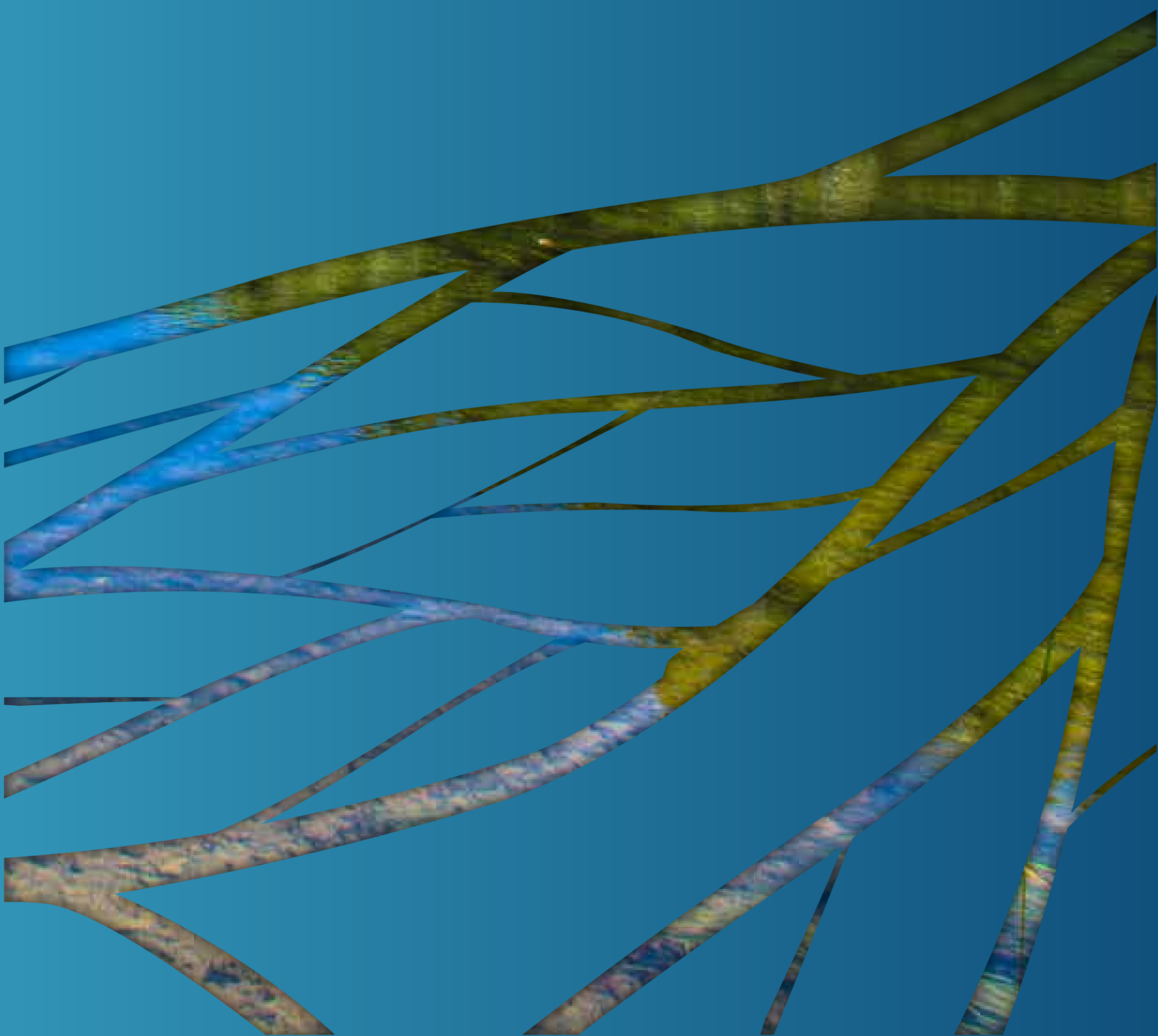
Southern Gulf NRM

CLIMATE CHANGE IN THE SOUTHERN GULF REGION:

A background paper to inform the Southern Gulf Natural Resource Management Plan



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DISCLAIMER

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Australian Government

Climate change in the Southern Gulf region:

A background paper to inform the Southern Gulf Natural Resource Management Plan

Gabriel Crowley
April 2016

EXECUTIVE SUMMARY

The region

The Southern Gulf region is situated in the far north-west of Queensland and covers all catchments that drain into the southern Gulf of Carpentaria between Karumba and just west of the Northern Territory border.

Land systems of the region are mostly extensive plains and dissected uplands in the south-west, around Mount Isa.

Only around 5% of the native vegetation of the region has been cleared, mostly for urban and agricultural development. The remaining native vegetation, mostly comprising tropical savannahs, grasslands and extensive coastal wetlands remains largely intact although disturbed by grazing and land degradation, in particular weed invasion.

The dominant land use in the region is cattle grazing undertaken on freehold land (chiefly in the south east of the region) or leasehold land (the remainder). The Boodjamulla National Park is a significant feature of the north west of the region. Land reserved for nature conservation has increased in recent years with the addition of new nature refuges and Indigenous Protected Areas.

Communities and Industries

The population of the Southern Gulf region is low and dispersed. Indigenous people make up approximately 22% of the population of the 35,000 people living in region. There is less than one person per square kilometre throughout the region, with the lowest densities in the Burke Shire and McKinlay Shire, and highest densities in the Doomadgee Aboriginal Shire and on Mornington Island.

Indigenous disadvantage in the region is high. The Indigenous unemployment rate in 2011 was approximately 23%, roughly 10 times that for non-Indigenous people. Private sector employment of Indigenous people is one third that of non-Indigenous people.

Only a small proportion of pastoralists across northern Australia possess characteristics to make them resilient to major stresses and upheaval: strategic planning skills; sound business management principles; preparedness to experiment and try new ideas; and strong links with industry and community networks.

Mining, cattle grazing, fishing and tourism are the region's most important industries. Each of these industries is subject to global fluctuations in commodity prices, leading to rapid changes in the economic fortunes of the region with associated social impacts. At a community level, the Southern Gulf has only moderate resilience.

Climate Change

The climate of the Southern Gulf region ranges from semi-arid environment in the south to semi-humid in the north. Most rain falls between November and March. The region is hot and humid, with mean maximum temperatures at Mount Isa approaching 40°C in summer and mean minimum temperature exceeding 10°C in winter. Summer maximums frequently exceed 40°C.

Rainfall is highly variable. In about one-third of years, rainfall falls short of the average by more than 100 mm, and exceeds the average by at least 100 mm in another third.

The impact of climate change is becoming evident in the region. Average temperatures in the Southern Gulf region have increased by more than 1.5°C since 1910. At Camooweal, the number of days hotter than 40°C have doubled from about 20 per year to about 40 per year over the same period.

High variability makes any trend in rainfall difficult to discern. However, despite recent droughts, Southern Gulf's wet season rainfall in the last 20 years was very much above the long-term average.

Predicted future change in the region's climate is that:

- Average temperature will continue to increase in all seasons
- There will be more hot days and warm spells
- Changes in rainfall are possible but unclear
- Extreme daily rainfall events will be more intense
- Mean sea level will continue to rise and the height of extreme sea level events will also increase
- There will be fewer, but more intense tropical cyclones

Climate Change and Biodiversity

The Region supports diverse ecosystems, wetlands and threatened species. Species considered a priority for climate change are those which have been assessed as vulnerable to climate change and for which the Southern Gulf region provides significant habitat. Southern Gulf species considered a priority for climate change action are:

Marine:
Australian snub-fin Dolphin, Green Turtle, Green Sawfish

Riparian:
Gulf Snapping Turtle, Freshwater Sawfish, Red Goshawk, Star Finch.

Terrestrial mammals:
Julia Creek Dunnart, Carpentarian Antechinus

Terrestrial birds:
Kalkadoon Grasswren, Night Parrot, Gouldian Finch.

Plants:
Pink Gidgee, Solanum sp.

Numerical modelling to predict climate change impacts on biodiversity in the Southern Gulf region tends to be less reliable than in other parts of Australia because of the relatively low density of weather recording sites in and near the region and because of relatively fewer biodiversity records that provide the basis for predictive modelling. In this situation, expert assessment is necessary to supplement and validate numerical models.

The Southern Gulf region contains three of the ten Australian ecosystems that are considered most vulnerable to climate change, namely saltmarsh and mangroves, near-coastal wetlands and tropical savannas. Indeed, very little of the region does not fall into one of these categories.

Refugia providing opportunities for plants and animals to minimise the adverse impacts of changing climate are very important priorities for conservation effort in response to climate change. In the Southern Gulf region, higher elevation (thus cooler and free of flooding) areas and floodplain (thus generally wetter and more humid) areas are among the most important refugia.

The region's vegetation communities are also expected to be influenced by climate change. Increased temperatures, intensity of wildfires, cyclones and flooding, and carbon-dioxide fertilisation (favouring shrubs and trees over tropical grasses), along with uncertain changes in rainfall, are expected to cause a reshuffling of plants and animals to create new ecological communities. These communities are still expected to have a recognisable savanna character. However, weeds are expected be favoured by disturbance caused by increased wildfire and cyclonic damage. Modelling based on current vegetation extent and moderate and extreme climate change scenarios indicates large shifts in vegetation will occur by 2070, however caution is required in the interpretation of the models because of the limited amount of baseline data.

Because climate change is likely to affect the nature and distribution of biodiversity in the region, it is necessary to take these changes into account in determining priority areas for future protection or investment. The Queensland Department of Environment and Heritage Protection used a combination of biodiversity records and expert opinion to identify Strategic Investment Areas (SIAs), which are either hubs, which are core areas of high biodiversity value, or corridors, which are interconnecting areas that provide migration pathways between the hubs.

Environments that are in good condition are most able to survive climate stresses. Therefore, the best way to instil climate change resilience in terrestrial environment in the Southern Gulf is to continue investing in best practice grazing, weeds, pest and fire management; and to encourage conservation agreements over high-conservation value area. For marine conservation, climate change resilience will be enhanced by efforts to reduce predation on turtle nests, reduce marine debris and improve the sustainability of commercial and recreational fishing.

Climate change and human capacity and community well-being

Climate change will directly affect the capacity of Southern Gulf natural resource managers to institute best practice production management and to address threats to biodiversity. Predicted increases in temperature of 1-2°C by 2030 will have adverse effects on human health in general and affect the ability of people to work outdoors.

Natural disasters (droughts, floods, cyclones and wildfires) also increase the risk of physical injury and damage and destruction of property. Economic disparity means that Indigenous communities in the north of the region will be particularly vulnerable to climate change. Also, high levels of debt in the pastoral industry are likely to hamper the ability of some pastoralists to cope with an increasingly severe climate.

The increasing stress climate change is expected to place on the natural resources will necessitate changes in management. An assessment of pastoralists in northern Australia concluded that only a small proportion of landholders are equipped to make the necessary adjustment.

Climate change and cultural heritage

Climate change has serious implications for cultural heritage. Many aspects of the natural environment that are vulnerable to climate change are culturally significant. Waterways and wetlands, in particular, hold special meaning for Indigenous people as ceremony and story places. They also provide food, medicines and materials for arts, crafts and livelihoods. Access to water and freshwater environments is pivotal for future Indigenous economic development.

Climate change and livelihoods

Impacts of climate change on the environment and human health and well-being will flow on to impacts on livelihoods. Pastoral operations will be affected by heat stress on cattle, degradation of resources (water, soil and grass) as a result of CO_2 fertilisation (which reduces the nutritional value of the grass), temperature increases, increased disturbance from floods and wildfires, and opportunistic spread of weeds and cattle ticks.

Building climate-resilience NRM enterprises starts with making appropriate decisions about land use and water allocation. Once established, enterprises can prepare for climate change by adopting management practices that increase efficiency of resource-use to minimise the impact of water, grain or grass shortages. Pastoral enterprises that use moderate stocking rates are more profitable through periods of dry weather than are those that overstock, and are most likely to perform well in difficult years.

As climate change is driven by increasing greenhouse gases, there is a market for management that reduces greenhouse emissions or store carbon. Natural resource management eligible for funding under the Australian Government's Emission Reduction Fund (ERF) includes tree planting, avoiding vegetation clearance, reducing methane emissions from agriculture and burning of savannas to reduce extent of late dry season fires. Carbon credits generated from these activities can be sold to the Government at auction or to other buyers on the open market. There are two forms of emission reduction that have potential in the Southern Gulf region; herd management to reduce methane emissions and savanna burning. Tree planting, regrowth and avoided deforestation are not applicable because of low biomass production of the region's woodlands

In addition to emission reduction, the conservation economy offers opportunities for improving the economic resilience of individuals, enterprises and the economy of the Southern Gulf. The conservation economy is particularly important for Indigenous communities.

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THE SOUTHERN GULF REGION

Environment

The Southern Gulf region is situated in the far north-west of Queensland and covers all catchments that drain into the southern Gulf of Carpentaria between Karumba and just west of the Northern Territory border (Figure 1). The region contains four distinct landscapes: coastal plains, eastern uplands, Mitchell Grass Downs and Northwest Highlands[1]. Low-lying plains dominate the north, and are comprised of the Gulf Plains bioregion and a small section of the Gulf Coastal bioregion in the Northern Territory. All Southern Gulf river systems drain on to these plains, with their channels increasingly anastomosing as they reach the coast. Inland, the plains are vegetated by extensive grasslands and low open eucalypt (Eucalyptus and Corymbia) and Melaleuca woodland. Floodplains contain chains of seasonal and permanent wetlands (Figure 2). The coastal vegetation includes extensive mudflats, which can be bare or support saline grasslands and saltmarsh communities. Mangroves line the coast and estuarine environments.

In the east of the region, the upper reaches of the Flinders River drain the Undara-Toomba basalts of the Einasleigh Uplands and White Mountains at the north-western corner of the Desert Uplands. These upland areas are vegetated with dry rainforests, eucalypt woodlands and low Acacia woodlands.

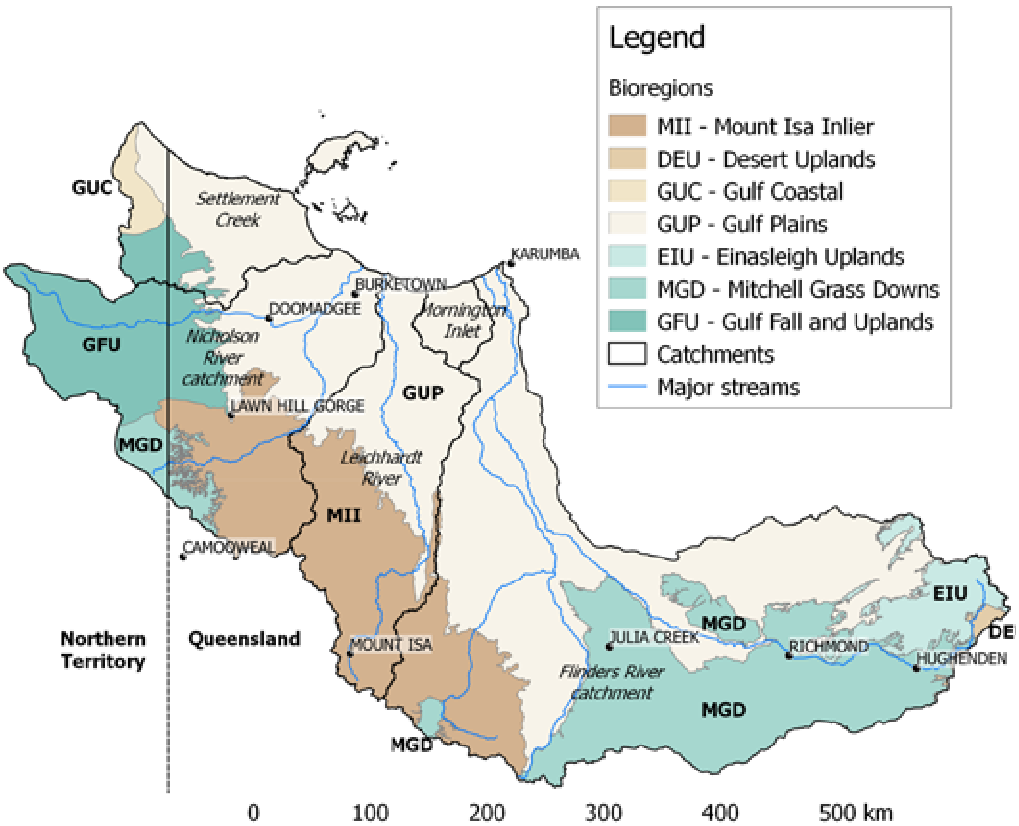

Figure 1. Southern Gulf landscapes

Source of data: Bioregions, Department of the Environment (2012)[2]; Regional Ecosystems, Queensland Department of Science, Information Technology and Innovation (2013, 2015a,b)[3,4,5]; Springs, Rod Fensham (pers. comm. 20 Nov 2013); Streams, Geoscience Australia (2004)[6]

In the region's south-east are the rolling plains of the Mitchell Grass Downs bioregion. This grassland bioregion also intrudes along the southwestern border the Southern Gulf region.

The Northwest Highlands, comprising the Mount Isa Inlier and the Gulf Fall and Uplands bioregions, are the most rugged and spectacular sections of the Southern Gulf region. Most major rivers rise in these bioregions, which contain the Selwyn Ranges, east of Mount Isa, and Lawn Hill Gorge. The dominant vegetation is low woodland of Snappy Gum *(Eucalyptus leucophloia)* and other small eucalypts with an understorey of spinifex. Steep gorges provide some of the only permanent water in the region.

The vegetation of the Southern Gulf is largely intact, with less than 5% of any catchment being cleared[7]. Moderate rates of vegetation clearance continue in the region. Clearance rates averaged 1.5 km^2 per year between 2005 and 2012, roughly doubling between 2012 and 2014[7]. Most clearance has been for pasture development[8]. The most endangered ecosystems are the springs associated with the Great Artesian Basin, many of which have become severely degraded (Figure 3). Most other threatened regional ecosystems are listed because of their limited extent or degradation, rather than clearance.

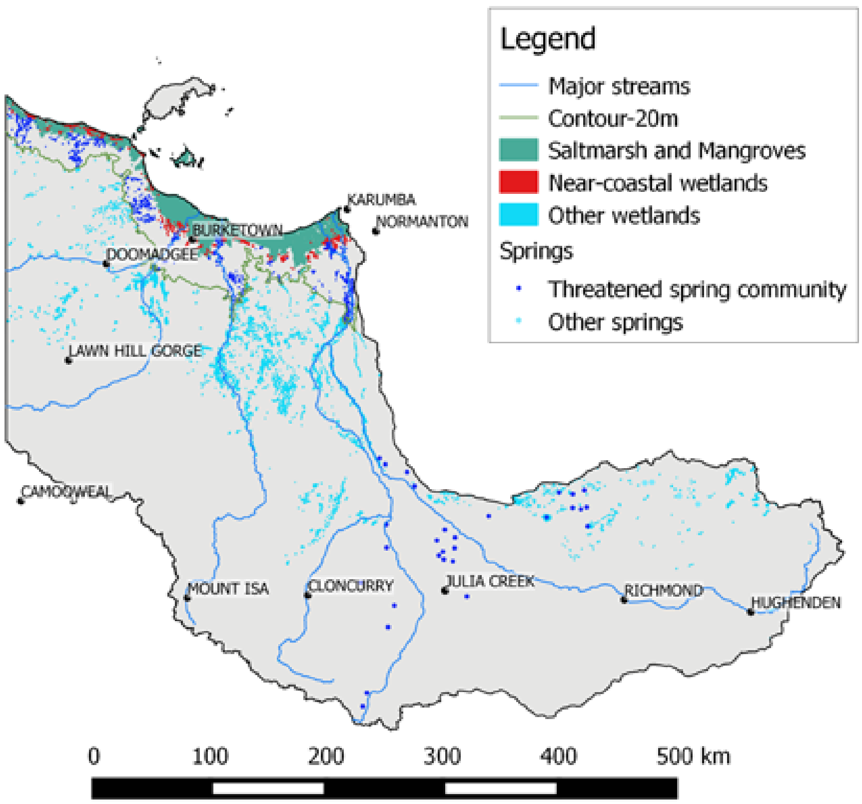

Figure 2. Wetlands ecosystems in the Southern Gulf region

Source of data: Wetlands (Regional Ecosystems), Queensland Department of Science, Information Technology and Innovation (2013, 2015a,b)[3,4,5]. Springs, Rod Fensham (pers. comm. 20 Nov 2013)

Land degradation is an issue, with biodiversity condition being rated as at least partially degraded across the majority of the region. Degradation of extensive grasslands and woodlands has been attributed to high total grazing pressure, poor fire management and Cloncurry Buffel Grass (*Cenchrus pennisetiformis*) invasion[9]. Weeds, notably Prickly Acacia (*Vachellia nilotica*), Rubber Vine (*Cryptostegia grandiflora*), Bellyache Bush (*Jatropha gossypiifolia*) and Calotrope (*Calotropis procera*) have invaded large areas of riparian corridor. Wetland ecosystems have also been degraded by pigs and livestock. Improvements in ground cover indicate grazing pressure has decreased over the last 30 years, but this trend has reversed in the eastern sections of the region over the last three years of drought[10].

Land use

Grazing is the dominant land use, although there are also large areas of Aboriginal land and protected areas (Figure 4). The region's conservation estate has more than doubled in recent years with the addition of four Nature Refuges and declaration of an Indigenous Protected Area over the Wellesley Islands and sections of the adjoining mainland and Gulf of Carpentaria. Conservation management of is a high priority of the region's Indigenous communities[11,12,13,14,15,16].

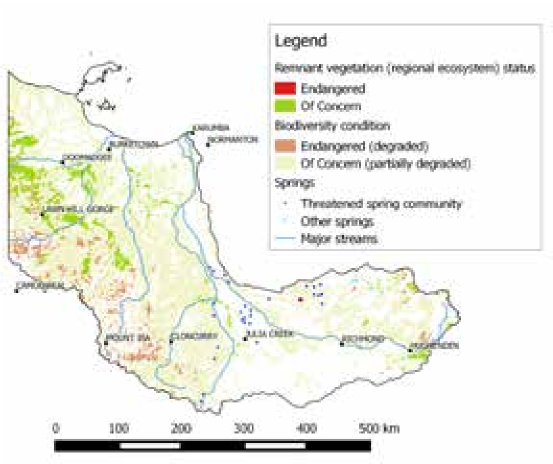

Figure 3. Threatened vegetation communities of the Southern Gulf region
Source of data: Regional Ecosystems, Queensland Department of Science, Information Technology and Innovation (2013, 2015a,b)[3,4,5;] Springs, Rod Fensham (pers. comm. 20 Nov 2013).

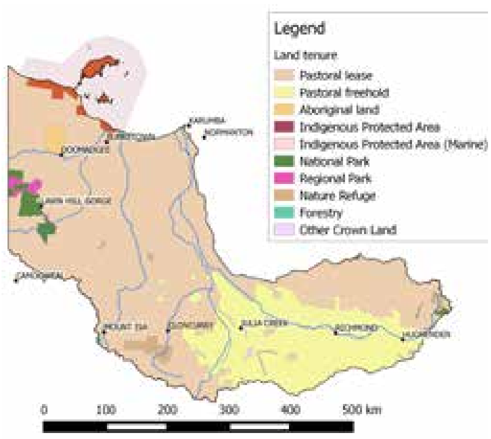

Figure 4. Land tenure of the Southern Gulf region
Source: Geoscience Australia (2004)[17], Department of the Environment (2014)[18], Queensland Government (2015)[19]

Community and economy

Table 1. Population of the Southern Gulf region

Source of data: Australian Bureau of Statistics (2015)20

Local Government Area	Total population *(Number of people)*	Indigenous population *(%)*
Mount Isa City	22,779	51.1
Cloncurry Shire	3,413	21.8
Carpentaria Shire	2,225	36.7
Flinders Shire	1,828	6.3
Doomadgee Aboriginal Shire	1,382	91.9
McKinlay Shire	1,085	3.8
Richmond Shire	845	5.8
Burke Shire	556	27.4
Mornington Shire	1,214	88.2

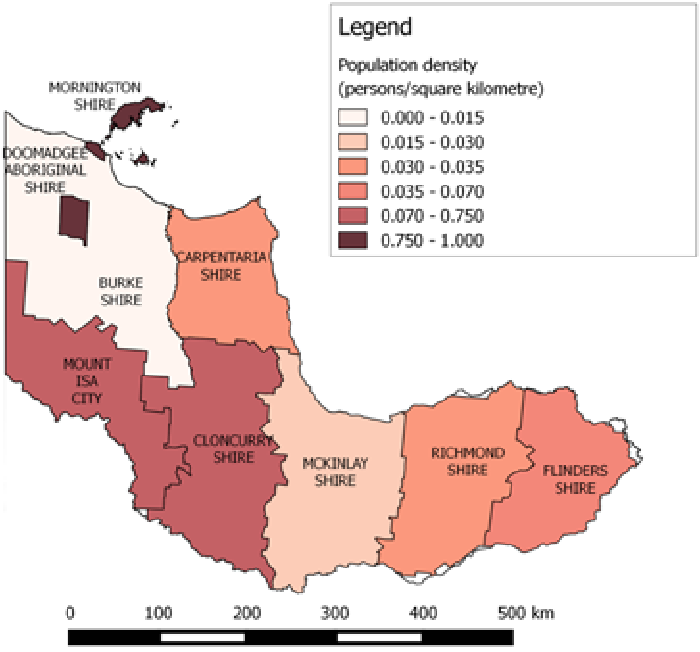

Figure 5. Population density in the Southern Gulf

Source of data: Australian Bureau of Statistics (2015)[20]

Mining, cattle grazing, fishing and tourism are the region's most important industries. The mining industry is the largest employer in the region, providing around one-quarter of jobs, followed by agriculture at about 9%[21]. The community has suffered from major changes in fortune in the mining and pastoral industries in recent years, as well as from droughts, floods and cyclones[22]. Declining cattle prices in real terms, temporary closure of the live export industry in 2011, and three years of drought have put many beef producers under financial stress[22]. Some producers may need to leave the industry because of burgeoning debt. However, increased international demand has increased market prices, and should improve the fortunes of the industry over the next few years. Mining, also important to the regional economy, has also suffered a downturn in recent years.

Indigenous disadvantage in the region is high. The Indigenous unemployment rate in 2011 was approximately 23%, roughly 10 times that for non-Indigenous people. Private sector employment of Indigenous people is one third that of non-Indigenous people[23].

Only a small proportion of pastoralists across northern Australia possess characteristics to make them resilient to major stresses and upheaval: strategic planning skills; sound business management principles; preparedness to experiment and try new ideas; and strong links with industry and community networks.[19] Southern Gulf NRM producers were a subset of this assessment, but resilience of other natural resource managers is unknown.

At a community level, the Southern Gulf has only moderate resilience across four key indicators (Figure 6)[24]. Economic vitality suffers from dependence on the resource sector, which exposes it to down-turns in global economic growth, but benefits from the increased demand for agricultural produce, which is driving cattle prices and expansion of irrigated agriculture. Economic development is impeded by inadequate infrastructure, which restricts market access, particularly in the wet season.

The region's knowledge base, aspirations and capacity benefit from the long association Traditional Owners have with their land and the relative stability of the pastoral sector. This history provided long-term experience of boom-and-bust cycles, and the community bands together in times of hardship. However, opportunities for knowledge-building are lost when students leave the area to access education and training, and as a result of high turnover of professional staff. General lifestyle satisfaction contributes to moderate community vitality, but is offset by inadequate health services and housing availability and high crime rates in the most populous areas. Governance in local government is relatively robust, but the region remains marginalised by centralised policy planning, and suffers from weak capacity for regional delivery across most sectors. Options for improving regional resilience include sustainable and equitable land use planning and water allocation; infrastructure development to improve NRM capacity; facilitating pathways out of debt; and restructuring drought relief and insurance arrangements.

Figure 6. Resilience rating of the Southern Gulf community in 2015

Source of data: Pearse and Dale (2015)[24]

CLIMATE

Southern Gulf climate

The climate of the Southern Gulf region ranges from semi-arid environment in the south to semi-humid in the north (Figure 7). Most rain falls between November and March. The region is hot and humid[25], with mean maximum temperatures at Mount Isa approaching 40°C in summer and mean minimum temperature exceeding 10°C in winter. Summer maximums frequently exceed 40°C[26]. Temperatures are most extreme in the south (9-27°C in winter and 24-39.5°C in summer) and less extreme in coastal areas (13-28°C in winter and 25-35°C in summer). Wet season humidity can be 10% higher at Burketown than at Julia Creek.

Rainfall is highly variable (Figure 8). In about one-third of years, rainfall falls short of the average by more than 100 mm, and exceeds the average by at least 100 mm in another third. In particularly dry years, rainfall can be less than 200 mm. Most rain comes from thunderstorms, which are strongly influenced by the intensity of the wet season and monsoon[26], or from tropical cyclones. The Southern Oscillation Index has a high influence on rainfall, and droughts are often associated with El Niño years, and extended periods of high rainfall with La Niña years.

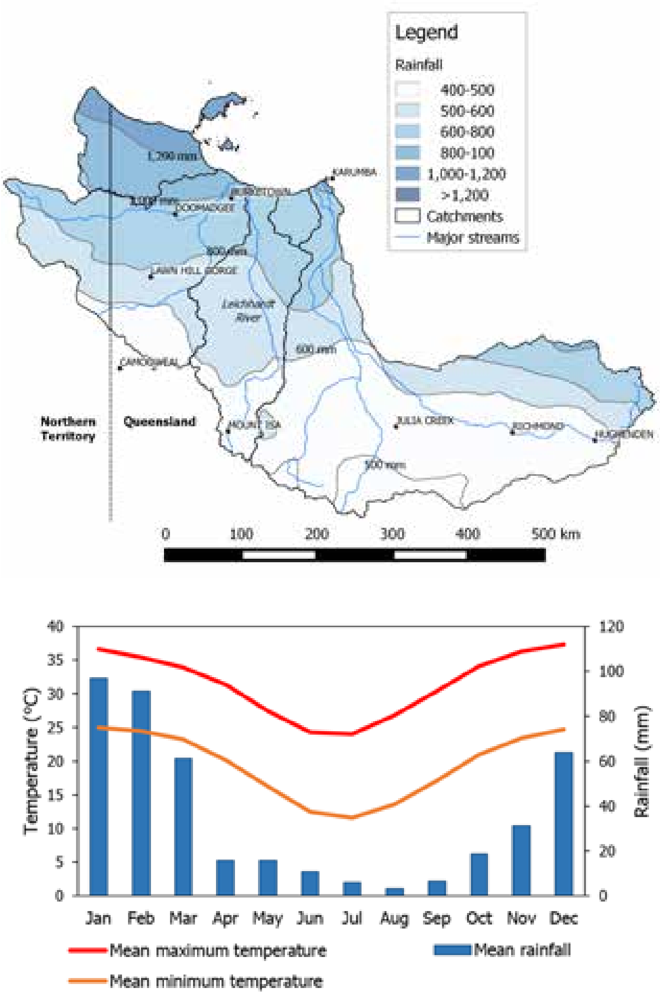

Figure 7. Southern Gulf region (a) and climatic statistics (b)

Source of data: Rainfall and temperature, Australian Bureau of Meteorology (2016)[27]; catchments Geoscience Australia (2004)[28]; Streams, Geoscience Australia (2004)[6]

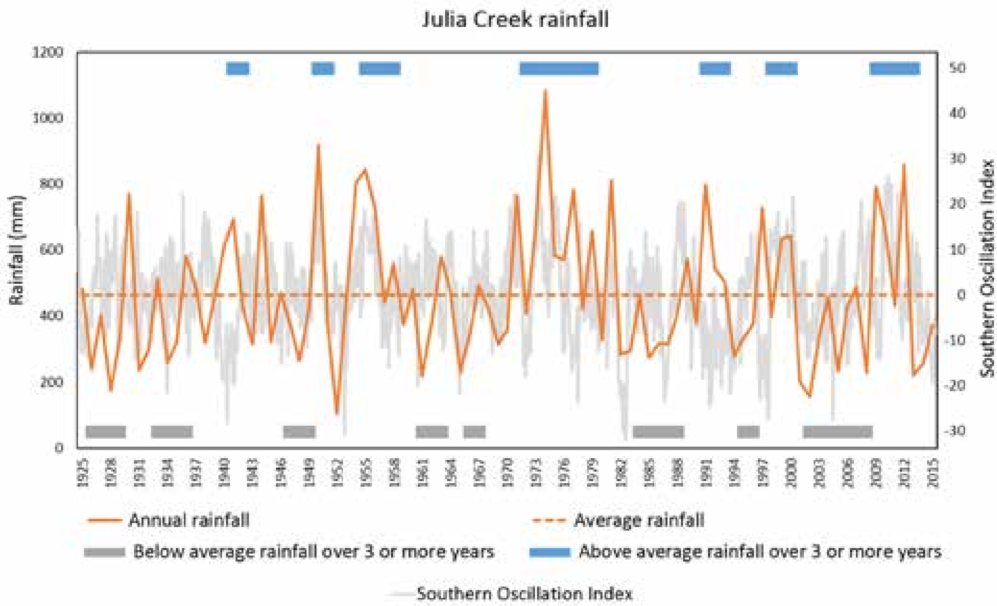

Figure 8. Rainfall statistics for Julia Creek, highlighting extended periods of low or high rainfall and the influence of El Nino/La Nina cycles

Source of data: Australian Bureau of Meteorology (2016)[27]

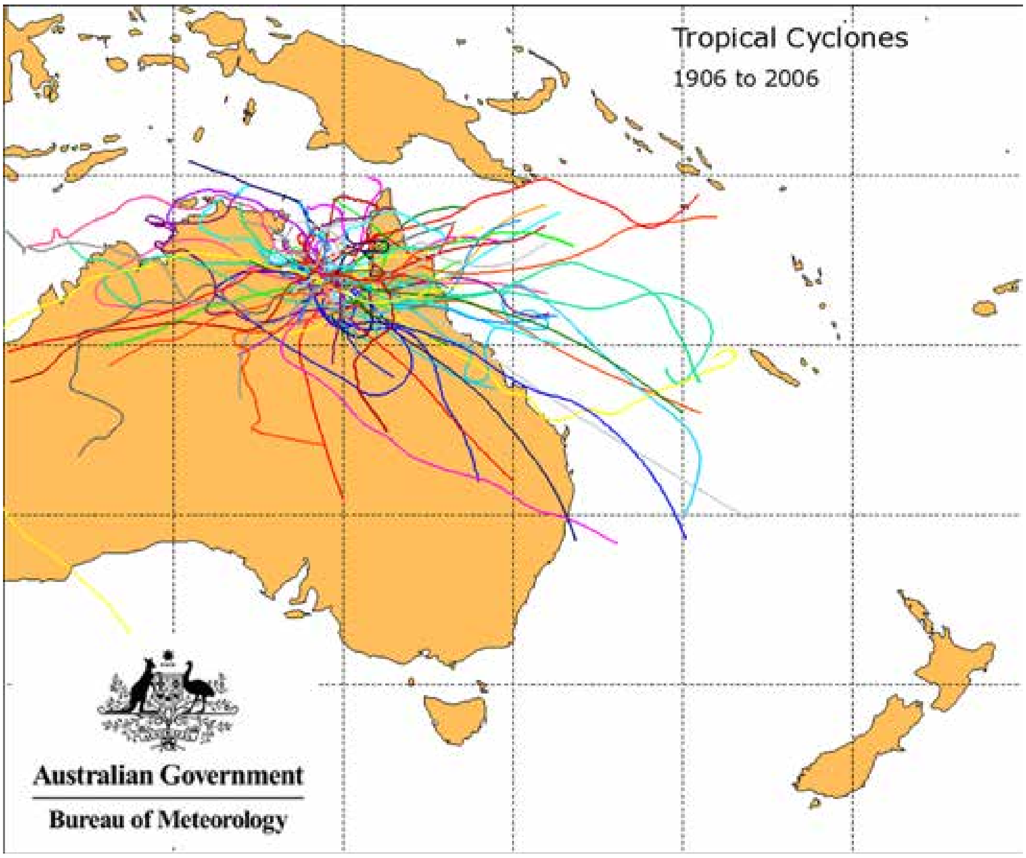

Figure 9. Tracks of cyclones that affected the Southern Gulf region over a 100 year period

Source of image: Australian Bureau of Meteorology (2016)[29]

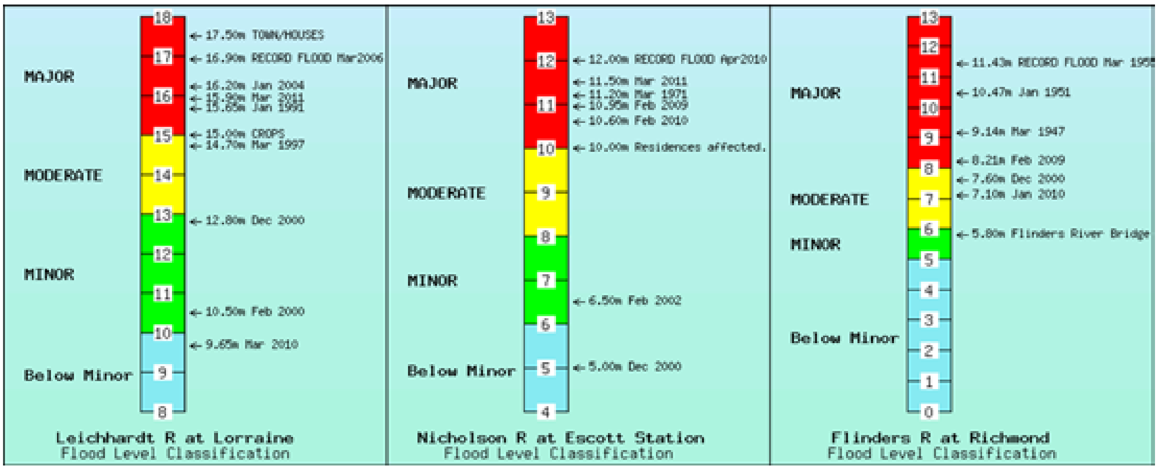

Figure 10. Flood records for the Leichhardt, Nicholson and Flinders Rivers

Source of images: Australian Bureau of Meteorology (2015)[31,32,33]

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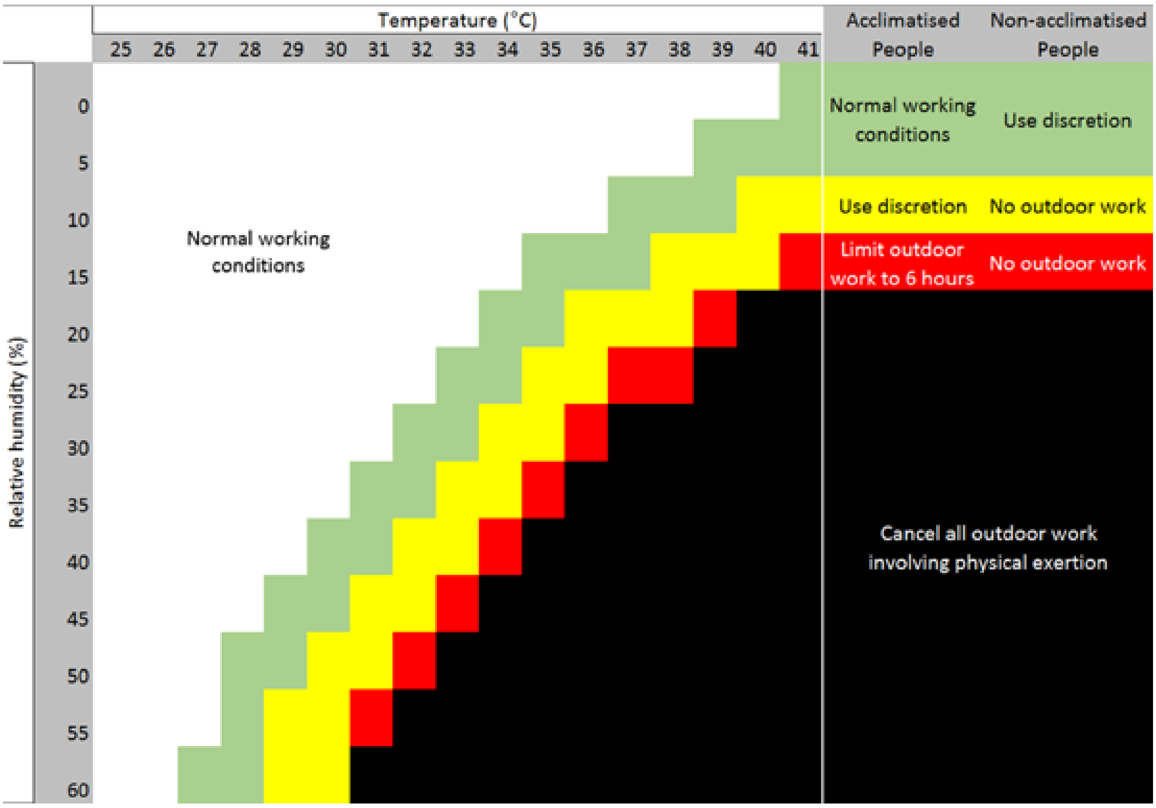

Figure 11. Impact of temperature and humidity on working conditions

Source of data: Hanna *et al.* (2011)[35] and Australian Bureau of Meteorology (2010)[36] NB: Recommended limits to strenuous work by acclimated workers effectively precludes NRM in the red zone[35]

The Gulf of Carpentaria averages two cyclones a year, most usually occurring between November and April (Figure 9). Cyclone are almost twice as likely during La Niña years as they are in El Niño years. Most properties would experience a cyclone once in every eight years. Nearly half the cyclones in the Gulf of Carpentaria have been in the least severe category (Category 1); less than 5% were classed as Category 5. Cyclones that have had devastating impacts on the Southern Gulf region have included one that hit Burketown on 5 Mar 1887, which caused sea level to rise by 5 metres and flooded most of the town. Cyclones that hit Mornington Island (1936, 1976), Bentick Island (1948) and Burketown (1976) destroyed most houses in their paths. In 1984, sea turtles were stranded 7 km inland up the MacArthur River in the Northern Territory by Category 5 Cyclone Kathy.

Floods are common in the lower reaches of most major rivers (Figure 10). Since records began, The Leichhardt River has exceeded moderate flood levels one year in five and the Gregory River one year in three. The Flinders River floods at Richmond in more years than not. Flooding of the Flinders River catchment in 2009 covered 9,000 square kilometres[30].

Hot conditions combined with high rainfall variability create a challenging environment for natural resource management[26]. Safe conditions for outdoor work depend on temperature and humidity and whether the person is acclimatised to local conditions.[34,35] Under relative humidities of 25-30% that are typical in the region during winter 27, working conditions start to become unsafe at about 36°C (Figure 11). As the wet season approaches and temperature and humidity rise, working conditions become increasingly unsafe, even for seasoned workers. These conditions effectively limit the period of safe working conditions in the region to 5-7 months per year for non-acclimatised workers and 7-8 months for acclimatised workers.

Flooding restricts access, even in average rainfall years; droughts can degrade pastures when there are no alternative grazing options[22]. Cyclones cause significant wind damage, flooding and coastal erosion somewhere in the region in most years[29]. The damage caused by extreme weather events inflicts financial hardship and emotional stress. Affected landholders have little capacity to focus on natural resource management or invest in practice improvement[37].

How the climate has changed

Australia' climate has changed since records began (Figure 12). Average temperatures in the Southern Gulf region have increased by more than 1.5°C since 1910. At Camooweal, the number of days hotter than 40°C have doubled from about 20 per year to about 40 per year over the same period (Figure 13a). High variability makes any trend in rainfall difficult to discern. However, despite recent droughts, Southern Gulf's wet season rainfall in the last 20 years was very much above the long-term average (Figure 13b). Frequency of cyclones appears to have decreased since the mid-1980s, but the number of severe cyclones has not changed (Figure 14). Sea level in Australia has risen an average of 1.4 mm per year between 1966 and 2009[38].

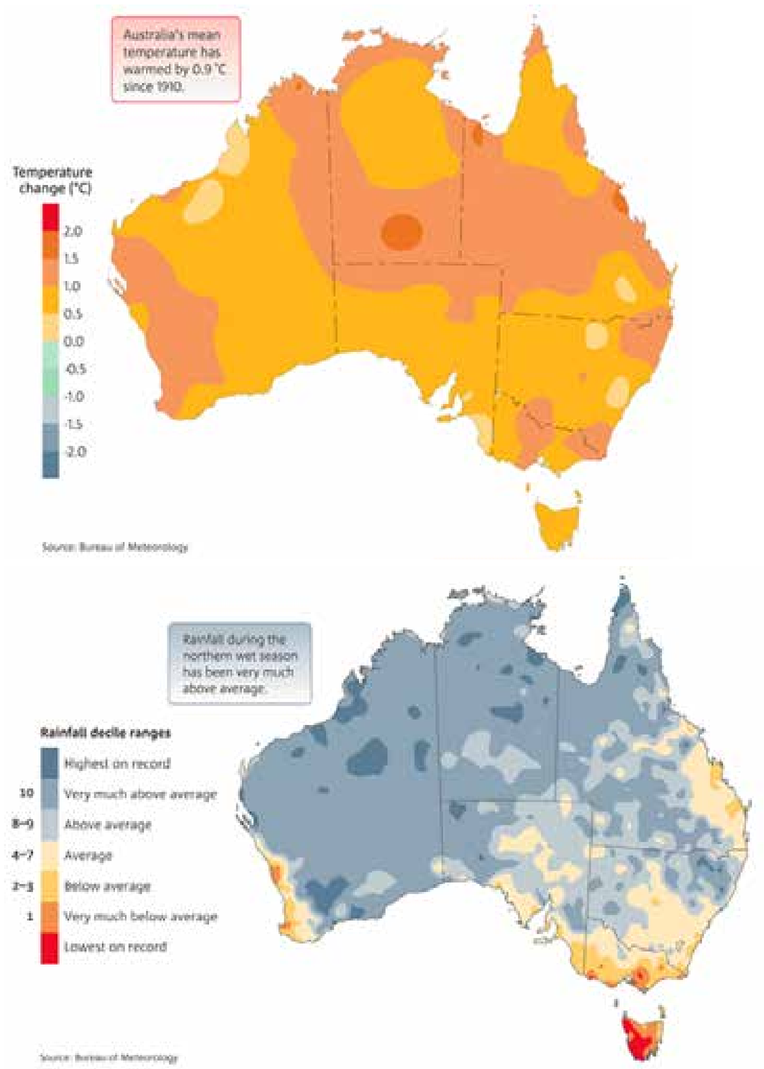

Figure 12. a) Changes in temperate across Australia since 1910; and b) comparison of wet season rainfall between 1995 and 2014 with the long-term average

SOURCE: Australian Bureau of Meteorology (2014)[39]

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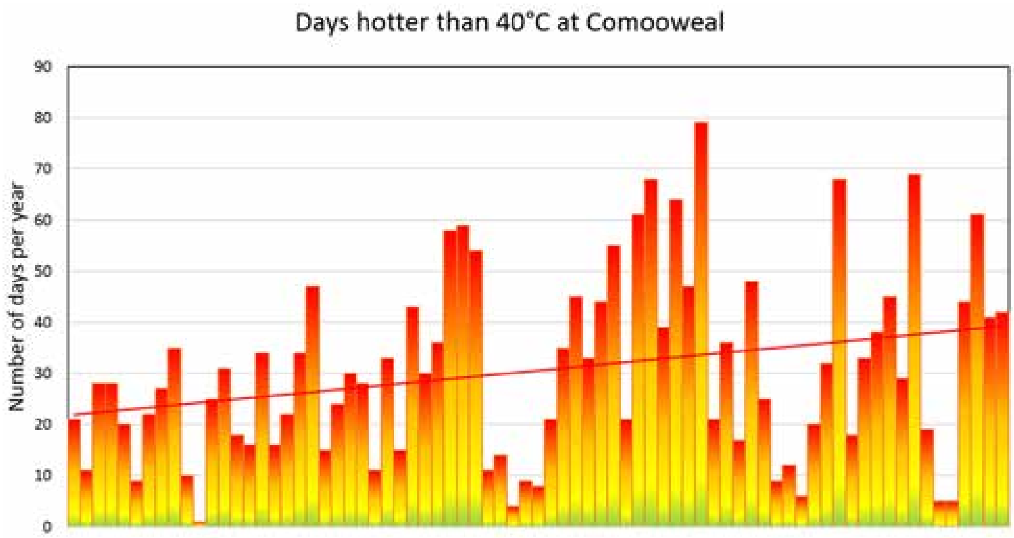

Figure 13. Changes in the number of hot days at Camooweal since 1910
SOURCE: Australian Bureau of Meteorology (2016)[27]

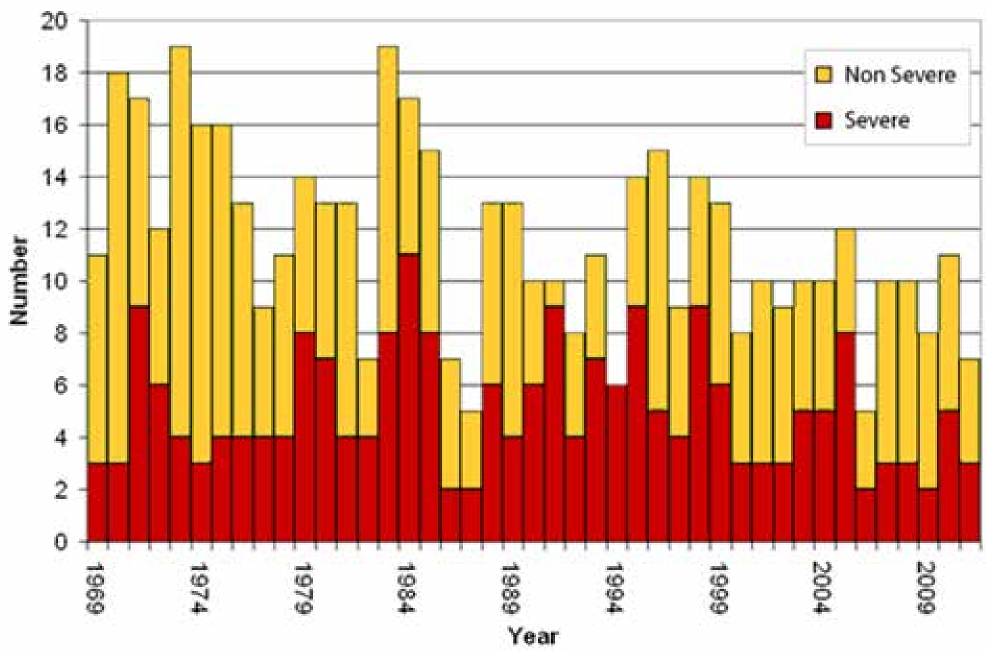

Figure 14. Number of severe and non-severe cyclones affecting Australia between 1970 and 2011
Source of data: Australian Bureau of Meteorology (2011)[40]
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Future climate change and impacts

The Southern Gulf's climate is predicted to keep changing (Figure 15)[38]. By 2030, temperatures are expected to rise by between 1 and 2°C (Figure 16), with greatest increases in the south-west of the region. The number of intensely hot days to double over current values[38], which could mean that temperatures exceed 40°C at Camooweal about 80 days a year (see Figure 13).

There is no clear indication about changes in rainfall or whether droughts will become more or less frequent, but they may become more intense. However, there is expectation of increases in the frequency of heavy rainfall events, and possibly flash-flooding as a result, and modelling of changes in faunal distributions are based on rainfall increasing by up to 15 mm/year by 2045 in the south of the region, and by up to 100 mm a year at the coast[41]. Sea level rise will continue by an extra 6-17 cm by 2030[38]. Effects of sea level rise will be exacerbated storm surges during cyclones.

Increases in atmospheric carbon dioxide also have significant ramifications through fertilisation of plant growth[42,43,44,45] and ocean acidification[46,47].

Climate change not only affects the environment, but will have flow-on effects to cultural heritage, social wellbeing and production. These are impacts are explored in the following sections.

Figure 15. Key climate change messages for the Southern Gulf region

Source: Moise *et al.* (2015)[38]

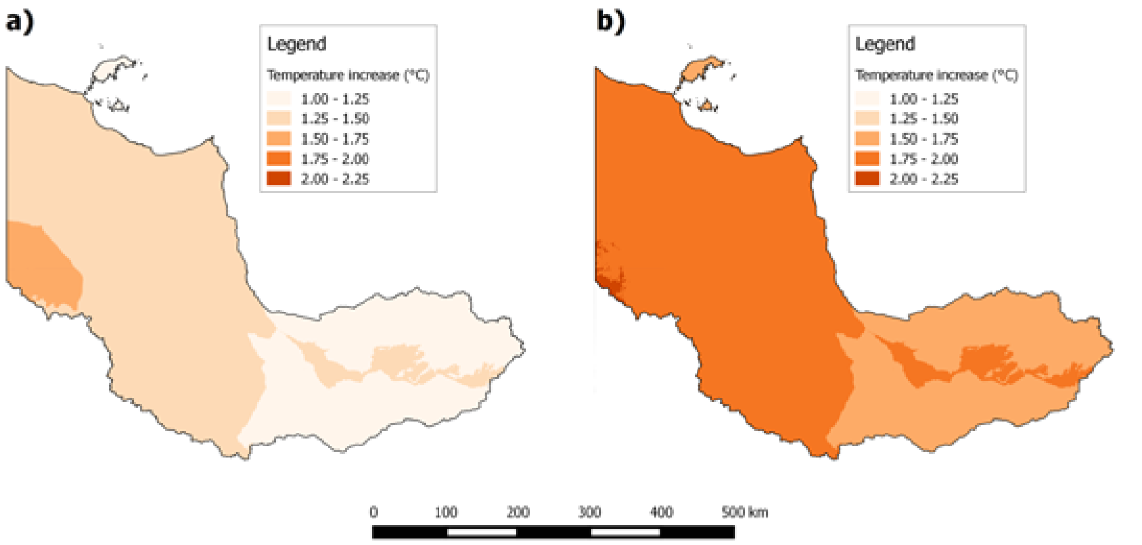


Figure 16. Expected temperature increases to 2045 showing estimates under (a) a moderate projection (RCP4.5), and (b) an extreme projection (RCP8.5)

Source: Gobius (2015)[41]

Biodiversity values

Ecosystems

The Southern Gulf region contains some of the most extensive intact native vegetation communities in Queensland[7]. Less than 5% of the region has been cleared or highly altered. Few communities are classified because of reduced extent. Only spring-fed wetlands (Regional Ecosystem 2.3.39) that have been degraded by water extraction, excavation, feral pigs and livestock and are considered modified enough to be classified as Endangered under Queensland's Nature Conservation Act (NCA 1992)[56]. Twenty-nine of the 33 known springs also support nationally-Endangered communities of species dependent on the Great Artesian Basin (Figure 3). The region also has 21 communities that are highly restricted in extent (each covering an area of less than 30 km^2). Despite the low level of clearance, much of the vegetation is degraded from overgrazing, weed invasion and uncontrolled fire regimes.

Freshwater wetlands

One of the most distinguishing features of the Southern Gulf region is its high-conservation value aquatic ecosystems (Figure 17). These range from extensive mudflats that support shorebirds to tiny swamps in the arid south-west and the Endangered Great Artesian Basin springs in the upper Flinders catchment [53]. Large areas are classified as Nationally Important Wetlands (Table 2). The Southern Gulf Aggregation is the largest continuous marine intertidal flat system in northern Australia and one of Australia's three most important areas for shorebirds[54].

Threatened species

The Southern Gulf region contains several threatened species, and is particularly important for species that have a large proportion of their population in the region (Table 3, Figure 18). The long-term fate of these species could depend on how they are managed in the Southern Gulf region. They are therefore a high priority for climate

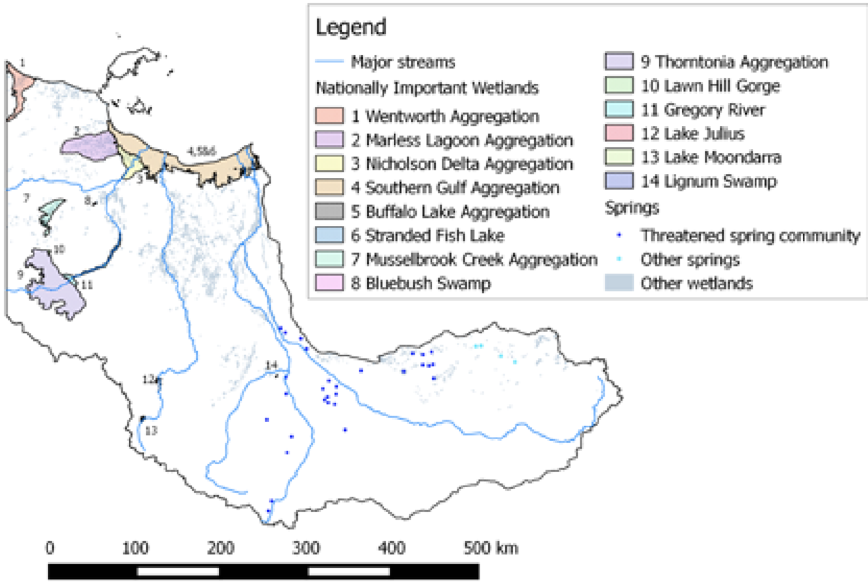


Figure 17. Wetlands of the Southern Gulf region

Source: Nationally Important Wetlands, Australian Department of the Environment (2010)[63], Springs, Rod Fensham (pers. comm. 20 Nov 2013), Other wetlands, Queensland Department of Science, Information Technology and Innovation (2013, 2015a, b)[58-60]

Table 2. Nationally important wetlands in the Southern Gulf region

Source: Environment Australia (2001)54

Name	Area (km2)	Description	Characteristic flora	Notable fauna
Bluebush Swamp	8.8	Shrubby wetland dominated by Acacia stenophylla	Waterlilies, aquatic grasses	Waterfowl
Gregory River	266	Largest perennial river in arid and semiarid Queensland	Waterlilies, fringing eucalypts, paperbark, swamp forest, figs	Estuarine and freshwater crocodiles
Lake Julius	19	Artificial deep-water lake with fringing forest	Waterweeds, aquatic grasses, fringing paperbark, pandanus	Pelican, heron, egret, grebe, brolga, tern, freshwater crocodile, freshwater fish
Lake Moondarra	18	Large, artificial, permanent lake		Waterfowl, grebe, pelican, heron, egret, waders
Lawn Hill Gorge	11	Permanent deep water within a spectacular limestone and sandstone gorge with perennial springs	Waterlilies, waterweeds, waterferns, rushes, sedges, fringing eucalypts, pandanus, Leichhardt pine	Frogs, freshwater turtles, freshwater crocodile, waterbirds
Lignum Swamp	2.8	Large semi-permanent vegetated swamp	Lignum, nardoo	Waterfowl
Marless Lagoon Aggregation	1670	Extensive, isolated seasonally rich lakes and vegetated swamps	Waterlilies, waterweeds, aquatic grasses and sedges, paperbarks and fringing eucalypts	Waterfowl (ducks, herons, pelican, ibis, stilt)
Musselbrook Creek Aggregation	451	*Acacia stenophylla*, *Eucalyptus microtheca* and *E. tectifica* vegetated swamp	Waterlilies	Waterfowl
Nicholson Delta Aggregation	636	Closed depressions in impeded drainage lines, floodouts, backplains and riverine channels merging with an extensive estuarine system of saline clay pans and tidal channels	Waterlilies, sedges, wild rice, other aquatic grasses	Herons, egrets and other waterfowl
Southern Gulf Aggregation, including	5,455	Largest continuous estuarine wetland aggregation of its type in northern Australia	Seagrass, mangroves, samphire, freshwater grasses	Shorebirds, dugong, marine turtles
Buffalo Lake Aggregation	19	Large shallow lake	Wild rice, other aquatic grasses, salt-tolerant herbs, fringing eucalypts	Swan, duck, terns, ibis, waders
Stranded Fish Lake	0.68	Estuarine lake with occasional saline influence	Notable absence of flora	Waterfowl
Thorntonia Aggregation	2,986	Perennial streams and springs associated with dissected limestone and dolomite formations	Waterlilies, waterweeds, waterferns, rushes, sedges, fringing eucalypts, pandanus, figs	Waterfowl
Wentworth Aggregation	823	Riverine systems, some with permanent pools	Waterlilies, *Sesbania*, aquatic grasses, fringing eucalypts, paperbarks, mangroves	Waterfowl, waders

Table 3. Priority species for climate action in the Southern Gulf region

Common name	Species	National Status	Queensland Status	Importance of Southern Gulf	Key bioregional provinces
Marine species					
Olive Ridley Turtle	*Lepidochelys olivacea*	Endangered	Endangered	Medium	-
Loggerhead Turtle	*Caretta caretta*	Endangered	Endangered	Medium	-
Leatherback Turtle	*Dermochelys coriacea*	Endangered	Endangered	Medium	-
Green Turtle	*Chelonia mydas*	Vulnerable	Vulnerable	Medium	-
Green Sawfish	*Pristis zijsron*	Vulnerable	-	Critical	-
Dwarf Sawfish	*Pristis clavata*	Vulnerable	-	Medium	-
Australian Snubfin Dolphin	*Orcaella heinsohni*	-	Vulnerable	Medium	-
Riparian species					
Gulf Snapping Turtle	*Elseya lavarackorum*	Endangered	Vulnerable	Critical	Armraynald Plains McArthur
Freshwater Sawfish	*Pristis prisits*	Vulnerable	-	Medium	Woondoola Plains
Red Goshawk	*Erythrotriorchis radiatus*	Vulnerable	Endangered	High	Armraynald Plains Donors Plateau
Star Finch (eastern)	*Neochmia ruficauda ruficauda*	Endangered	Endangered	Medium	Mount Isa
Mammals					
Julia Creek Dunnart	*Sminthopsis douglasi*	Endangered	Endangered	Critical	Central Downs
Carpentarian Antechinus	*Pseudantechinus mimulus*	Vulnerable	-	High	Mount Isa
Other birds					
Gouldian Finch	*Erythrura gouldiae*	Endangered	Endangered	High	McArthur Mount Isa
Night Parrot	*Pezoporus occidentalis*	Endangered	Endangered	Uncertain	Mount Isa
Kalkadoon Grasswren	*Amytornis ballarae*	-	-	Critical	Mount Isa
Plants					
Pink Gidgee	*Acacia crombiei*	-	Vulnerable	Critical	Northern Downs Claraville Plain Undara-Toomba Basalt
Solanum	*Solanum carduiforme*	-	Vulnerable	High	McArthur Armraynald Plain

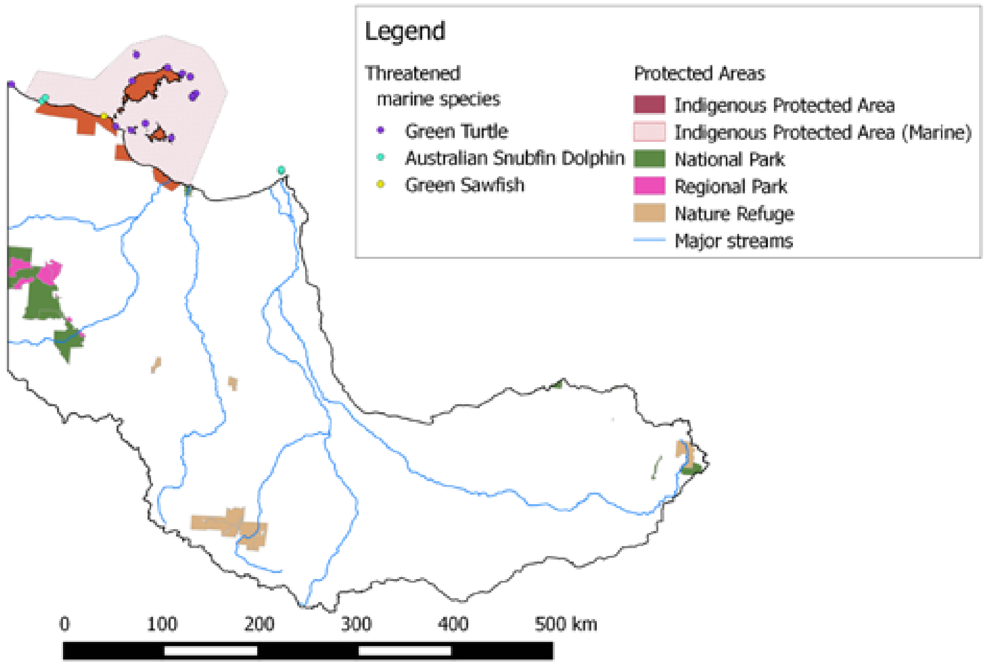


Figure 18. Priority marine species for climate change action

Source of data: Species, Atlas of Living Australia (2016)[56]; Protected Areas, Australian Department of the Environment (2014)[18]; Streams, Geoscience Australia (2004)[6]

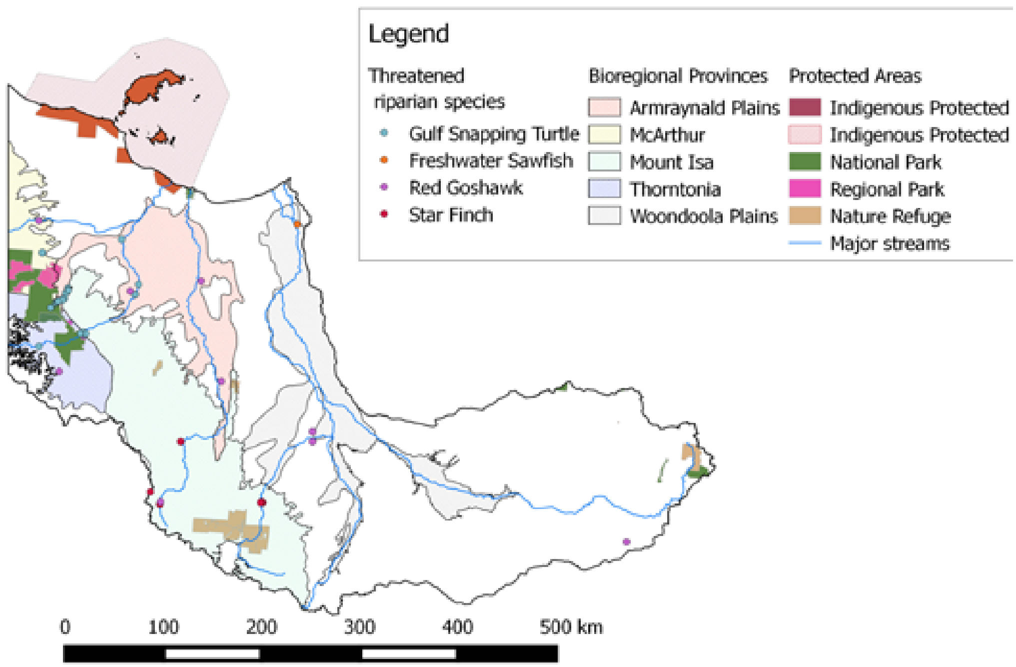
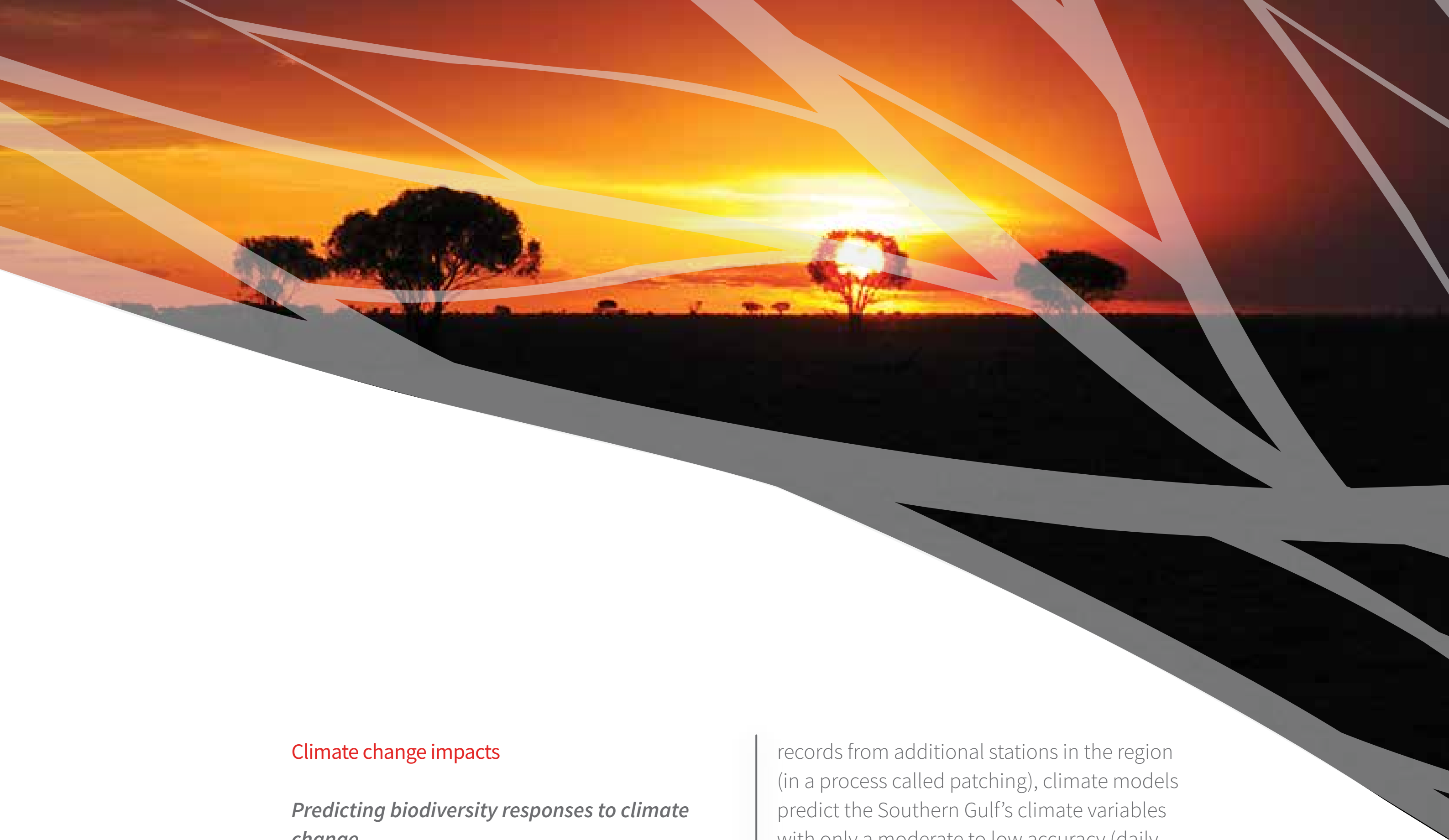


Figure 19. Priority riparian species for climate change action

Source of data: Species, Atlas of Living Australia (2016)[56]; Bioregional Provinces, Department of the Environment (2012)[57]; Protected Areas, Australian Department of the Environment (2014)[18]; Streams, Geoscience Australia (2004)[6]



Climate change impacts

Predicting biodiversity responses to climate change

There are several approaches to assessing likely climate change impacts on biodiversity. Bioclimatic modelling – the most commonly used approach in northern Australia – identifies where species occur at present; the climatic envelope in which they occur; how this envelope is projected to change; and, therefore, how species' distributions should respond[58,59,60,61,62,63]. Bioclimatic models are useful tools for processing large volumes of data and predicting climate change responses on a landscape scale. However, "their efficacy in assessing extinction risk, delineating suitable future habitats, and predicting ecological outcomes is unproven" (Dawson *et al.* 2011), and they tend to predict greater climate change impacts on species distributions than is found in experiments subjecting a species to the same suite of climate change conditions[64].

The efficacy of bioclimatic modelling for predicting future distributions also depends on its ability to model current climatic surfaces accurately. This, in turn, depends on the density of climate stations, which is low in northern Australia. There are only two long-term temperature stations in the Southern Gulf region (Richmond and Burketown) and two just outside the region (Camooweal and Normanton), and long-term rainfall is available from only Burketown and Lorraine within the region, and Camooweal just outside the region[65]. Large distances (at least 190 km) between these stations hamper the accuracy of modelling the region's current climate. Even with inclusion of short-term records from additional stations in the region (in a process called patching), climate models predict the Southern Gulf's climate variables with only a moderate to low accuracy (daily maximum temperature error 0.6 to >1.8°C; daily minimum temperature error 1.4 to 1.9°C; daily pan evaporation error 1.6 to 2.0 mm; daily atmospheric pressure error ca 0.6 hPa; daily vapour pressure error 2 to >3 hPa; and monthly rainfall error 20 to >40 mm)[66]. This makes the accuracy of current climate modelling in the Southern Gulf amongst the lowest in Australia. Moreover, because the climate in areas with complex microrelief is hard to model accurately, modelling generally fails to predict the location of refugia, such as those located in gorges[67].

Bioclimatic modelling also requires accurate knowledge of where species and communities currently occur. The Southern Gulf has a relatively low density of biodiversity records, and parts of the region have no biodiversity records at all (Figure 23). So bioclimatic models are likely to have a lower accuracy for the Southern Gulf region than they are for more-thoroughly sampled parts of Australia. Modelling can also fail to produce reliable results because species' distributions rarely perfectly match their ecological tolerances, and models do not yet incorporate species' intrinsic capacity to adapt as conditions change[68]. Therefore, bioclimatic models should be used in combination with other sources of information, such as paleoecological records, direct observations, ecophysiological and population models and experimentation[67,68,69].

An alternative approach to assessing biodiversity responses to climate change, expert assessment,

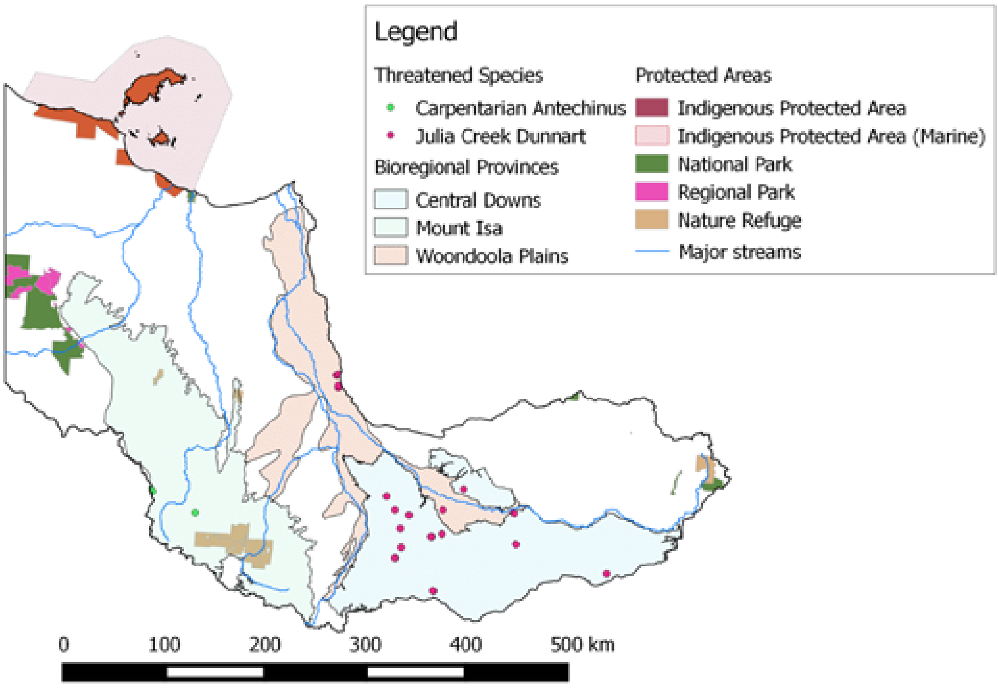


Figure 20. Priority mammals for climate change action

Source of data: Species, Atlas of Living Australia (2016)[56]; Bioregional Provinces, Department of the Environment (2012)[57]; Protected Areas, Australian Department of the Environment (2014)[18]; Streams, Geoscience Australia (2004)[6]

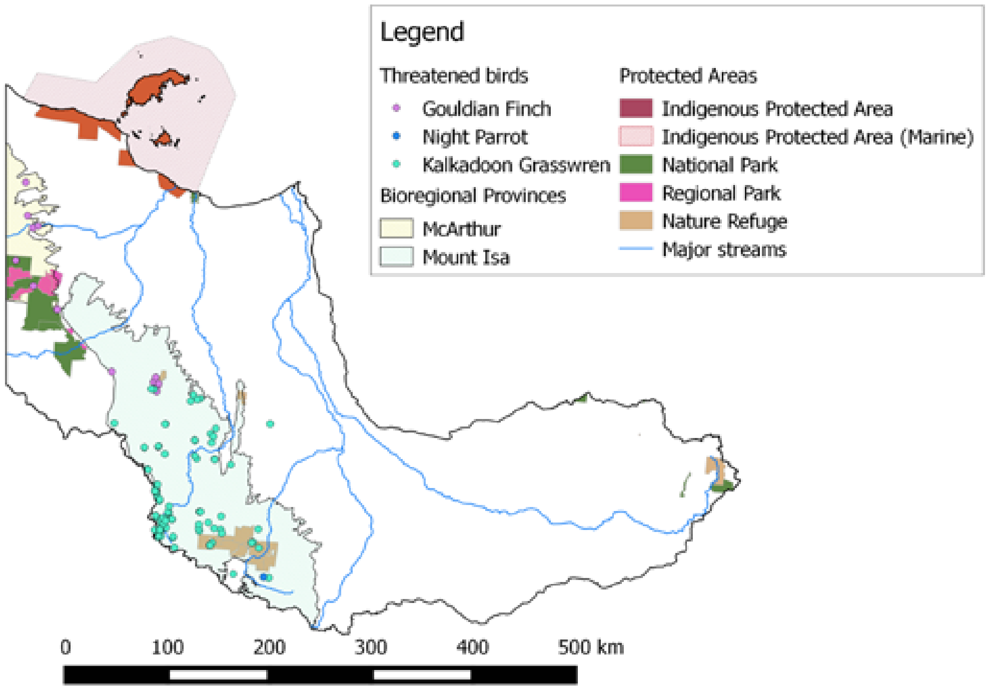


Figure 21. Priority birds for climate change action

Source of data: Species, Atlas of Living Australia (2016)[56]; Bioregional Provinces, Department of the Environment (2012)[57]; Protected Areas, Australian Department of the Environment (2014)[18]; Streams, Geoscience Australia (2004)[6] uses spatial information where this is reliable, but places greater emphasis on detailed knowledge of species and systems, where these currently occur and an understanding of biological function and responses to past changes in climate. Examples of this approach being used in northern Australia include publications by Laurance *et al.* (2011)[48], Close *et al.* (2015)[71] and Queensland Department of Environment and Heritage Protection (2016)[72]. In the following section, both expert assessments and bioclimatic modelling are reviewed to identify the likely impacts of climate change on biodiversity in the Southern Gulf region, and the best management approaches for averting climate change impacts.

Ecosystems

The Southern Gulf region contains three of the ten Australian ecosystems that are considered most vulnerable to climate change[48], namely saltmarsh and mangroves, near-coastal wetlands and tropical savannas (Figure 24). Indeed, very little of the region does not fall into one of these categories. Coral reefs, also highly vulnerable to climate change, are present in the Southern Gulf of Carpentaria, but outside the Southern Gulf NRM region[73]. Saltmarsh and mangroves will be particularly vulnerable to rises in sea-level and storm damage associated with intense cyclones; near-coastal wetlands risk salinisation with saltwater intrusion; and tropical savannas will be vulnerable to increasing heat stress and fire intensity, and weed invasion associated with increased disturbance (Table 4). These impacts are further examined in subsequent pages.

Coastal and marine environments

Coastal and marine environments will be affected both by climate change and the underlying cause of climate change. Increased atmospheric CO_2 concentrations will also result in an increase oceanic CO_2. As a result, sea water in the Gulf of Carpentaria will acidify, which, in turn, will impair uptake of the calcium needed to build coral

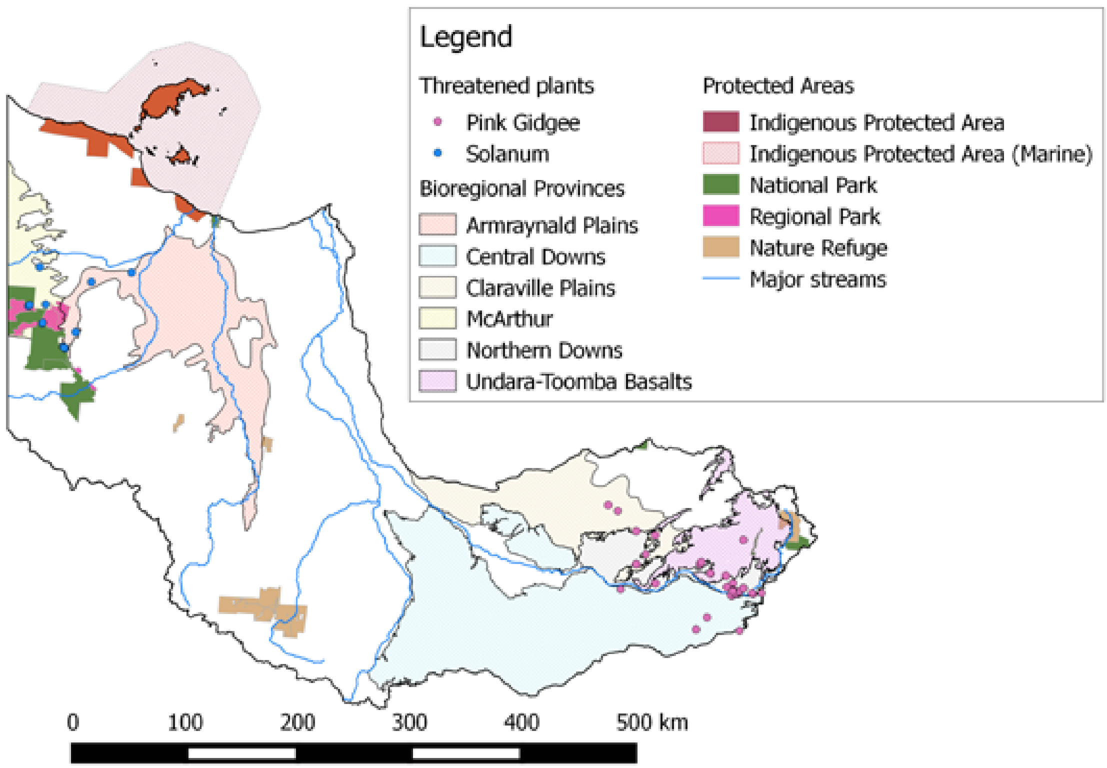


Figure 22. Priority plants for climate change action

Source of data: Species, Atlas of Living Australia (2016)[56], Bioregional provinces, Department of the Environment (2012)[57]; Protected Areas, Australian Department of the Environment (2014)[18]; Streams, Geoscience Australia (2004)[6]

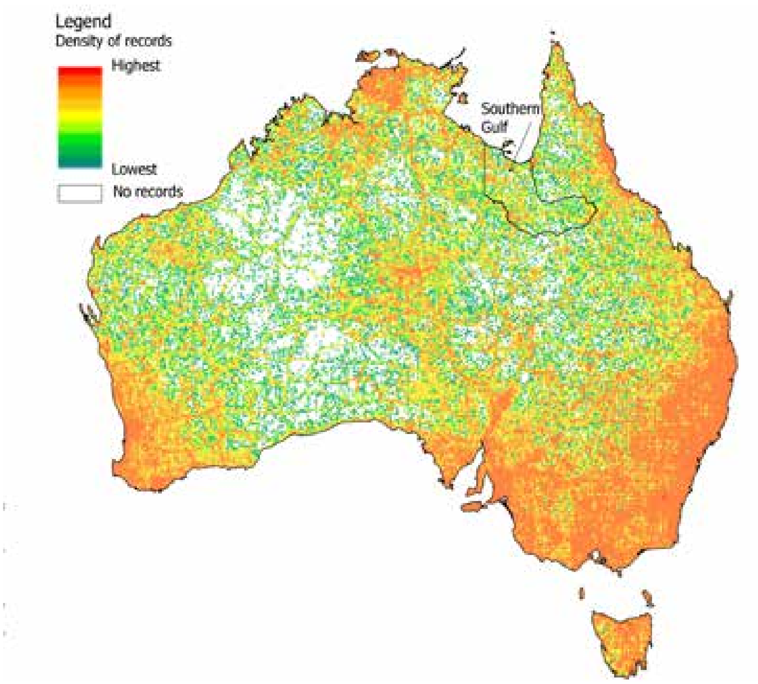


Figure 23. Density of biodiversity records across Australia

Source: Adapted from ALA (2016)[70]

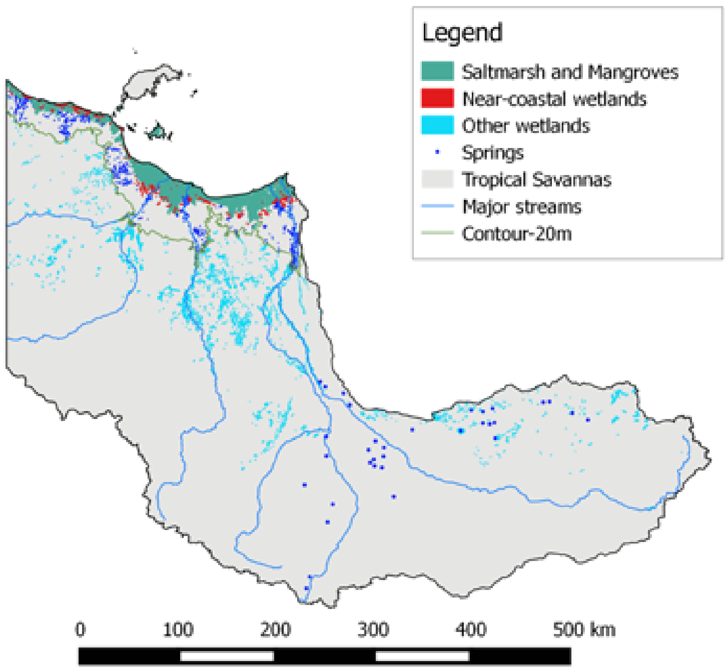


Figure 24. Climate change-sensitive ecosystems in the Southern Gulf region

Source of data: Wetlands (Regional Ecosystems), Queensland Department of Science, Information Technology and Innovation (2013, 2015a,b)[3,4,5]. Springs, Rod Fensham (pers. comm. 20 Nov 2013)

skeletons and shell-forming molluscs, although, crustaceans (including prawns) are not expected be affected[46]. Reefs that fringe Mornington and Bentick Islands will also be affected by temperature rise (causing coral bleaching) and sea-level rise[77,78]. Storm surges associated with an increase in cyclonic intensity are also likely to damage the reefs. Sea grass beds are likely to be degraded by sea-level rise, temperature increase, heavy rain events and intense tropical storms[79]. These changes will affect the habitat of turtles and dugong and productivity of marine fisheries[46].

Climate change will also affect the biology of marine animals. Increased temperatures are expected to increase the proportion of females in marine turtle populations, as well reduce nesting success on exposed beaches[77]. Sea-level rise and increased storm-surges are also likely to destroy nesting beaches[77]. Nevertheless some models predict an increase in marine turtles in the Gulf of Carpentaria[79].

Sea-level rise and increased storm surges are also likely to cause shoreline retreat and flooding of low-lying coastal plains and islands[78]. This is expected to erode the shoreward mangrove fringe, while increasing marine influence will allow mangroves to establish further upstream[80].

Freshwater wetlands

Near-coastal freshwater wetlands on the low-lying coastal plain of the Gulf of Carpentaria will be particularly vulnerable to the combination of sea level rise and storm-surge damage[81]. However, all wetlands are vulnerable to changes in flow regime that can change wetland and channel configuration through erosion and sediment deposition[76]. Such impacts will be most pronounced under extreme rain events, such as those associated with severe cyclones, and will be exacerbated by feral animal damage and poor land management practices that promote erosion.

Water availability is tied up with rainfall, runoff and temperature. As temperatures rise, the environment will demand more water to offset moisture stress and evaporation. So, even without any change in rainfall, freshwater availability may decline[82]. This is likely to affect groundwater aquifers, seasonal streams, and wetlands may dry earlier in the year than they presently do. Tainting of water supplies by saltwater will also become an issue in near-coastal environments. Flash-flooding associated with intense downpours may pollute water supplies with sediment, cause erosion and damage wetlands.

Terrestrial species

Individual plant and animal species have a narrow range of temperature and rainfall conditions in which they operate best; and are likely to respond differently to expected increases in carbon dioxide[75]. Plants and animals of the tropical savannas are expected to be among the first to suffer high levels of stress as a result of climate change, and, by 2070, to be among the most severely stressed organisms on the planet[83].

Changes in plant diversity and abundance will further affect fauna, causing a loss or increase in habitat and food resources[84]. Moreover, many animals may die from heat stress, which, when

Table 4. Climate-change-sensitive ecosystems of the Southern Gulf region

Adapted from Laurence *et al.* (2011) 48, Woinarski *et al.* (2007)74, Steffen *et al.* (2009)75, Capon *et al.* (2013)76

Saltmarsh and mangroves	
Values	**Threats**
• High primary productivity • High marine biodiversity • Stabilise coastal sediments • Protect the coast from storm surges and tsunamis • Filter nutrients and pollution • Wildlife habitat • Fish and prawn nurseries	**Current** • Soil loss from paddocks **Climate change** • Sea-level rise drowning ecosystem and allowing inland expansion • Increasing storm intensity eroding shorelines and undermining habitat • Ocean acidification affecting shell-forming animals • Changes in salinity affecting species composition • Changes in flow regime affecting species composition

Near-coastal wetlands	
Values	**Threats**
• Rich species diversity • Filter nutrients and pollution • Regulate gas exchange • Stabilise sediments • Mitigate floods • Wildlife habitat • High cultural significance	**Current** • Water extraction • Damage from pigs and feral cattle • Weed invasion • Soil loss from paddocks **Climate change** • Saltwater intrusion from sea-level rise leading to plant and animal death and colonisation by mangroves and other salt-tolerant species • Changes in flow regime and resultant erosion and sedimentation, causing plant and animal death and habitat loss and fragmentation • Increased evaporation rates affecting water levels

Tropical savannas	
Values	**Threats**
• Largely intact vegetation in good condition • High diversity plants and animals (most still present) • Several restricted-range species, notably in sandstone ranges • Carbon stores	**Current** • Altered fire regimes resulting in species loss and elevated carbon emissions • Transformer grasses that replace native species and alter fire regime • Loss of small mammals • Degradation from overgrazing • Woody thickening • Pressure for agricultural development **Climate change** • Increased heat stress impacts on plants and animals • Increased wildfire severity and spread eliminating fire-sensitive species and promoting weed spread • Increased storm activity promoting weed spread

combined with other stresses, is expected accelerate the loss of small mammals[85].

In the past, most species in Australia have survived climate change by staying put rather than migrating[86], and not all species are adapted for dispersal[87]. Cool, wet, humid or fire-protected areas are most likely to provide enduring habitat through an increasingly dry climate [88,89]. At a landscape scale, this includes gorges, gullies and caves[60,69]. At a microhabitat scale, rock piles, logs, hollow trees, deep litter and the shaded southern sides of steep hills are also important[90]. The Southern Gulf region is relatively flat, so there are few refuges where species can escape severe climatic conditions. The Lawn Hill Gorge-Camooweal area is already recognised as for its unique suite of animals, including mammals, birds, crustaceans and land snails[91,92,93]. More significantly, this “well-watered and richly resourced refugia”[94] enabled Indigenous people to survive 4,000 years of arid conditions through the last ice age[95]. Refuge for terrestrial biota will also be required from the floods that regular inundate the region[30,60]. This increases the importance of the North-west Highlands and other elevated areas, notably Donor’s Plateau, which sits in the middle of the Gulf Plains.

Modelling based on current plant and animal distributions and on current and projected climate surfaces has been used in an attempt to identify current biodiversity hotspots and areas that are most likely to provide refuges under climate change (Figure 26). Other than the high value Southern Gulf and Wentworth aggregations (see Figure 17), a small area of Julia Creek Dunnart habitat (Figure 20), and slightly larger areas of Gouldian Finch and Kalkadoon Grasswren habitat (Figure 21), the model of current biodiversity values (Figure 26a) fails to capture the high biodiversity areas discussed above. It also fails to capture the areas which have been highlighted as potential refugia based on an understanding of species’ responses to climate change (see Figure 25). Indeed, it could be argued that the high priority area in the southwest represents the section of the Mount Isa bioregional province with the least biodiversity value, while that in the south captures almost no biodiversity value at all. The failure of the model to predict current high value biodiversity values is likely to be the result of the scarcity of biodiversity records in some areas; the low density of climate stations; the imperfect correlation between species distributions and their ecological tolerances (see Predicting biodiversity responses to climate change); and the use of all species in the models, rather than a focus on high conservation value species and ecosystems. Given the model’s poor representation of current biodiversity values, basing conservation effort on this modelling would be fallacious.

Terrestrial ecosystems

The region’s vegetation communities are also expected to be influenced by climate change. Increased temperatures, intensity of wildfires, cyclones and flooding, and carbon-dioxide fertilisation (favouring shrubs and trees over tropical grasses[82,42], along with uncertain changes in rainfall, are expected to cause a reshuffling of plants and animals to create new ecological communities. These communities are still expected to have a recognisable savanna character[48]. However, weeds are expected be favoured by disturbance caused by increased wildfire and cyclonic damage.

Modelling based on current vegetation extent and moderate and extreme climate change scenarios indicates large shifts in vegetation will occur by 2070 (Figure 27). Under both scenarios, tussock grassland (MVG19), eucalypt open woodlands (MVG11) and eucalypt woodlands (MVG5) will continued to dominate the vegetation, and the extent of other forests and woodlands (MVG10) will decline by up to 70%. Under the moderate scenario, low-closed forest and tall closed shrublands (MVG15), other shrublands (MVG17) and

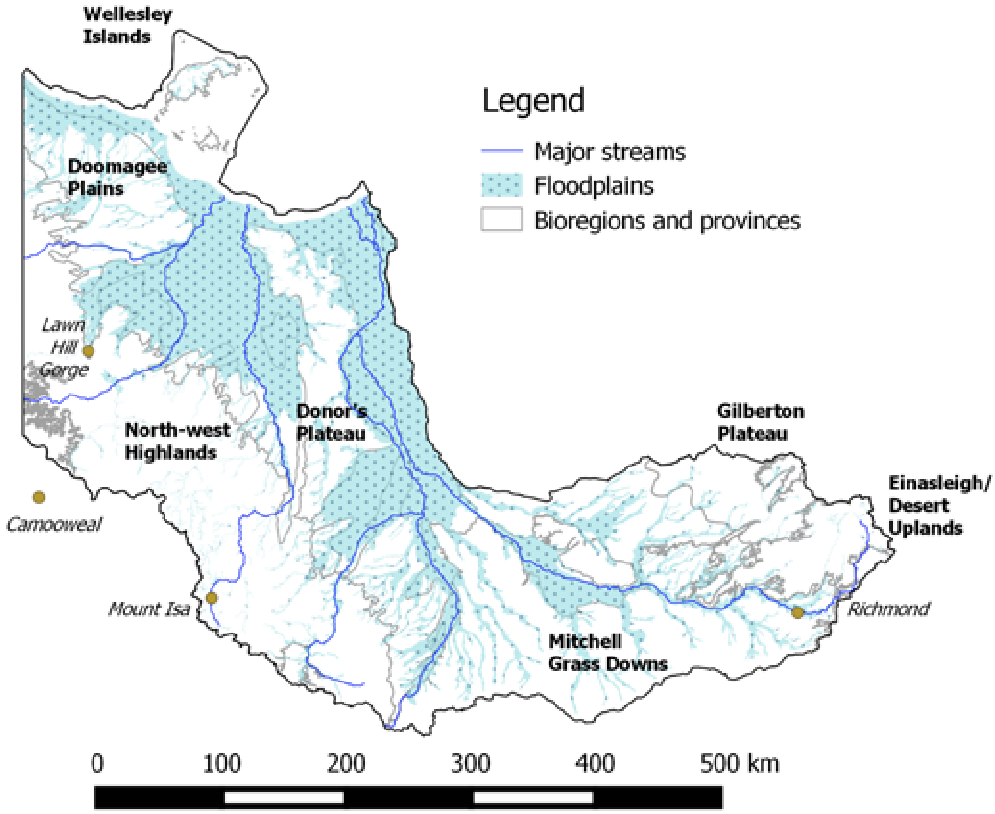


Figure 25. Important areas for biodiversity resilience to climate change, highlighting Lawn Hill Gorge and provinces that are elevated above flood level

Source of data: Floodplains, Queensland Department of Natural Resources and Mines (2013)[96]; Bioregional provinces, Department of the Environment (2012)[57]; Streams, Geoscience Australia (2004)[6]

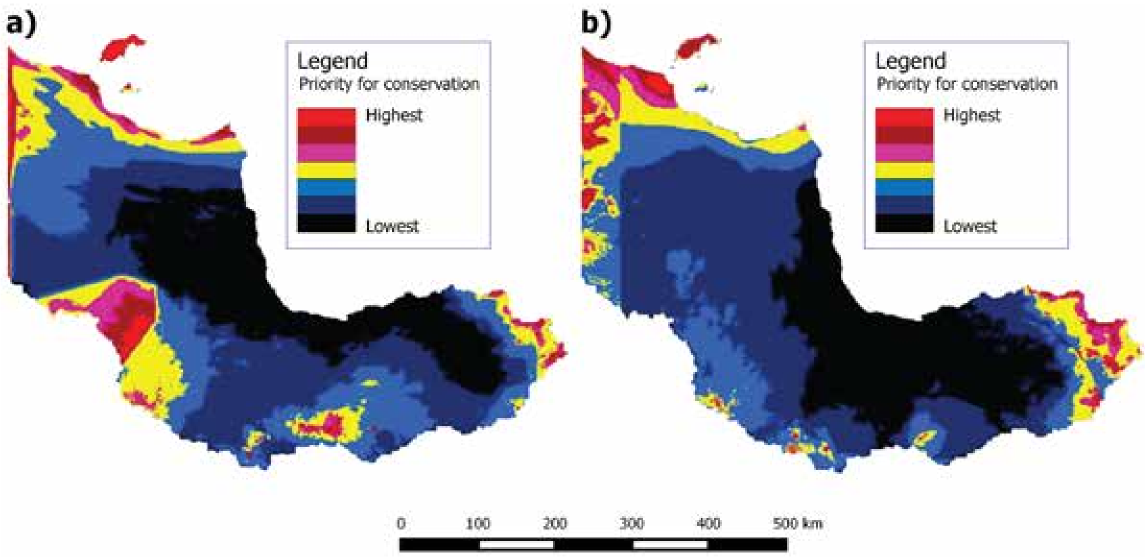


Figure 26. Priority landscapes in the Southern Gulf region based on (a) current faunal distributions, and (b) 2085 climate modelling

Source of image: Gobius (2015)[41] based on Reside *et al.* (2013)[59]

chenopod shrublands, samphire shrubs and forblands (MVG22) will increase to more than 10 times their current extent. Other grasslands, herblands, sedgelands and rushlands (MVG21), not currently present, will occupy about 1.2% of the region, and eucalypt open forests (MVG3) and acacia open woodlands (MVG13) will be lost from the region. Under the extreme scenario, MVG17, MVG3 and tropical eucalypt woodlands/ grasslands (MVG12) will increase to more than 10 times their current extent; MVG21, heath (MVG18) and rainforest and vine thickets (MVG1), not currently present, will occupy 7.7%, 0.1% and 0.01% of the region, respectively; and casuarina forests and woodlands (MVG8) and MVG15 will be entirely lost. The fact that these outcomes are so markedly different reflects the high level of uncertainty in modelling the likely impacts of climate change on vegetation communities[41]. Moreover, the fact that rainforests and eucalypt open forests are favoured in one scenario also raises the need for caution in interpreting these results. These communities require reliably mesic conditions. Yet climatologists conclude that the region's climate will become more arid as a result of increased temperatures and evaporation, and that there is no reliable indication of an increase in rainfall (see Future climate change and impacts).

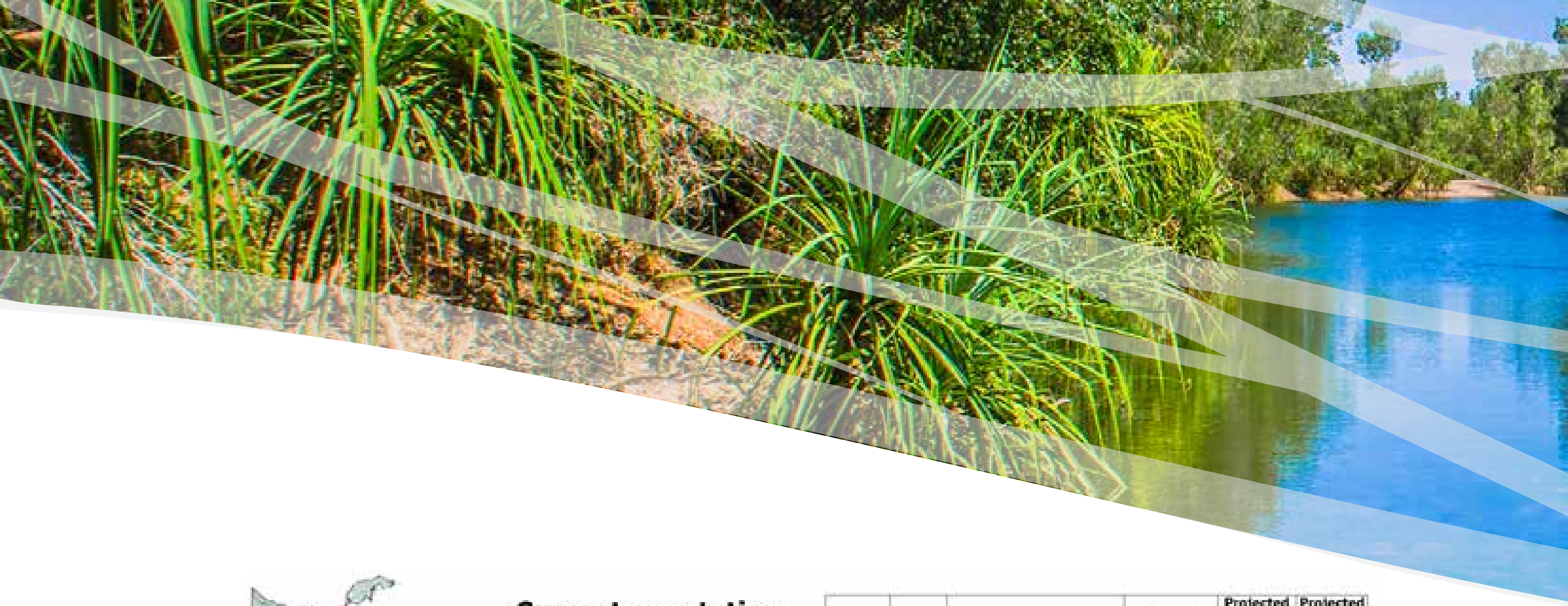
Spatial prioritisation of conservation effort

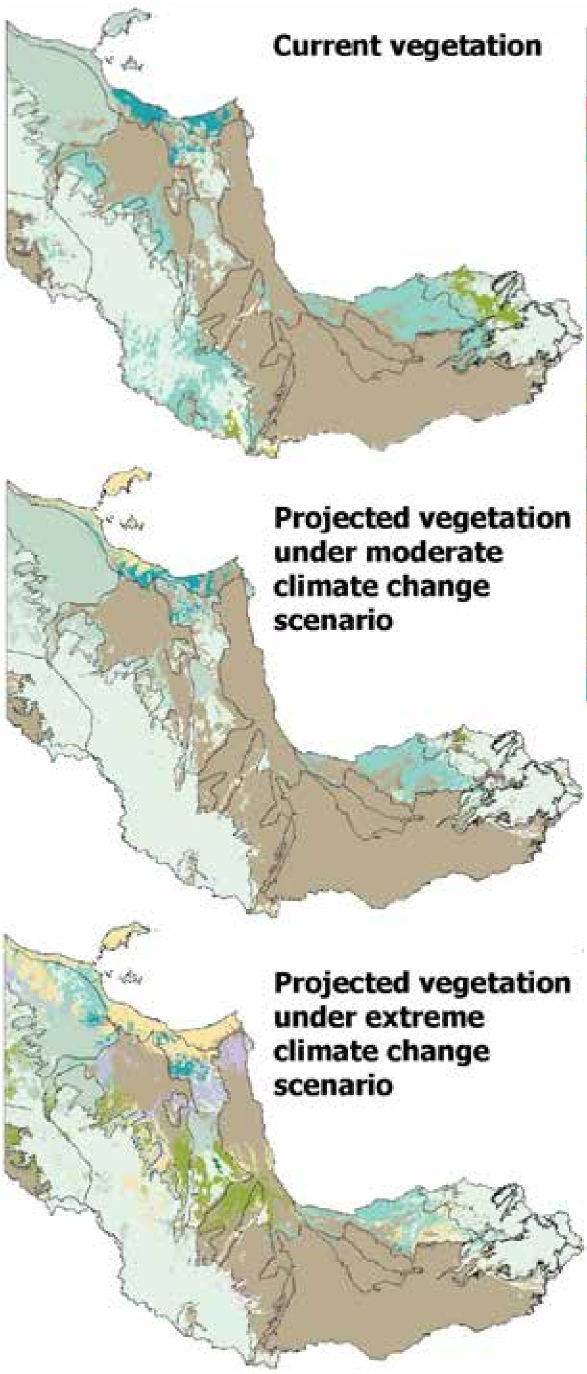
Work to conserve biodiversity will fail to have enduring benefits if the areas in which it is invested later become unsuitable habitat because of vegetation clearance, flooding, salinisation, aridity or temperature rise. So it is important to identify areas where these problems are unlikely to be an issue. Biodiversity conservation in the face of climate change relies on conserving our present range of biodiversity; identifying areas of current and future habitat; and ensuring landscape connectivity to facilitate natural migration or – in extreme cases – assist colonisation[97,98]. For some biodiversity values, this can be achieved using a landscape-scale approach through preserving a diversity of landscapes within protected areas; focusing conservation effort in areas that currently have high biodiversity values and are at low risk of anthropogenic (such as vegetation clearance) and natural disturbance (such as fire and flood); and ensuring the environmental health of the intervening landscapes[60,67,97,99]. It will also be necessary to focus effort on species that are particularly vulnerable to climate change[100,101].

The Queensland Department of Environment and Heritage Protection used a combination of biodiversity records and expert opinion to identify Strategic Investment Areas (SIAs), which are either hubs, which are core areas of high biodiversity value, or corridors, which are interconnecting areas that provide migration pathways between the hubs (Figure 28). SIAs adequately capture the priority conservation values identified in this report. All Nationally Important Wetlands that are not already conserved in the Protected Area estate are largely or entirely contained in SIAs, with the exception of Lake Moondarra (Figure 29). The SIAs capture representative areas of Regional Ecosystems with an Endangered or Of Concern remnant vegetation or an Endangered biodiversity status, as well as a large number of EPBC-listed springs (Figure 30). All of priority terrestrial species and Green Turtle nesting sites are also found in at least one SIA (Figure 31). Therefore these SIAs meet both the above requirements for protecting current biodiversity values as well as for ensuring preservation of biodiversity in face of climate change.

Prioritisation of conservation actions

Conservation actions to preserve and restore priority conservation values have been prioritised through





Key	Code	Description	Current distribution (%)	Projected change (Moderate scenario)	Projected change (Extreme scenario)
	MVG1	Rainforest and vine thickets	Absent	/	+++
	MVG3	Eucalypt open forests	Present	---	+++
	MVG5	Eucalypt woodlands	11.0	+	-
	MVG6	Acacia forests and woodlands	1.5	--	++
	MVG8	Casuarina forests and woodlands	0.1	--	---
	MVG9	Melaleuca forests and woodlands	0.3	--	--
	MVG10	Other forests and woodlands	12.4	--	--
	MVG11	Eucalypt open woodlands	27.1	+	+
	MVG12	Tropical eucalypt woodlands/ grasslands	0.1	-	+++
	MVG13	Acacia open woodlands	0.2	--	--
	MVG15	Low-closed forest and tall closed shrublands	Present	+++	---
	MVG16	Acacia shrublands	0.1	--	++
	MVG17	Other shrublands	Present	+++	+++
	MVG18	Heath	Absent	/	+++
	MVG19	Tussock grasslands	45.1	/	-
	MVG20	Hummock grasslands	0.7	-	-
	MVG21	Other grasslands, herblands, sedgelands and rushlands	Absent	+++	+++
	MVG22	Chenopod shrublands, samphire shrubs and	Present	+++	--
	MVG23	Mangroves	1.5	--	-

Key to vegetation change symbols

Code	Change
+++	Major gain
++	Moderate gain
+	Minor gain
/	No change
-	Moderate loss
--	Major loss
---	Total loss

Figure 27. Current and predicted vegetation of the Southern Gulf region

Source of image: Gobius (2015)[41]

a number of national and state processes (Table 5). Actions identified in these processes and associated plans will also help maintain and restore environmental conditions and conserve other native species. Surveys will be required to identify new populations of poorly known species (especially Pink Gidgee[102]), and monitoring to assess trends in those most at risk of decline (especially marine turtles[103], sawfish [104,105], Gouldian Finch[106], and Kalkadoon Grasswren[55]), and habitat fencing may be appropriate for springs and a few restricted-range species. However, most management for priority species and communities involves restoring environmental condition and instituting sustainable production and fishing practices. For marine and freshwater species, this mostly involves reducing marine debris and reducing bycatch. Management of priority terrestrial species, communities and wetlands involves management of pest animals, weeds, fire and grazing (including moderate grazing regimes, wet season spelling and maintaining water remote areas to minimise grazing pressure on parts of each property). Monitoring will be required to assess the effectiveness of conservation effort and to direct future investment.

Environments that are in good condition are most able to survive climate stresses[75]. Those burdened by weeds, pest animals, uncontrolled wildfire, pollution or poor management practices are most likely to degrade even further if affected by floods, droughts or cyclones. For example, grazing lands with good grass cover are less likely to be scoured by flood waters than are areas of bare ground[107]. Wetlands are most likely to emerge from particularly wet or dry years in good condition if they are not being trampled, grazed and dug-over by feral animals[108]. Birds and small mammals drinking at the last waterhole in the area are least likely to survive if they are sharing that waterhole with cats, foxes or wild dogs[109]. Fish and frogs are most likely to persist in a waterway in which wetlands can continue their role of filtering sediment and pollution[110]. Therefore, the best way to instil climate change resilience in terrestrial environment in the Southern Gulf is to continue investing in best practice grazing, weeds, pest and fire management; and to encourage conservation agreements over high-conservation value area. For marine conservation, climate change resilience will be enhanced by efforts to reduce predation on turtle nests, reduce marine debris and improve the sustainability of commercial and recreational fishing.

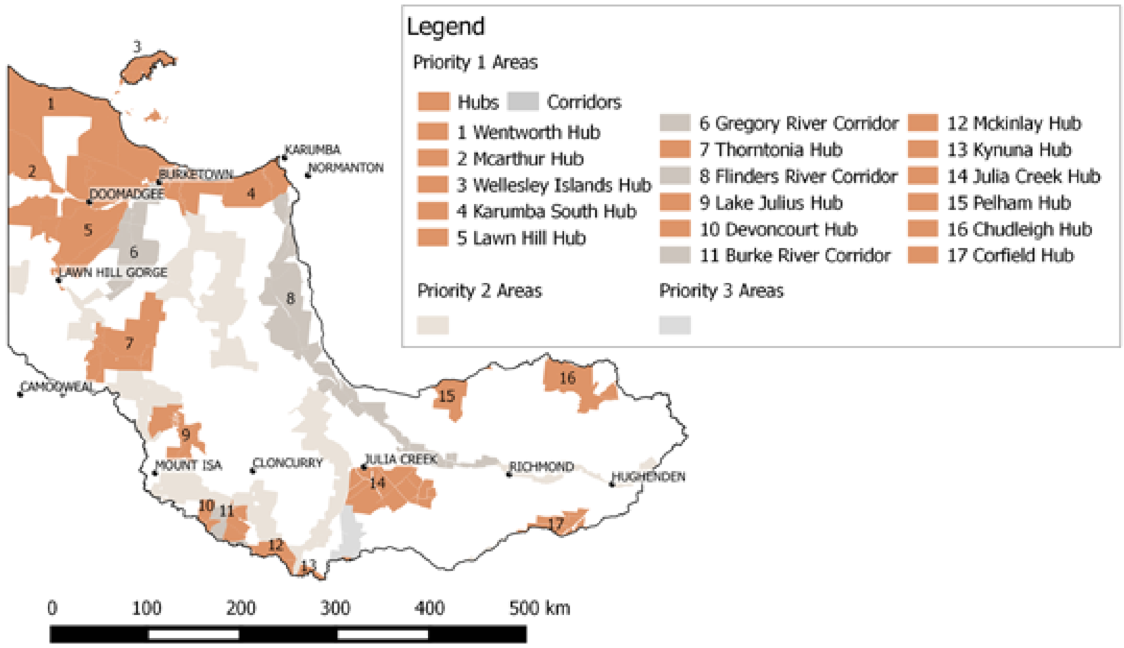


Figure 28. Strategic investment areas in the Southern Gulf region

Source of data: Queensland Department of Environment and Heritage Protection (2016)[8]

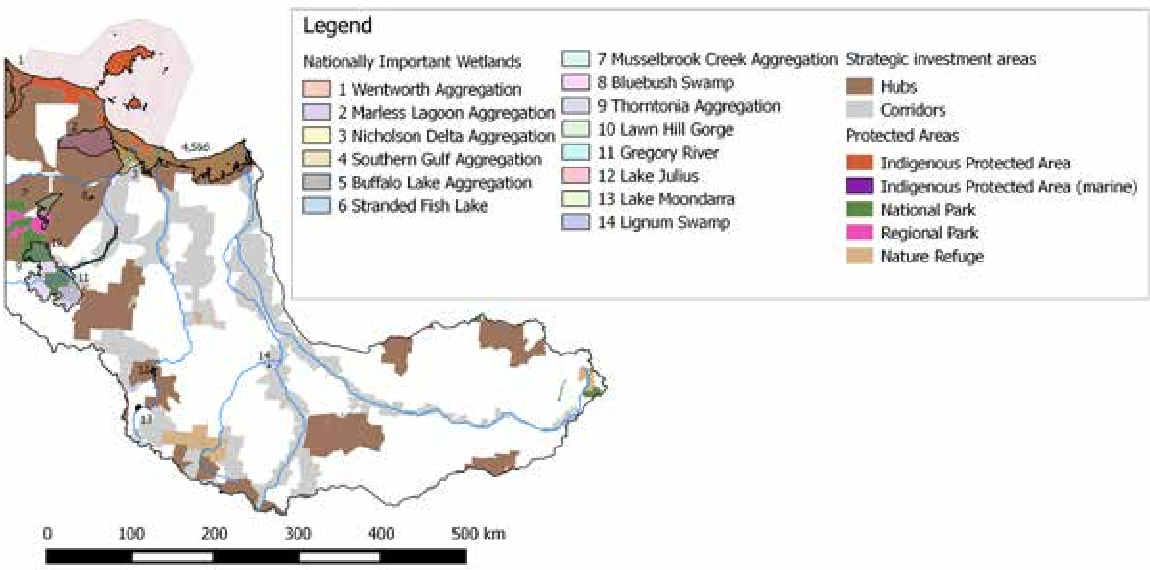


Figure 29. Strategic investment areas overlain by Nationally Important Wetlands

Source of data: Nationally Important Wetlands, Australian Department of the Environment (2010)[63], Strategic Investment Areas, Queensland Department of Environmental Heritage Protection (2016)[72]; Protected Areas, Australian Department of the Environment (2014)[18]; Streams, Geoscience Australia (2004)[6]

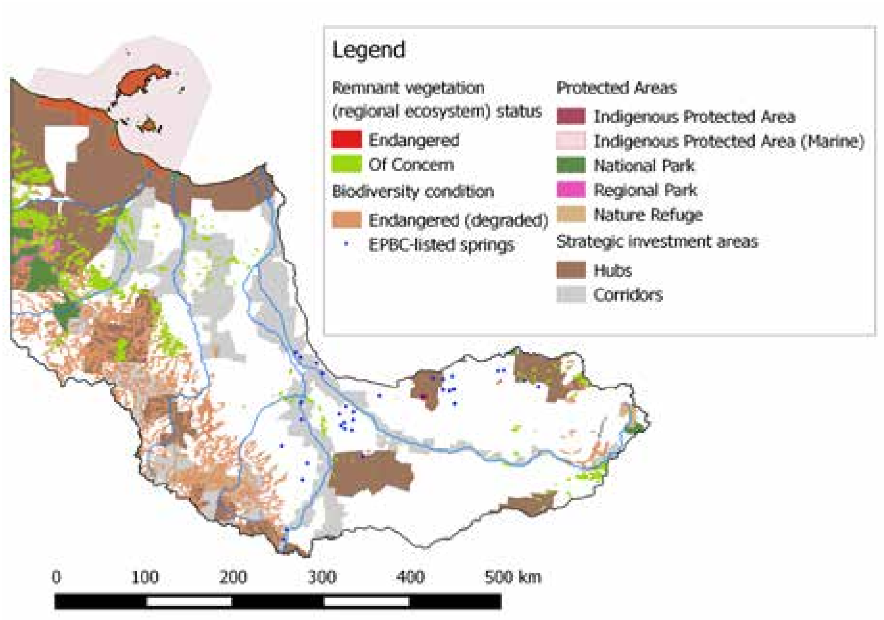


Figure 30. Strategic investment areas overlain by priority threatened ecological communities

Source of data: Strategic Investment Areas, Queensland Department of Environmental Heritage Protection (2016)[72]; Protected Areas, Australian Department of the Environment (2014)[18]; Streams, Geoscience Australia (2004)[6]

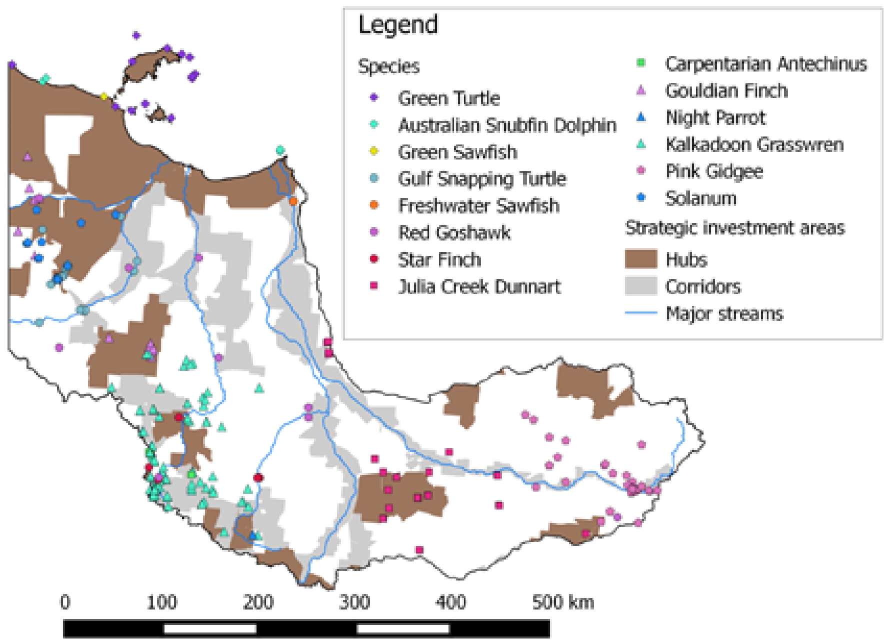


Figure 31. Strategic investment areas overlain by records of priority species

Source of data: Species, Atlas of Living Australia (2016)[56], Strategic Investment Areas, Queensland Department of Environmental Heritage Protection (2016)[72]; Protected Areas, Australian Department of the Environment (2014)[18]; Streams, Geoscience Australia (2004)[6]

Table 5. Management recommended for the protection and recovery of Southern Gulf priority species

Source of information: 111 Australian Department of the Environment (2016)112, Queensland Department of Environment and Resource Management (2010)113

Codes: AWD, Austrian Wetlands Database111; BoT, Back-on-Track113; LA, Listing Advice, CA, Conservation Advice; RP, Recovery plan

Common name	Plans	Community awareness	Marine debris	Barriers to migration	Flow regime	Water quality	Bores	Commercial fishing	Recreational fishing	Unsustainable hunting	Cats/ foxes	Pigs	Wild dogs	Weeds	Grazing	Water-remote areas	Fire	Collectors	Conservation agreements	Fence	Survey/monitor
Marine species																					
Olive Ridley Turtle	RP		+					+		+											+
Loggerhead Turtle	RP		+					+													+
Leatherback Turtle	RP																				+
Green Turtle	RP		+					+		+		+	+								+
Green Sawfish	LA		+	+	+			+	+	+								+			
Dwarf Sawfish	CA		+	+	+			+	+	+								+			
Australian Snubfin Dolphin	BoT		+					+													
Riparian species																					
Gulf Snapping Turtle	CA					+				+		+		+	+		+				
Freshwater Sawfish	CA		+	+	+	+		+	+												
Red Goshawk	CA	+												+	+		+	+			
Star Finch (eastern)	CA														+		+				
Mammals																					
Julia Creek Dunnart	RP	+									+			+	+	+			+		+
Carpentarian Antechinus	RP										+						+				
Other birds																					
Gouldian Finch	RP											+			+		+		+		+
Night Parrot	CA										+				+		+		+		
Kalkadoon Grasswren	BoT										+			+	+		+		+		+
Plants																					
Pink Gidgee	CA	+																	+	+	+
Solanum	CA	+																	+		
Threatened communities																					
Great Artesian Basin Springs/RE 2.3.39	RP	+					+					+								+	+
Nationally Important Wetlands																					
Bluebush Swamp	AWD					+						+			+						
Gregory River	AWD													+							
Lake Julius	AWD																				
Lake Moondarra	AWD					+								+	+						
Lawn Hill Gorge	AWD											+									
Lignum Swamp	AWD														+						
Marless Lagoon Aggregation	AWD											+									
Musselbrook Creek Aggregation	AWD														+						
Nicholson Delta Aggregation	AWD													+	+						
Southern Gulf Aggregation	AWD											+		+	+						
Thorntonia Aggregation	AWD											+									
Wentworth Aggregation	AWD											+			+						

CLIMATE CHANGE AND HUMAN CAPACITY AND COMMUNITY WELL-BEING

Climate change impacts

Climate change will directly affect the capacity of Southern Gulf natural resource managers to institute best practice production management and to address threats to biodiversity. Predicted increases in temperature of 1-2°C by 2030 (see Future climate change and impacts) will have adverse effects on human health in general[114] and affect the ability of people to work outdoors. In the Southern Gulf, the period of safe working conditions will be reduced by approximately one month for every degree of temperature rise (Figure 32). Such changes are also likely to influence people's decision whether to keep working in NRM or indeed to remain living in the Southern Gulf region.

Natural disasters (droughts, floods, cyclones and wildfires) also increase the risk of physical injury and damage and destruction of property (Table 6), and have flow-on effects to emotional and financial stress, community well-being and the regional economy. So predicted increases in such events as a result of climate change will increase the challenges already faced by the Southern Gulf community. Economic disparity means that Indigenous communities in the north of the region will be particularly vulnerable to climate change[24]. Also, high levels of debt in the pastoral industry are likely to hamper the ability of some pastoralists to cope with an increasingly severe climate[22,24,51].

Table 6. Potential impacts of natural disasters on people and communities

Adapted from Lindell (2003)[115], Fraser *et al.* (2005)[116], Kent and Alston (2008)[117]

Impacts
Physical
Injury and death
Property damage
Health
Anxiety, depression, grief
Fatigue and physical illness
Substance abuse
Societal
Family breakdown
Homelessness
Conflict and grievances
Economic
Loss of assets (houses, businesses)
Loss of operational capacity

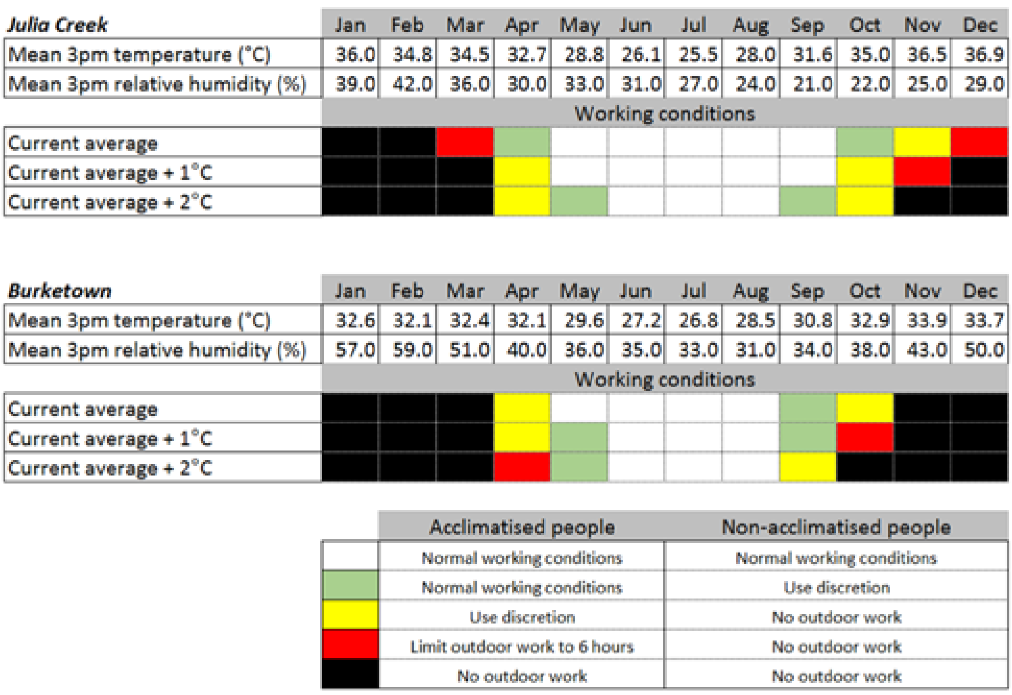


Figure 32. Impact of temperature rise on working conditions

Source of data: Australian Bureau of Statistics (2010, 2016)[27,36]

Adaptive capacity

The increasing stress climate change is expected to place on the natural resources will necessitate changes in management. An assessment of pastoralists in northern Australia concluded that only a small proportion of landholders are equipped to make the necessary adjustment (Table 7). Young people with a transferable skill set appear to have the best capacity to cope with and adapt to change. Producers with a strategic approach to business management and a high level of environmental awareness appear most likely to have good approaches to risk assessment and planning and be interested adapting to change, while those who were strongly attached to their land were least likely to exhibit these skills or attitudes. Those with a financial buffer seem best able to cope with climate shocks. Finally producers that are well-networked into the community and industry are most likely to be aware of the need to change and have most options for doing so.

Climate change resilience

Responses to climate change range from resisting change, through accommodating and adapting to change, and directing changes by managing the landscape to create new opportunities[119]. Capacity to response positively to climate change has three elements: personal skills and attitudes; community relationships and networks; and access to resources and institutional support. Extension and outreach can help build resilience in individual land holders to assist them deal with climate shocks (Table 8). In particular, community resilience will be enhanced through Indigenous economic development, including ranger programs, and by assisting pastoralists to find a pathway out of crippling levels of debt[22,24].

Communities in which family, friends and neighbours know, trust and support one another, are best able to cope with climate variability and other traumatic events[120]. However, where traditional responses are no longer adequate, receptiveness to fresh ideas is also important. Natural resource managers need to be appraised of climate change and mitigation options, and to develop skills and networks that will enable them to implement them.

Table 7. Climate change resilience of northern Australian pastoralists

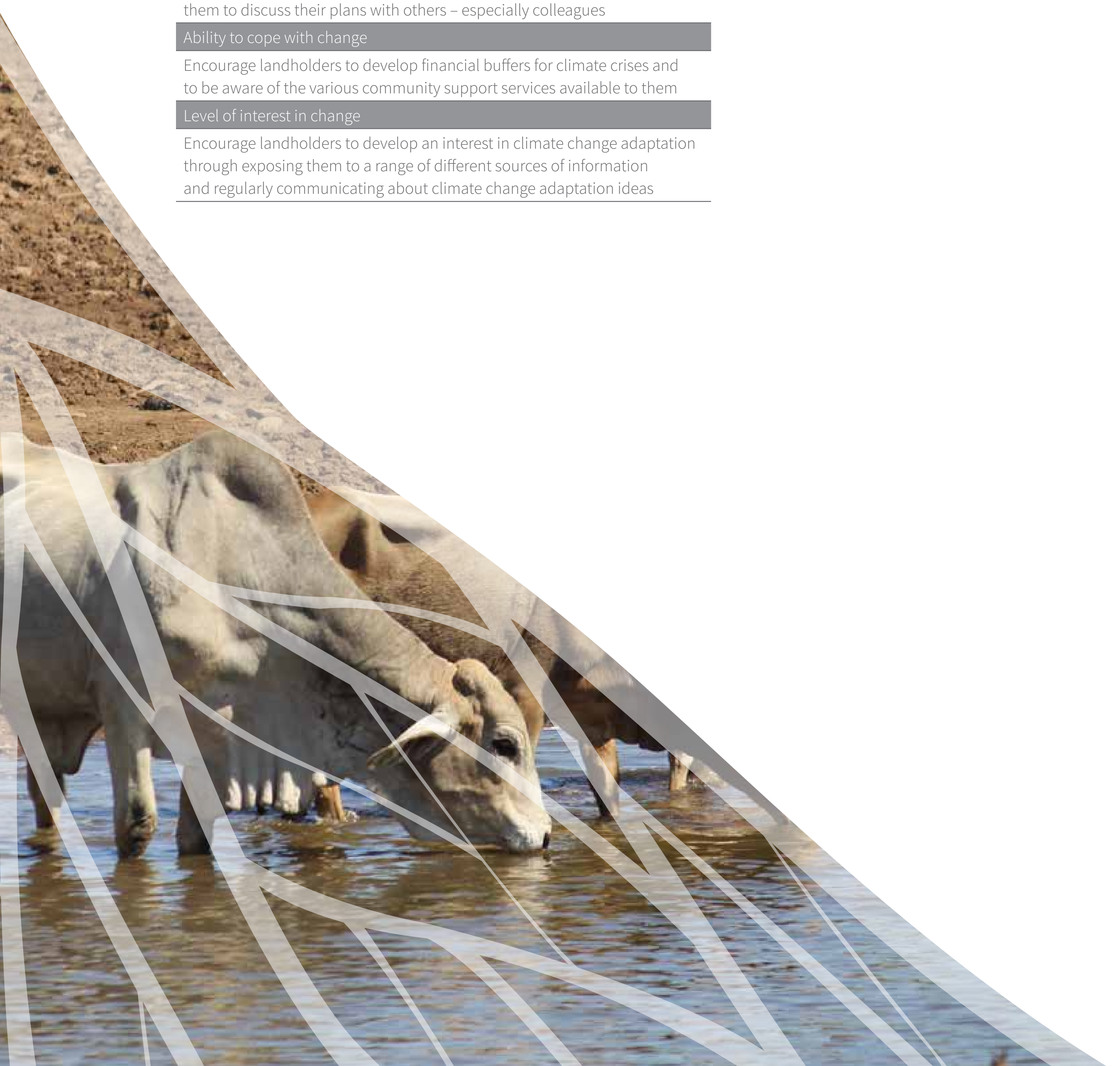
Adapted from Marshall *et al.* (2014)[118]

Group	Characteristics	Response
Low resilience		
1 (43.1%)	• Owner with no children at home • Weak occupational identity • Average age: 59 years • Diverse income sources • Weak networks • Small enterprise Average property size: 72,728 ha Average workforce: 1.9 employees Average herd size: 4,600 head Business turnover A$1-5 m	Little interest in adapting to the future Low skills for planning, experimenting, reorganising and learning
2 (41.0%)	• Owner with children at home • Diverse income sources • Lack strategic business direction • Average age: 51 years • Medium-size enterprise Average property size: 111,634 ha Average workforce: 3.4 employees Average herd size: 7,000 head Business turnover A$1-5 m	Limited capacity to manage risk and uncertainty Least likely to cope
High resilience		
3 (13.4%)	• Owner/manager with children at home • Strong occupational identity • 100% of income from the cattle industry • Strong psychological and financial buffer • Strong networks • Average age: 52 years • Very large enterprise Average property size: 364,639 ha Average workforce: 8.9 employees Average herd size: 12,000 head Business turnover A$1-5 m	Most likely to cope
4 (2.6%)	• Manager • Average age: 41 years • Strong occupational identity • 100% of income from the cattle industry • Strong strategic business direction • Environmentally aware • Strong networks • Large enterprise Average property size: 218,428 ha Average workforce: 6.3 employees Average herd size: 2,000 head Business turnover more than A$5 m	Manages risk well Likes to experiment with options Interested in change

Table 8. Recommended action for building climate change in northern Australian pastoralists

Source: Marshall *et al.* (2015)[51]

Action plan
Perception of risk and managing for uncertainty
Facilitate landholders to learn about managing risks and uncertainty
Ability to plan, learn and reorganise
Facilitate landholders to develop skills to plan for the future, and encourage them to discuss their plans with others – especially colleagues
Ability to cope with change
Encourage landholders to develop financial buffers for climate crises and to be aware of the various community support services available to them
Level of interest in change
Encourage landholders to develop an interest in climate change adaptation through exposing them to a range of different sources of information and regularly communicating about climate change adaptation ideas



CLIMATE CHANGE AND CULTURAL HERITAGE

Climate change has serious implications for cultural heritage[121,122]. Many aspects of the natural environment that are vulnerable to climate change are culturally significant. Waterways and wetlands, in particular, hold special meaning for Indigenous people as ceremony and story places. They also provide food, medicines and materials for arts, crafts and livelihoods. Access to water and freshwater environments is pivotal for future Indigenous economic development.

Climate change may affect species of totemic or material significance to Indigenous people [122]. Near-coastal sites are likely to be lost to sea-level rise, and freshwater sites converted to saltwater or degraded through erosion or sedimentation (see Climate change and biodiversity). These losses will compound degradation and loss of cultural heritage that has resulted in the region from dispossession and removal of Indigenous people from their land, commercial fishing, pastoralism, weeds and feral animals, altered fire regimes[123]. In addition, the capacity of Indigenous communities to undertake cultural heritage management will be affected by rising temperature that make it unsafe to undertake physical outdoor work (see Climate change and human capacity and community well-being).

While addressing the impacts of climate change on cultural heritage condition will generate particular challenges, it will be assisted by management to enhance the climate change resilience of biodiversity (see Climate change and biodiversity) and human capacity (see Climate change and human capacity and community well-being).

CLIMATE CHANGE AND LIVELIHOODS

Climate change impacts

Impacts of climate change on the environment and human health and well-being will flow on to impacts on livelihoods. Cultural and natural resource management by Indigenous communities will face difficulties as a result of climate change impacts on environmental condition, safety of working outdoors and accessing markets for bush tucker production[122].

Fish catches are likely to be affected by ocean acidification[46], degradation of estuarine environments and sea grass beds caused by storm damage, and changes to flow regime and sediment loads[77]. Severe cyclones may increase the periods when fishing fleets are unable to operate in rough weather and cause significant damage to boats and harbour facilities. An expected increase in the number of days that temperatures exceed levels when humans can safely remain outdoors will affect most industries in the region (see Climate change and human capacity and community well-being).

Pastoral operations will be affected by heat stress on cattle, degradation of resources (water, soil and grass) as a result of CO_2 fertilisation (which reduces the nutritional value of the grass), temperature increases, increased disturbance from floods and wildfires, and opportunistic spread of weeds and cattle ticks (Table 9). These pressures will necessitate increased investment in infrastructure. Significant costs and interruption to operations will be incurred as a result of flood and cyclone damage to property and regional infrastructure. The increasing frequency of such events will make recovery more difficult[24], as well as more costly as insurance rates continue to rise[124]. Where these factors combine to place businesses in financial jeopardy, they will take their toll on the health and well-being of producers, their families and the regional economy.

Tourism in the Southern Gulf region will also be adversely affected by climate change, not least because of increasingly torrid conditions. Other potential climate change impacts that could reduce visitation rates include disruption by natural disasters; perception of a degraded environment; loss of recreational fish stocks; perception of increased disease risk (e.g. from malaria); and geopolitical instability[77].

Climate change will also have implications for new and emerging industries. Agricultural development relies on irrigation water and high quality agricultural land. Water resources are vulnerable to climate change that may both reduce supply (through increased evaporation rates and prolonged droughts) and increase demand (to avert heat stress in crops and livestock)[82]. However, an awareness of climate change has also provided opportunities in the Southern Gulf, with the capacity for enterprises to engage in carbon emission reduction programs[125].

Climate change will also necessitate increased expenditure on infrastructure as a result of damage caused by increased flood and cyclonic intensity, and the need to mitigate such impacts[124,126]. By 2030 near-coastal infrastructure will need to be 13 cm higher in the landscape to avoid saltwater damage than it does today[38].

Table 9. Likely impacts of climate change on pastoral production and livelihoods

Adapted from Crowley (2016)[22]

Variable	Contributing factors	Likely impact
Environment		
Surface water	Increased temperatures	Reduced water availability
Soil stability	Increased rainfall intensity & cyclone intensity	Increased soil erosion
Ground cover	CO_2 fertilisation Increased temperatures, heatwaves, wildfire extent & soil erosion	Reduced ground cover
Soil carbon	Increased temperatures	Reduced soil carbon
Cattle ticks	Increased temperatures	Increased numbers of cattle ticks, with an expanded distribution
Weed spread & water use	Increased temperatures & cyclonic disturbance	Increase weed spread & management costs
Woody thickening	Increased wildfire severity CO_2 fertilisation	Uncertain impact on woody thickening
Forage production	CO_2 fertilisation Increased temperatures & evaporation Uncertain changes to wet season length & growing season Uncertain changes in woody thickening Reduced ground cover	Reduced forage production & forage quality
Grain for feed	Increased demand for grain for biofuel Increased competition for agricultural land	Reduced availability & increased cost
Animal health	Increased temperatures, evaporation & heatwaves	Increased heat stress & water requirements
Animal production	Increased cattle tick abundance, wildfire severity & animal heat stress Reduced water availability, forage production & quality	Reduced liveweight gain & reproductive rates Increased mortality rates Reduced animal production
Property infrastructure	Increased animal water needs & heat stress Reduced water availability Increased cyclonic damage & wildfire severity	Increased need for shade, cooling sprays, watering points & replacement of damaged infrastructure
Profitability	Reduced animal production Increased infrastructure, grain & weed management costs	Reduced income, gross margins & hence profitability
Infrastructure		
Water storage & distribution	Accelerated degradation	Interruptions to supply Increased maintenance costs
Road & rail transport	Increased severity of flooding & cyclone damage to road & rail network causing delays or re-routing Increased road maintenance costs Increased risk from road damage	Reduced access to properties & ability to get cattle to market Increased cattle mortality risk Increased transport & insurance costs
Ports	Increased storm damage, flooding & corrosion	Increased frequency & duration of port closures causing shipping delays Increased cattle mortality risk Increased transport & insurance costs
Power generation	Increased power disruption Accelerated degradation of network	Interruption to meatworks operation
Communications	Increased frequency & duration of network outages	Disruption of communication services
Buildings	Building damage & accelerated deterioration	Disruption of lives & business operations
Social		
Emotional stress	Reduced income, gross margins & profitability	Increased personal stress & family breakdown

Building climate-resilient NRM enterprises

Building climate-resilience NRM enterprises starts with making appropriate decisions about land use and water allocation[127]. This means assessing risks to that any new land use might suffer or impose on the environment other enterprises in the region. An example of this is the assessment made of risk of water shortages to new agricultural development on the Flinders River. This study concluded that irrigation may not be possible in very dry years, and that "the combined risks of secondary salinity and flooding may reduce the area of soil that is suitable for dryland or irrigated cropping"[128].

Once established, enterprises can prepare for climate change by adopting management practices that increase efficiency of resource-use to minimise the impact of water, grain or grass shortages. Pastoral enterprises that use moderate stocking rates are more profitable through periods of dry weather than are those that overstock, and are most likely to perform well in difficult years[51,129]. In addition, by growing and storing their own hay, pastoral enterprises can not only increase profitability in good years, but reduce the impacts of drought [130]. Agricultural enterprises that use trickle irrigation are more profitable and likely to survive water-shortages than those using furrow irrigation[131].

Climate-resilient enterprises also have the ability to adjust operations in response to changing conditions[51]. This may mean adjusting pastoral operations, such as adjusting stocking rates by selling cattle or sending them for agistment[129], or switching from irrigated crops in favourable seasons to dryland crops in poor years. In short, building climate-resilience requires the adoption of best-practice natural resource management, minimising risks to both the enterprise and the environment. Extension programs will be needed to demonstrate management options that respond to climate variability.

Resilience also means being able to prepare for and recover quickly from disasters. Institutions must be in place that both encourage resilience-building and facilitate recovery. Hence reform of the disaster recovery funding and insurance arrangements is a high priority[24]. Overcoming transport difficulties and poor wet season access will improve both capacity to prepare for climate extremes and recover from them[22,24].

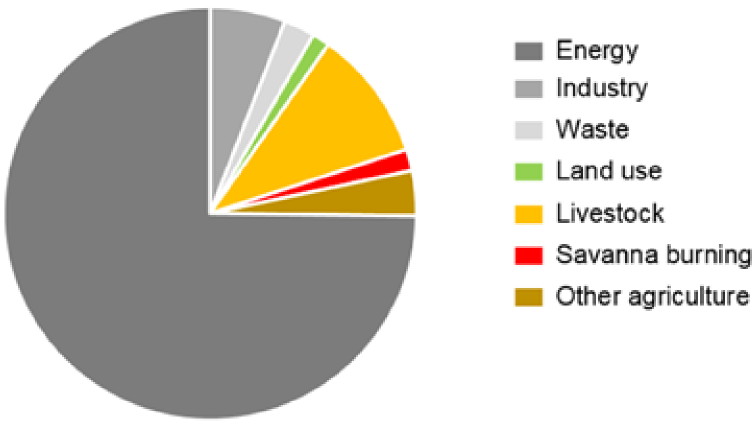


Figure 33. Australia's greenhouse gas emissions in 2013

Source: IPCC (2014)[132]

Table 10. Potential for Southern Gulf natural resource managers to contribute to greenhouse gas reduction

Source: Crowley (2016)[125]

Greenhouse gas emission reduction activity	Potential
Reduce methane emissions from livestock ,	High
Fire management to abate GHG emissions	Low
Avoided deforestation	not applicable
Tree planting and regrowth	not applicable
Improving soil carbon	watching brief

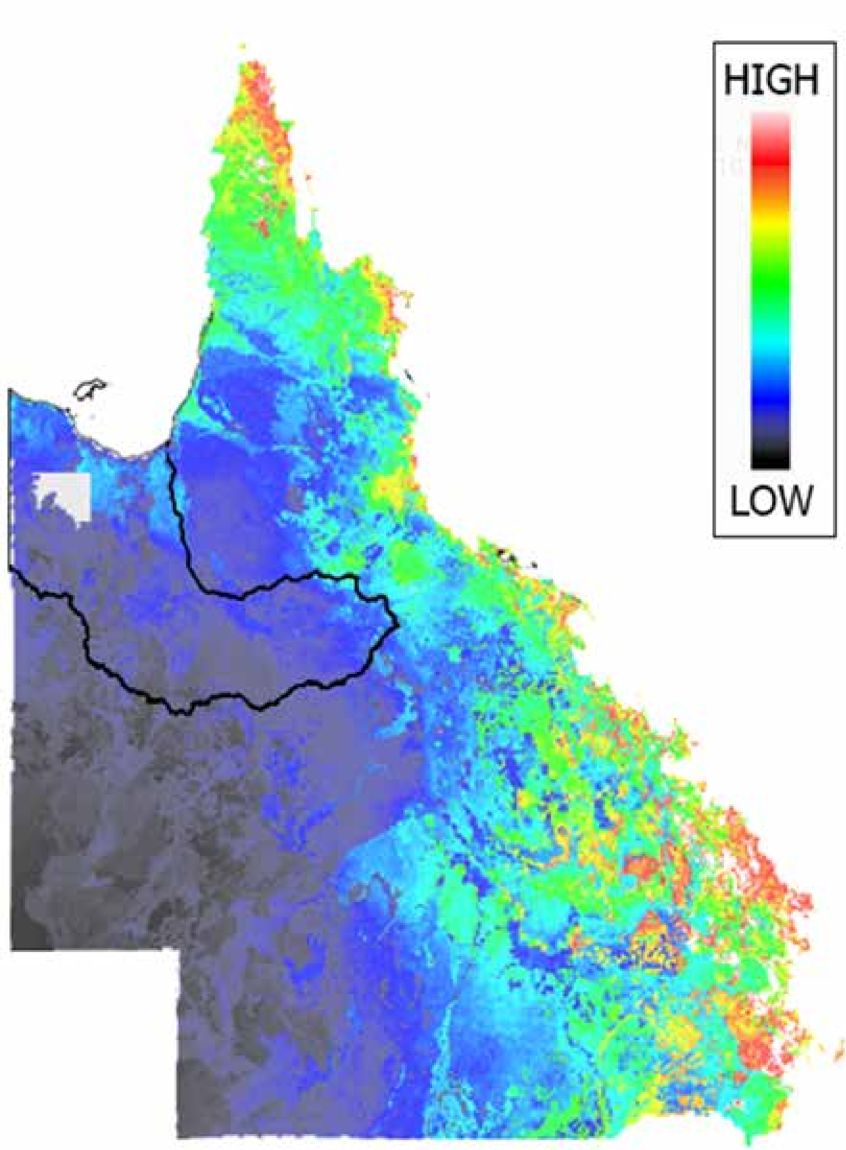


Figure 34. Priority areas for tree planting in Queensland based on carbon values

Source: Department of Environment and Heritage Protection (2015)[133]

Entering the carbon economy

As climate change is driven by increasing greenhouse gases (Figure 33) , there is a market for management that reduces greenhouse emissions or store carbon. Natural resource management eligible for funding under the Australian Government's Emission Reduction Fund (ERF) includes tree planting, avoiding vegetation clearance, reducing methane emissions from agriculture and burning of savannas to reduce extent of late dry season fires (Table 10). Carbon credits generated from these activities can be sold to the Government at auction or to other buyers on the open market. In the first two ERF auctions, carbon credits were purchased by the Australian Government for an average of $13.95/tonne in April 2015 and $12.25/ tonne in November 2015 . So, activities to reduce greenhouse gas emissions can not only mitigate climate change, but also provide income and improve enterprise viability.

Landholders can participate in this market by undertaking a range of emission reduction activities that generate carbon credits. There are two forms of emission reduction that have potential in the Southern Gulf region; herd management to reduce methane emissions and savanna burning. Tree planting, regrowth and avoided deforestation are not applicable because of low biomass production of the region's woodlands (Figure 34)[133].

Adoption of management practices to improve soil carbon appears to be a promising prospect at first glance. However, the complex pathways of carbon accumulation and loss mean that no suite of practices can presently be guaranteed to increase carbon stored in the soil[22]. An ERF method has been approved that enables landholders to measure soil carbon sequestered by adjusting grazing land management, but this does not stipulate how this is to be done . None of the 15 ERF-registered soil carbon projects has so far yielded any carbon credits, although seven projects have committed to selling their credits to the Australian Government. Southern Gulf NRM will maintain a watching brief in this area.

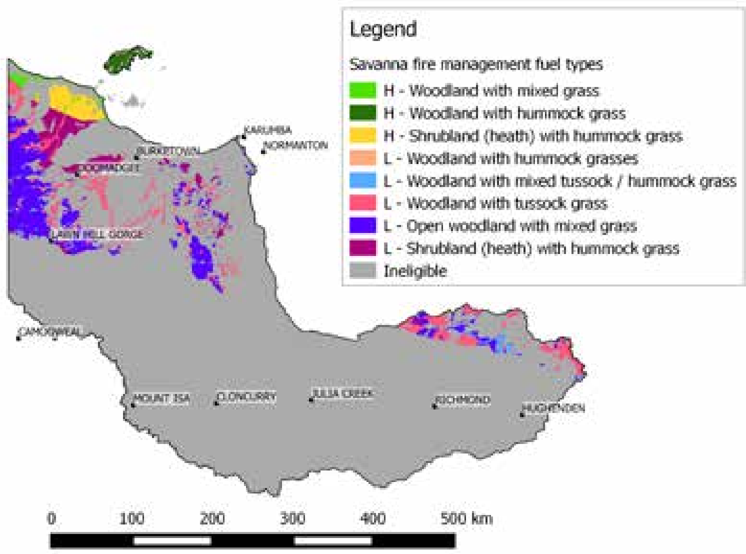


Figure 35. Eligible fuel type for Savanna Fire Management projects
Source: Crowley *et al.* (2016)[43]

Savanna burning to reduce methane and nitrous oxide emissions from late dry season fires is applicable in just over one-third of the Southern Gulf region (Figure 35). However, for fire management projects to be economically viable, it is also necessary for the project area to contain a significant area of eligible fuel types , for the current fire regime to have frequent, extensive and severe late dry season fires, and for the carbon price to be high enough to cover costs of project management and administration. Even at a carbon price of $40/tonne, few areas in the Southern Gulf region would meet those criteria[135]. It would therefore appear that there is limited scope for economically viable savanna fire management projects in the region at current prices.

The most promising opportunity for improving livelihoods from the carbon economy in the Southern Gulf region is through reducing methane emissions from livestock[22]. In 2011, the Southern Gulf region contained about 5% of the Australian cattle herd, with the Mitchell grass country in the south-eastern part of the region having some of the highest concentrations of cattle in the country. So this is an area in which reduction of livestock emissions should be a high priority. However, massive destocking in response to drought conditions may delay this option for some time[136].

There are currently two approved ERF methods to reduce emissions from livestock (Table 11). Substituting nitrate for urea licks on a property with 30,000 breeders is only expected to provide an annual income of $18,000, with an after-cost profit of $4,000. The herd performance method is far more promising. Modelled case studies in the Kimberley and Northern Territory for properties with 10,000-15,000 breeders showed and expected annual income from emission reduction of $300,000 to $600,000 and an after-cost profit of $27,000 to $70,000[22,137]. Projects using this ERF method therefore have potential for increasing the profitability of adopting best-practice herd management. In general, it appears that management practices that improve herd performance, will also decrease the carbon input required to produce each kilogram of meat[22,138]. Examples of changes to management that are expected to both reduce emissions and improve herd performance include[139,140]

- Fencing and additional water points
- Rotational grazing
- Herd segregation / supplementation
- Irrigation or forage cropping
- Increased selection pressure, culling and reduced breeder numbers

In April 2016, one herd management project and one soil carbon project were registered in the Southern Gulf region, although neither had yet go to the stage of accruing carbon credits[141]. Several other methods for reducing methane emissions from pastoral enterprises are under development and also look promising.

Carbon-friendly technologies with NRM benefits can provide alternative energy sources and reduce emissions. A good example is installation of solar-powered pumps to allow water points to be established away from environmentally sensitive streams and wetlands. Because adoption of such technologies help the Australian Government achieve its Renewable Energy Target, they may also be eligible for funding through the Australian Government's Small-scale Renewable Energy Scheme[161].

Table 11. Strategies to reduce greenhouse gas emissions from livestock

Adapted from Crowley (2016)[22]

Strategy	Sources	ERF method
Improve feed conversion efficiency		
Replacing urea lick with nitrate	142	Current
Other dietary adjustments	143,144,145,146,147,148,149,150,151,152,153	Potential
Improve herd management and growth rates		
Herd management	140,145,147,154,155	Current
Genetic selection of livestock	156	Unlikely[138,157]
Improve feed quality		
Moderating stocking rate to improve pasture quality	158,159	Unclear
Grain-based feed-lotting	145,152,156,160	Unclear

Conservation economy

In addition to emission reduction, the conservation economy offers opportunities for improving the economic resilience of individuals, enterprises and the economy of the Southern Gulf (Table 10). The conservation economy is particularly important for Indigenous communities. The Wellesley Islands and adjacent mainland have already been declared an Indigenous Protected Area, and another is proposed for Gangalidda country northeast of Burketown. Funding has been obtained for management of both areas through Commonwealth and state government land and seas ranger programs. However funding is never secure and requires a long-term commitment by investors[162]. Bush Heritage Australia is active in the Southern Gulf region through its partnership with Waanyi Garawa[47], but the area is not currently a priority for other non-government organisations

Table 12. Potential for other conservation economy activities to contribute to Southern Gulf livelihoods
Source: Crowley (2016)[125]

Activity	Potential
Indigenous business and employment	
Indigenous Protected Areas	Moderate
Indigenous ranger programs	Moderate
Biodiversity conservation	
Threatened species and communities	Low
Managing biodiversity for climate change resilience	Low
Weed and pest animal management	High
Marine debris removal	Low
Biosecurity surveillance	?
Water	
Maintaining riparian condition	Moderate
Improving GBR water quality	not applicable
Best practice management	
Water quality improvement	Low
Stewardship to improve grazing land condition	?

Landholders entering into conservation agreements with the Queensland Government by declaring a Nature Refuge over all or part of their property may also be eligible for financial assistance through NatureAssist[45]. There are currently four Nature Refuges in the region (Figure 4). The Queensland Government is currently refining its priorities under the Nature Refuges program. However, areas in the Southern Gulf region that are most likely to attract such funding must be in good condition and have appropriate management arrangements and contain one or more of the following features

- Threatened species or their habitat
- Endangered or Of Concern regional ecosystems
- Habitats and ecosystems that are poorly represented in existing protected areas
- Significant wetlands

Other land with high conservation values may also be eligible for more enduring funding under Queensland's Environmental Offsets Framework[46]. In this case, the land must provide like-for-like environmental values to those that will be damaged in a development project, such as might arise through clearing vegetation for mining or agriculture. The land must also be in a Strategic Investment Offset Area (Figure 28). These areas have been selected for their high conservation value and the linkages they provide between such areas, and hence have a high likelihood of providing resilience in the face of climate change[8].

CONCLUSIONS

Climate change poses serious challenges to the natural and cultural resources, community and economy of the Southern Gulf region. Principal challenges will come from rising sea-level, increased ocean acidification, rising temperatures and evaporation, and increase intensity of cyclones and floods. These will stress an environment that is already degraded by overgrazing, weed invasion, feral animal damage and poor fire management. People will suffer both directly and indirectly from climate change, being stressed by increasingly hot weather, but also by the damage and degradation of the landscapes on which their livelihoods depend. There is a need to build resilience of the landscape by addressing current threats, and of the NRM community by improving adoption of sustainable practices and bolstering adaptive capacity. The region's economy will also benefit from this resilience-building. The conservation and carbon economy also provides opportunities to build regional resilience by providing additional revenue streams from emission reduction activities and biodiversity management.

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