seasonally inundated areas. The catchment is that of Station Creek and a number of unnamed streams draining out of the Coast Range, and Water Park Creek, which receives water from a large number of streams draining out of elevated country to the north. Dominant landforms are tidal flats, intertidal flats, supratidal flats, beach, tidal creeks, estuary, drainage depressions, stream channels, swamps and lakes. During wet season events the tidal creeks and estuaries are diluted by freshwater flooding and stream flow from the catchments. Water in the bay is saline and mostly shallow (< 5 m) with a few deeper channels. A levee bank at the southern reaches of Fishing Creek restricts tidal influence and impounds freshwater. Freshwater inflow into the area is thought to be present through most years. The bay is an important area for recreation, particularly fishing and contributes to the productivity of regional commercial fisheries. It is important as a benchmark for research because of the relatively undisturbed habitats. |
| Ecological features | The Corio Bay site is a good example of a complex of marine, estuarine and freshwater wetland types. It is significant for the diversity of habitat, due to the extensive areas either tidally influenced or subject to freshwater inundation and the corresponding diversity of the associated fauna. The bay is an important nursery for juvenile fish and crustaceans. Five wetland habitats occur: shallow estuarine waters; intertidal areas both unvegetated and with mangroves; beach and strand communities; saltwater meadow and marshlands; freshwater swamps and seasonally inundated areas. Grasslands, mixed sedgelands and open forests to low open woodlands occur above the tidally inundated areas all around the bay. Important communities include: open coastal dune forest communities (26 species); closed coastal dune forest communities (59 species); modified inland dune forest communities (22 species); closed grassland/open forest (48 species); freshwater swampland (32 species); closed swampland (16 species); and drainage channel forest (20 species). The freshwater wetlands are dominated by grasses, some ferns (notably *Acrostichum speciosum* and *Blechnum indicum*), and sedges. There is notable diversity in the brackish and saline marsh flora with species including *Acrostichum speciosum, Baumea juncea, Crinum pendunculatum, Fimbristylis ferruginea, F. polytrichoides, Hibiscus tiliaceus, Ischnostemma cornosum, Limonium australe, Livistona* sp., *Paspalum vaginatum, Salicornia quinqueflora, Sesuvium portulacastrum, Sporobolus virginicus, Suaeda arbusculoides, S. australis* and *S. maritima*. Mangrove species present reflect the influence of freshwater in the estuarine areas and include *Acanthus ilicifolius, Aegialitis annulata, Aegiceras corniculatum, Avicennia marina, Bruguiera gymnorhiza, Ceriops tagal, Excoecaria agallocha, Lumnitzera racemosa, Rhizophora stylosa* and *Xylocarpus granatum*. The site is important for a variety of fauna including water birds (species list available on the DIWA website). A Corio Bay Fish Habitat Area covers areas below high water mark of the bay, Water Park and Fishing creeks and the site includes part of the Shoalwater and Corio Bays Area Ramsar site. |
| *** Dismal Swamp-Waterpark Creek — wetland area is about 1000 hectares spread over the Water Park Creek catchment of 11,694 hectares** | |
| Description | Dismal Swamp and Water Park Creek are composed of a local catchment supporting a range of wetland types with similarities to the more extensive sand mass wetlands of south-eastern Queensland (such as Fraser Island). The wetlands include permanent, seasonal and ephemeral creeks with clear (white) water, some contracting to a string of permanent waterholes during dry periods; permanent dune lakes and large swamps, some (e.g. Dismal Swamp) heavily stained with organic acids (black water). Water Park Creek is an important source of fresh water for the Capricornia Coast population centres. The area is popular for recreation and the high degree of naturalness, presence of threatened species, and species at distributional limits (especially those adapted to sand mass acidic/oligotrophic wetlands) make the area highly valuable for scientific research. The northern section is within the military training reserve. |

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| Ecological features | The wetland is part of the greater Shoalwater Bay area. Habitats include swampland, open, closed and shrubby sedgeland, significant open water (lake) habitat, and open water habitat surrounded by sedgeland and woodland/heathland (in the dune lakes). Dismal Swamp and some of the dune lakes are oligotrophic, supporting relatively little aquatic macrophyte vegetation and few fish species. *Eucalyptus tereticornis* and *Melaleuca leucadendra* closed and open forests surround the wetlands. Low closed mangrove forest occurs on the lower reaches of Water Park Creek where it becomes part of the Corio Bay wetland. Notable flora include the vanilla lily (*Sowerbaea subtilis*), swamp orchid (*Phaius tancarvilliae*), bog clubmoss (*Lycopodiella serpentina*) and comb fern (*Schizaea malaccana*) in the closed sedgeland communities. A large number of plant species are at or near the limit of their distributions in this area. Sixteen species of freshwater fish, in 10 families, have been recorded in the Shoalwater Bay Training Area and most of these would be present in the Water Park Creek-Dismal Swamp area. An outlying population of the vulnerable honey blue-eye (*Pseudomugil mellis*) occurs in Dismal Swamp and the sand dune lakes, and is at the northern extremity of its restricted distribution here. Oxleyan pygmy perch (*Nannoperca oxleyana*) may also occur in these oligotrophic wetlands. The riparian billabongs provide restricted foraging habitat for the fishing bat (*Myotis adversus*), and the southern section of the site includes a small section of the Corio Bay Fish Habitat Area. |
| *** Island Head Creek-Port Clinton Area — wetland area is 27,033 hectares** | |
| Description | A group of shallow embayments and estuaries with sandy beaches, rocky headlands, extensive tidal flats, mangroves and adjacent freshwater swamps; which is part of the much larger aggregation of the Shoalwater-Corio Bay area. Coastal dunes with Quaternary aeolian sands; Quaternary/Tertiary alluvial and marine deposits in coastal swamps and sand flats; recent and Quaternary estuarine and marine deposits in sand/mud flats and mangrove swamps; adjoined by Peninsula Range Volcanics (Permian/Cretaceous) and Shoalwater Formation (Lower-Middle Devonian). Soils are predominantly sands and uniform saline clays (muds). Wetlands include permanent, shallow, saline bays and estuaries; permanent and semi-permanent shallow freshwater swamps and dune lakes. Tidal range in Port Clinton can be > 5 m and water tends to be turbid, especially during periods of high tidal range. The major source of freshwater input to Port Clinton is Sandy (Cowan) Creek, which arises to the south and is fed by groundwater from the Manifold Hills sand mass. The site is part of the greater Shoalwater Bay Training Area. The area is distant from the effects of large rivers with highly disturbed catchments, and the local catchment is well protected. It includes significant Aboriginal cultural heritage values, and is highly valued area for scientific research due to its naturalness and the presence of such a diversity of tropical/subtropical/temperate flora and fauna. Military training, grazing and commercial fishing/crabbing occur. |
| Ecological features | The wetlands are in an overlap zone between several bioregions, and many species are at or near the limits of distribution. Species of the semi-arid Brigalow Belt occur in association with coastal, tropical and subtropical species. At least 18 species of mangroves are known from the Shoalwater Bay area, the greatest diversity of which occurs in the Island Head Creek-Port Clinton area. Notable flora that are likely to occur include the vanilla lily (*Sowerbaea subtilis*), swamp orchid (*Phaius tancarvilliae*), bog clubmoss (*Lycopodiella serpentina*) and comb fern (*Schizaea malaccana*). The Clinton Lowland provides potential habitat for the vulnerable honey blue-eye (*Pseudomugil mellis*) and endangered oxleyan pygmy perch (*Nannoperca oxleyana*). 71 species of marine fish reach their distributional limits in the Shoalwater Bay area; 13 commercial fisheries species have strong mangrove habitat associations; and four species of marine turtles occur: loggerhead (*Caretta caretta*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*) and flatback (*Natator depressus*). Numerous migratory and sedentary shore and other waterbirds occur in the area including the beach stone-curlew (*Esacus neglectus*) and 27 JAMBA and CAMBA species. At least six species of shorebirds occur in numbers greater than 1% of national and international populations. The dense mangrove swamps provide potential habitat for the vulnerable water mouse (*Xeromys myoides*). |
| *** Iwasaki Wetlands — wetland area is 646 hectares** | |
| Description | This site is a southern extension of the Corio Bay wetlands, and is an extensive area of wetlands linked to Corio Bay by Fishing Creek. It supports large colonies of waterbirds throughout most of year and is probably one of the largest privately owned wetland complexes in Australia. Landforms include large, shallow, freshwater marshes and ponds mostly protected from saltwater intrusion by an extensive system of bund walls. Inundation of freshwater areas is more or less permanent, although most dry out during severe drought. It also contains shallow, saline marshes and mangrove swamps with tidal influence. The water quality is recorded as being very good. These wetlands are a major tourist attraction for the owners of the Iwasaki Resort (now Mercure Capricorn Resort) and surrounding area. The area is a popular recreational destination for the local population and has significant scientific values. Uses include recreation (fishing, boating, bushwalking), conservation, extensive grazing on modified and native pasture and broadacre agriculture. |
| Ecological features | Extensive freshwater and saline wetland habitats with distinct boundaries provide habitat for large numbers of waterbirds and shorebirds, as well as many opportunities for research, recreation and tourism. Extensive freshwater marshes are dominated by grasses with lesser areas of freshwater sedge marshes, large areas of mangrove shrubland and closed forest, bare saline clay pans and saltmarsh with halophytic grasses and samphires. The grass and sedge marshes provide significant breeding habitat for numerous waterbirds; mangroves provide habitat and breeding ground for marine fish and invertebrates; mangroves, saltmarsh and salt flats provide important habitat for migratory and other shorebirds; flora is almost entirely native, with very few incursions of exotic species. The area is a breeding site for large numbers of waterbirds including magpie geese (*Anseranas semipalmata*), black swans (*Cygnus atratus*), brolgas (*Grus rubicundus*) and cotton pygmy |

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| | geese (*Nettapus coromandelianus*). Significant populations of migratory birds, listed on the JAMBA and CAMBA use the area on their annual migrations. The beach stone-curlew (*Esacus neglectus*) also occurs in the area. |
| *** Yeppoon-Keppel Sands Tidal Wetlands — wetland area is 10 144 hectares** | |
| Description | The site is an area of disjunct coastal wetlands between Yeppoon and Keppel Sands on the Capricorn Coast. This coastline features sandy beaches, rocky headlands, offshore islands, shallow bays, mangrove-lined estuaries, salt flats and saltmarsh, and freshwater marsh and forest. Soils are predominantly sandy with some mud fraction. Permanent, shallow, saline tidal waters occur throughout the area; slightly higher tidal saltmarshes and clay pans are occasionally inundated; and small areas of permanent and semi-permanent freshwater marsh occur, especially where bund walls have been created to keep back saltwater. There are significant freshwater inputs to the Cawarral Creek system and Causeway Lake and water quality is generally good although there is some pollution from stormwater and effluents. Most of the wetlands in this group are popular for fishing and crabbing, the Capricorn Coast is a popular tourist destination, Ross Creek is used by many locals as a boat anchorage and the area has significant Aboriginal cultural value. The site includes Bell Park, which is listed on the Queensland Heritage Register. Uses include urban development, recreational fishing/crabbing, road transport and extensive grazing on native and modified pasture, intensive plantation agriculture and quarrying. |
| Ecological features | The wetlands in this aggregation provide a relatively undisturbed habitat in an otherwise highly disturbed and increasingly populated area. The major habitat types are mangrove closed forests and shrublands with a diverse invertebrate fauna; saltmarsh with a variety of halophytic grasses, low shrubs and forbs; bare sand flats exposed at low tide; bare saline clay pans; estuarine waters and shallow embayments; freshwater swamps and occasionally inundated palm forest. At least 10 species of mangroves occur in the area, some of which are approaching their distributional limits (e.g. *Xylocarpus australasicus*); mangrove communities provide an important breeding area and habitat for fish and invertebrates; extensive stands of cabbage palm (*Livistona* sp.) occur in freshwater areas adjacent to Cawarral Creek, some of which are under occasional tidal influence. The area includes the Cawarral Creek Fish Habitat Area. Numerous commercial and recreational fisheries species live and breed here; and the beach stone-curlew (*Esacus neglectus*) has been recorded on beaches and sand flats. Colonies of flying foxes (*Pteropus scapulatus, P. alecto* and the vulnerable *P. poliocephalus*) occur in the mangrove areas. |
| *** Port Curtis — wetland area is 31 232 hectares** | |
| Description | The site includes all tidal areas in the vicinity of Gladstone, from the southern end of The Narrows to Canoe Point, including the seaward side of Facing Island and Sable Chief Rocks, and southern Curtis Island west of North Point. Partially enclosed embayment and shallow estuaries, including small, continental rocky islands, intertidal flats and estuarine islands. The geology consists of two main groups — Holocene estuarine deposits (lowlands), and Wandilla and Shoalwater formations; both Devonian (islands and coastal hills), plus relatively smaller areas of Holocene tidal delta sands and beach ridges near the mouth of the Boyne River, and Pleistocene alluvium, associated with the Boyne and Calliope rivers. It includes permanent, shallow estuarine and marine waters; significant freshwater input is from Calliope and Boyne rivers; elevated natural turbidity occurs throughout the area; water quality is generally good, though several point sources exist for sewage, stormwater and industrial effluents. Several sites of high archaeological significance occur on Facing Island, and a number of shipwrecks are also found along the coast. Gladstone Harbour is the major port of central Queensland — 20% of Queensland's and 5% of Australia's export revenue is earned through this port. The area provides an important access to the Great Barrier Reef and has a developing tourism industry particularly at offshore islands (Capricorn–Bunker Group). The harbour facilities and other infrastructure in Gladstone continue to provide incentive for major ongoing industrial development. Major uses are shipping, industrial and urban development, commercial and recreational fishing/crabbing, boating, camping, extensive grazing, conservation and habitat protection. |
| Ecological features | There are extensive mangrove forests and shrublands (3300 ha), seagrass beds (2430 ha) and salt flats (2800 ha) in Port Curtis. Mangroves exhibit distinct banding from seaward to land — *Avicennia* spp. fringe on the seaward margin through a *Rhizophora* zone (main zone) a *Ceriops* zone on the coastal salt flat to a *Ceriops* fringe (between salt flat and terrestrial vegetation). Seagrasses are generally intertidal due to the natural turbidity of the waters. The most abundant species is *Zostera capricornia*, with *Halophila ovalis* and *Halodule uninervis* also common. Coastal salt flats are mostly bare clay pan, with lesser areas ranging from low/dwarf open halophytic shrubland (e.g. *Sarcocornia* sp. and *Suaeda* spp.), to open and closed grasslands dominated by sand couch (*Sporobolus virginicus*). Seagrass beds provide habitat for commercially fished crustaceans, as well as being the preferred feeding grounds of several JAMBA and CAMBA migratory waders including eastern curlew (*Numenius madagascariensis*), grey-tailed tattler (*Heteroscelus brevipes*), terek sandpiper (*Xenus cinereus*) and bar-tailed godwit (*Limosa lapponica*), and dugong (*Dugong dugon*) and green turtles (*Chelonia mydas*). The seagrass species *Halophila tricostata* is at the limit of its distribution, as are several species of mangrove: *Acanthus ilicifolia, Avicennia eucalyptifolia, Xylocarpus australasicus* and *Bruguiera exaristata*. A significant algal reef community occurs along the outside of Facing Island. A number of birds listed under JAMBA and CAMBA occur throughout the area; high tide roosts for large colonies of waders occur at Chinaman Island, the ash ponds in Gladstone, and the western side of Facing Island. The main feeding areas for these waders are the Targinie and Pelican Banks intertidal flats. Significant fauna include beach stone-curlew (*Esacus neglectus*), radjah shelduck (*Tadorna radjah*), eastern curlew (*Numenius madagascariensis*), chestnut teal (*Anas castanea*), little tern (*Sterna albifrons*), sooty oyster-catcher (*Haematopus fuliginosus*) and black-necked stork (*Ephippiorhynchus asiaticus*). Port Curtis includes major nesting sites (25–50 individuals per year) for the endemic flatback turtle (*Natator depressus*) on the ocean beaches of Facing Island and southern Curtis Island, while green |

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| | turtles (*Chelonia mydas*) nest infrequently in the area. Loggerhead (*Caretta caretta*) and hawksbill (*Eretmochelys imbricata*) turtles also frequent the area. Significant coral reefs occur at Sable Chief Rocks, Manning Reef and Farmers Point. Colonies of flying foxes (*Pteropus scapulatus, P. alecto* and the vulnerable *P. poliocephalus*) occur in some the mangrove areas. |
| *** The Narrows — wetland area is 20,903 hectares** | |
| Description | The site is the passage between Curtis Island and the mainland, including the tidal wetlands on north-western Curtis Island, and Graham Creek east of Deception Creek. Landforms include the tidal passage between the mainland and a continental island, supra and intertidal flats and estuary landforms. Significant oil shale deposits are found below the more recent sediments. The Narrows include permanent, shallow, saline marine and estuarine waters with freshwater inflows from creeks on Curtis Island and the mainland. Several registered sites of Aboriginal significance occur along The Narrows and it is a major commercial and recreational fishing and crabbing area. |
| Ecological features | Habitat types include: saline coastal flats; mangrove forests; intertidal sand and mud flats; seagrass beds; and open marine and estuarine waters. The Narrows is an unusual landform feature, being one of only four tidal passages in Australia. At least two mangrove species (*Bruguiera exaristata* and *Xylocarpus australasicus*) are at or near the southern limit of their distribution in The Narrows. The *Xylocarpus australasicus* here appears to be a hybrid between *X. australasicus* (southern limit Mackay) and *X. granatum* (northern limit Maryborough). Seagrass beds are an important habitat for various fish and invertebrate species, as well as feeding grounds for dugong (*Dugong dugon*) and marine turtles: loggerhead (*Caretta caretta*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*) and flatback (*Natator depressus*). Inshore dolphins occur in the area as do a number of migratory waders protected under JAMBA and CAMBA. Beach stone-curlew (*Esacus neglectus*) have been recorded on Black Swan Island. The estuarine crocodile (*Crocodylus porosus*), though rarely sighted, is near its southern limit in this area. The site includes a portion of the Fitzroy River Fish Habitat Area on the north-western side of Curtis Island. |
| *** North-east Curtis Island — wetland area is 9541 hectares** | |
| Description | The site is the north-eastern side of Curtis Island, between Cape Keppel and Cape Capricorn, incorporating the extensive marine plain south of Yellow Patch Inlet, and also Rundle Island. It is a shallow embayment some 20 km long, with small rocky headlands at each end, small estuaries, offshore islands and sandbars, coastal lowlands, a parabolic dune system and exposed sand mass. The bay and estuary are fringed largely by mangroves, behind which there is a 4000 ha marine plain, which is tending to the southern limit of such habitat. Waters are permanent, shallow, saline estuaries and embayment, tidally inundated salt flats, shallow, intermittently inundated marine plain (saline and freshwater marsh), and an extensive bund wall preventing tidal influence from Yellow Patch Inlet has been breached so that the marine plain is still tidal. A number of Aboriginal shell middens occur in the area. The historic lighthouse at Cape Capricorn is listed on the Queensland Heritage Register. The site is an important grazing resource and has significant tourism/recreation values (e.g. estuarine boating and fishing). There is a popular and spectacular mooring site in Yellow Patch Inlet, and Yellow Patch sand blow is a significant landscape feature. |
| Ecological features | Mangrove forest and shrubland forms an extensive fringing community along the estuaries and protected coastline of the bay with distinct banding from seaward to land: *Avicennia* fringe on the seaward margin through a *Rhizophora* zone (main zone), a *Ceriops* zone on coastal salt flat, to *Ceriops* fringe (between a salt flat and terrestrial vegetation). The most prominent feature of this wetland site is the vast (4000 ha) marine plain, which represents the southern limit of this habitat type; the marine plain supports swampy or mixed grassland, dominated by green couch (*Cynodon dactylon*), *Paspalum* sp. and *Digitaria* sp., often in pure swards. The extensive marine plain provides unique grassland communities near the southern limit of this habitat type; these also provide a major habitat for two species of birds (the Critically Endangered Capricorn yellow chat (*Epthianura crocea macgregori*) and the zitting cisticola (*Cisticola juncidis*)) as well as feeding and roosting habitat for the radjah shelduck (*Tadorna radjah*), several hundred brolga (*Grus rubicundus*) (permanent residents) and several thousand magpie geese (*Anseranas semipalmata*) (seasonal vagrants). The red goshawk (*Erythrotriorchis radiatus*), black-necked stork (*Ephippiorhynchus asiaticus*) and little bittern (*Ixobrychus minutus*) have also been seen in the area. Osprey (*Pandion haliaetus*) and beach stone-curlew (*Esacus neglectus*) occur on Rundle Island, which has a fringing coral reef. The area supports a variety of flora and fauna, both terrestrial and marine, some of which are threatened species. The extent of the marine plain, at the southern limit of the habitat type, the presence of threatened fauna, migratory waders, notable landscape features and the overall near-natural condition of the area in general combine to make this site a highly significant wetland at the regional, state and national levels. The site includes a section of the Fitzroy River Fish Habitat Area. |

Our country, Our future.

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