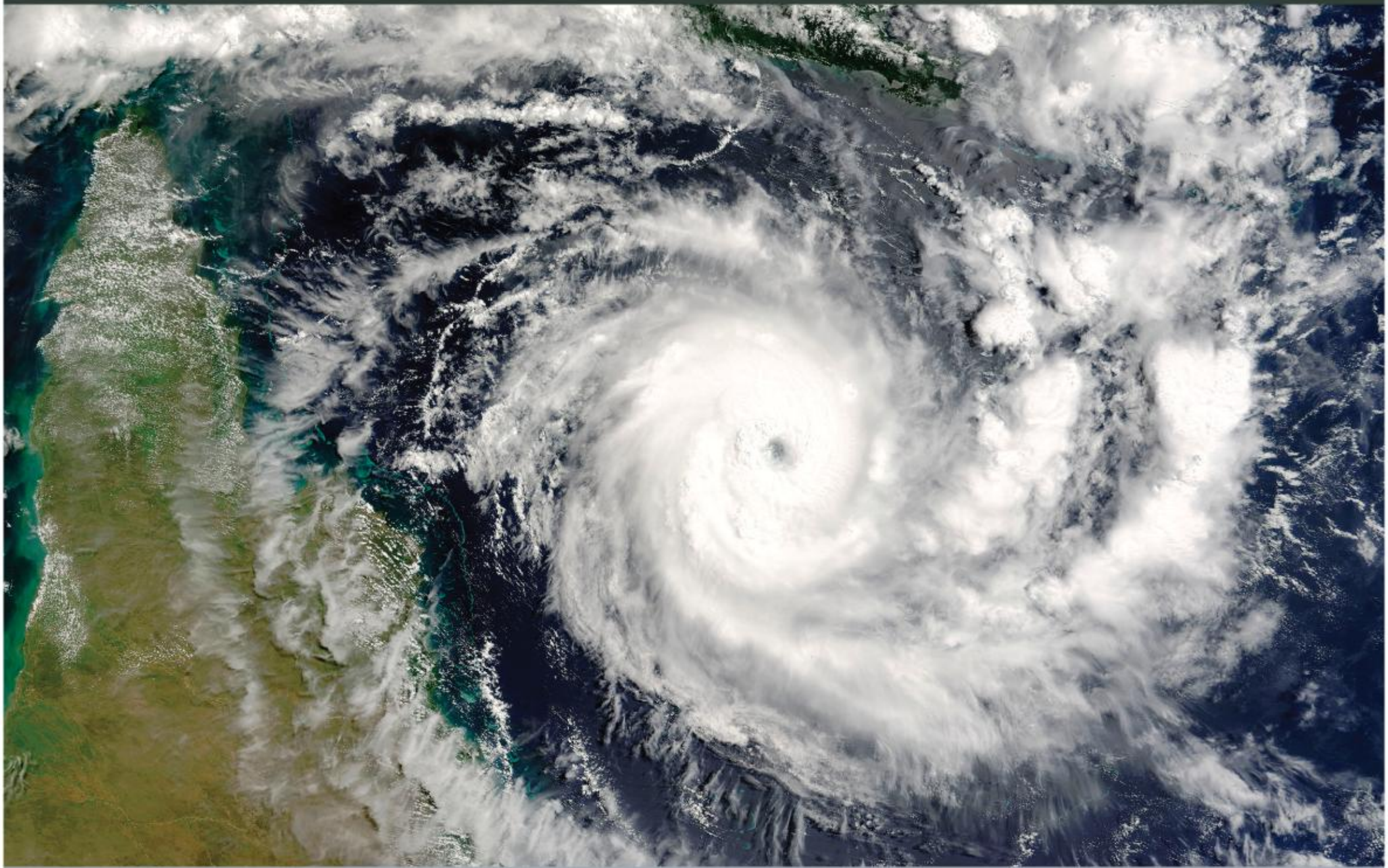
WET TROPICS
NRM CLUSTER

CLIMATE CHANGE IN AUSTRALIA
IMPACTS & ADAPTATION INFORMATION FOR AUSTRALIA'S NRM REGIONS



Adaptation Pathways and Opportunities for the Wet Tropics NRM Cluster region

Volume 2. Infrastructure, Industry, Indigenous peoples, Social adaptation, Emerging planning frameworks, Evolving methodologies and Climate adaptation planning in practice.

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4. Adaptation pathways and opportunities for infrastructure

Catherine Moran and Stephen M. Turton

IN A NUTSHELL
• Adaptation options for infrastructure can be classified as either 'protect', 'accommodate' or 'retreat'. In general, current community support is strongest for 'protect' options, although these are often expensive, may be inconsistent with other sectors (e.g., biodiversity conservation) and will be likely to work only under low or moderate climate impacts. • Many 'Accommodate' options will require investment in the development of new technologies (e.g., new agricultural crops, protection of materials from deterioration, water recycling) and local networks (e.g., power generation and distribution, water collection and storage and produce distribution). • For some climate change impacts and under high emissions scenarios, 'retreat' will be the only available adaptation option for infrastructure.

Precis

This chapter canvasses some of the adaptation options for infrastructure in the Wet Tropics Cluster (WTC) region. Specifically, this chapter considers potential options for adaptation to climate change impacts for water and power supplies, transport networks, buildings including urban development and waste management. This chapter is written for the NRM community and is intended to provide a framework for considering options when developing potential adaptation pathways for the WTC region. The key messages associated with each of the topics addressed in this chapter are:

TOPIC	KEY MESSAGES
Anticipating increased deterioration of infrastructure	172. Adaptation options for higher rates of deterioration of concrete, steel, timber and other materials include the use of existing or new technologies, increasing the cycle of maintenance and repair and improving standards for new structures. 173. Adapting to more frequent damage to infrastructure in general will require budgetary provision for more frequent maintenance, repair and replacement.
Increasing system redundancy	174. An option for adapting to more frequent interruptions to a range of infrastructure functions and services is to increase redundancy in the system, thereby reducing dependence on a single mode of infrastructure.
Insurance	175. A potential adaptation option for all infrastructure sectors is to increase the level of insurance against climate change impacts. Insurance premiums may also be used to discourage infrastructure in vulnerable areas.
Rainfall variability	176. Adaptation options to address the reduced availability of freshwater include increased use

TOPIC	KEY MESSAGES
	of water-saving devices, large-scale recycling and re-use programs, instigating behavioural change and encouraging domestic rainwater collection.
Higher temperatures	177. Higher evaporative losses from water storage compounds may potentially be addressed using physical and chemical covers or by storing water in underground aquifers. 178. Adaptation options for industry when cooling water temperatures are high include temporary shut-down, the development of new technologies, switch to industries that do not require cooling water and partnership with industries that can make use of warm water. 179. Adaptation options for buildings in response to increased temperatures include improved design and upgrading, as well as the use of vegetation for shading and to provide green areas. It will be difficult to mitigate periods of severe heat-related health risk in some areas, especially where there is limited access to air-conditioning.
Sea level rise	180. Protective adaptation options for inundation from sea level rise are common across infrastructure sectors. These include the use of engineering techniques such as sea walls, dykes, storm surge barriers, beach nourishment and sand dune revegetation, which are intended to physically prevent sea water inundation and coastal erosion. 181. Adaptation options to accommodate inundation by sea water include the elevation of infrastructure in these areas, improved drainage, shut-down of infrastructure facilities during inundation and increased cycle of maintenance and repair. The relocation of infrastructure to elevated or inland areas is a Retreat adaptation option that is likely to be important for susceptible critical infrastructure (e.g. Cairns base and private hospitals). 182. Adaptation options for seawater contamination of freshwater supply include installation of tidal gates, desalination, switch to salt-tolerant crops, managed aquifer recharge, the relocation of operations upstream and a shift to localised collection and distribution of water, particularly rainwater. 183. Adaptation options for transport infrastructure in response to inundation include shut-down during inundation events, technological adaptations, and increased reliance on local commodities. Retreat will not be possible where access to coastal areas (e.g. for sea ports) is required.
Heavy rainfall	184. Adaptation options for buildings in response to heavy rainfall include incorporating structural features that reduce vulnerability to flooding. 185. Adaptation options for dams in response to extreme rainfall events include integrated catchment management to reduce sedimentation and improved design standards. 186. Adaptation options for sea ports in response to increased sedimentation and debris transport during extreme rainfall events include more frequent dredging, improved sediment control and reduced harbour capacity.
More intense tropical cyclones	187. Potential adaptation options in response to extreme events include the replacement of wooden poles with stronger material, laying underground supply cables in areas not affected by seawater intrusion, improving mobile network coverage, improved systems in remote locations and transition to localised generation and supply networks. 188. Adaptation options for transport infrastructure in response to extreme events include

TOPIC	KEY MESSAGES
	increasing freight storage capacity, and development of new technologies.---
	189. Adaptation options for buildings in response to damage from intense cyclones include upgrading pre-1980 buildings to current engineering standards and increasing the number of and access to cyclone shelters.

Introduction

An earlier report (Moran and Turton 2014) outlined broad impacts of climate change on infrastructure in the WTC region. Infrastructure provides and supports the basic needs of communities and any decline in the condition, reliability, supply of, or access to infrastructure will impact across remote, rural and urban communities. This chapter provides information for community discussion about potential ways of adapting to these impacts.

Infrastructure tends to be large-scale and complex and many of the policy and regulatory options for adapting infrastructure to climate change will be the responsibility of Local, State and Federal Governments. While some of these decisions (e.g. location of major roads) are beyond the direct control of the NRM community, an informed NRM community can have influence over these. In addition, many adaptation decisions will be made at the level of communities (e.g. town water supply) and individuals (e.g. household power supply).

Strategies for active adaptation of infrastructure to climate change impacts fall into one of three categories (Pittock and Jones 2000; Linham and Nicholls 2012):

1. 'Protect': Implement defensive actions or structures to prevent exposure to impacts and enable continued use or occupation of an area
2. 'Accommodate': Allow for continued use or occupation of an area, but make changes to develop resilience to impacts
3. 'Retreat': Cease use or occupation of an area and relocate to less vulnerable area that is not exposed to impacts.

These categories can be further subdivided, but in this chapter we present adaptation options in these broader categories. We note that a fourth category of adaptation is recognised as 'autonomous adaptation' (or 'do nothing') and depends on reactive rather than proactive action, usually following natural disasters (King *et al*. 2013). We don't explicitly examine this option in this chapter.

Variation in the economic cost of different adaptation options is related to the different categories of adaptation: Protection is often most expensive whereas options in the 'Accommodate' category are often relatively inexpensive. 'Retreat' options may also be very expensive, and additionally require substantial behavioural and cultural change which can present major psychological hurdles. There is also variation in the ecological cost of options within the three categories of adaptation, with options in the Protect category likely to be least consistent with ecological protection (Davey *et al*. 2013). An integrated analysis of the ecological, economic, cultural or social costs and benefits associated with potential adaptation options is beyond the scope of this chapter. However, it is acknowledged that there are trade-offs associated with most adaptation options and that developing adaptation pathways will need to balance potentially competing economic, social and ecological objectives.

The amount of adaptation that will be required to avoid and reduce exposure and increase resilience to climate change impacts is related to the amount of climate change that will happen. This is dependent on the level of mitigation of global greenhouse gas emissions that can be achieved. Under a 'best case' scenario where emissions are rapidly and substantially reduced, it will still be necessary to adapt to 'locked in' impacts that are the result of past and existing emissions due to the long residence time of Co_2 in the atmosphere. Various adaptation strategies may effectively address many climate change impacts under this scenario. However, with uncurtailed emissions, predicted changes in climate will exceed our capacity to adapt in many cases. Then, even adaptation strategies based on Retreat may not be sufficient to maintain functional infrastructure.

Structure of this chapter

The intention of this chapter is to present a framework for considering some of the possible adaptation options associated with different infrastructure elements in the WTC region. The first three sections of the chapter outline potential adaptation options that are common across climate change impacts and infrastructure sectors, namely: i) anticipating increased deterioration of infrastructure; ii) increasing system redundancy ; and iii) insurance. These options are not repeated in key messages for each subsequent section, although they remain relevant to water supply, power supply, transport networks, buildings and waste management. The following five sections of the chapter outline potential adaptation options in relation to specific climate change impacts: rainfall variability, high temperatures, sea level rise, heavy rainfall and more intense tropical cyclones. We use a series of tables at the end of the chapter to summarise adaptation options for each infrastructure sector by category of adaptation strategy (i.e. Protect, Accommodate and Retreat).

The adaptation options in this chapter are not exhaustive lists of all potential options, but represent the range of ideas considered in recent reports and scientific literature. The desirability, financial cost, social or ecological dimensions of these options are not explored in this chapter; these considerations will necessarily involve engagement with stakeholders in the region.

Anticipating increased deterioration of infrastructure

Adaptation options for higher rates of deterioration of concrete, steel, timber and other materials include the use of existing or new technologies, increasing the cycle of maintenance and repair and improving standards for new structures.

Higher temperatures, more intense heavy rainfall events and associated flooding, together with sea level rise in coastal areas, will increase the wetting-drying cycle, leading to more rapid deterioration of a range of building materials, including concrete, steel and timber, asphalt, coatings and sealants (McEvoy *et al*. 2013; Barnett *et al*. 2013). Adaptation options include increasing the cycle of maintenance and repair and - for new structures - developing new building standards and enforceable codes that account for impacts of climate change. Ongoing research into different types of cements, interactions between climate-change impacts (e.g. sea level rise and chloride penetration) and new technologies may yield new adaptation options (Wang *et al*. 2010a).

Climate change will increase corrosion of concrete structures through increased penetration of atmospheric CO_2 and chloride. These increased deterioration processes will be compounded by increased exposure to salt and wave impact through sea level rise and increased levels of exposure to extreme weather events. Impacts on the safety, functionality and durability of concrete will be significant (Wang *et al*. 2010a). Adaptation options for existing concrete structures include retrofitting using existing technologies, such as surface coating, cover replacement, cathode protection, realkanisation and chloride extraction (Wang *et al*. 2010a). The best option for a given structure will depend on specific levels of exposure, exposure to other climate change impacts, cost and effectiveness (Wang *et al*. 2010a). In general, surface coating will be the cheapest, but least effective, while cover replacement is most effective and also most expensive (Wang *et al*. 2010a).

Adapting to more frequent damage to infrastructure in general will require budgetary provision for more frequent maintenance, repair and replacement.

In addition to degradation rates of materials, one of the pervasive impacts of climate change on infrastructure will be more frequent and more extensive damage to infrastructure (e.g. through intense cyclones) and the need for more frequent maintenance, repair and replacement as part of an accommodative adaptive strategy.

Increasing system redundancy

An option for adapting to more frequent interruptions to a range of infrastructure functions and services is to increase redundancy in the system, thereby reducing dependence on a single mode of infrastructure.

More intense tropical cyclones as well as heat waves and inundation events (see Turton 2014) will interrupt the provision of critical infrastructure services, such as power supply. Installing a backup power supply for these times is a means of increasing redundancy in the power supply system. Many residents and businesses in the WTC region already have generators for this reason. Other options include the installation of renewable energy micro grids to supply backup power when the national grid is interrupted. In the case of industries such as Mackay sugar mill, sufficient power is generated from biomass (bagasse) energy to run mill operations independently of the national grid during the crushing season as well as to meet a substantial proportion of community energy needs. Renewable energy micro grids are also an option for areas of the WTC region that are not connected to the national grid, where small populations and geographical isolation mean that it would be uneconomic to do so (and where connection to the national grid is not welcomed by parts of the communities such as Daintree). Most of these areas currently depend on local power generation but this is predominantly from diesel generators. Advances in battery storage technology and affordability are improving the feasibility of domestic photovoltaic systems supplying household power needs. Renewable energy household or micro grid systems may present an option for providing reliable energy that is not affected by interruption of the national energy grid or diesel supply chains. There is also the potential for this strategy to have the dual benefit of reducing greenhouse gas emissions and so contributing to climate change mitigation. In the WTC region, renewable hydro-electric power from the Barron Gorge power station currently contributes a large proportion of power requirements around Cairns. The *Climate Change and Greenhouse Gas Reduction Act 2010* is an Australian example of legislated greenhouse gas emission reduction through altering the mix of electricity generation, developing approximately 1 900 gigawatt hours of emissions-free electricity per year by 2020 (Australian Capital Territory 2012).

Increased redundancy in the transport and freight distribution network will also improve adaptive capacity in the WTC region. For example, transport of export goods from production areas to sea ports typically depends on a single mode of transport and interruptions have consequences through the supply chain and to port operation. Building in modal redundancy in supply chain systems has been identified as an adaptive strategy for major transport networks (Scott *et al*. 2013). Redundancy in private transport options will also contribute to adaptation. Again, there are existing examples of this in the WTC region, where transport of people and goods shifts to air and sea during the wet season when road transport is not feasible, although costs are high. It is striking that large-scale infrastructure plans for the region generally do not currently consider likely consequences of climate change either in terms of the need for backup infrastructure (e.g. supply-chain infrastructure for the Abbott Point terminal) or investor behaviour (especially in relation to stranded assets).

Insurance

A potential adaptation option for all infrastructure sectors is to increase the level of insurance against climate change impacts. Insurance premiums may also be used to discourage infrastructure in vulnerable areas.

Using insurance as a means of 'spreading the risk' has been widely used as a form of climate adaptation and is likely to continue to be part of adaptation strategies (Scott *et al*. 2013). However, the availability of insurance cover has been partly responsible for development of infrastructure in vulnerable areas (King *et al*. 2013). There is scope for insurance to be used as a tool to discourage infrastructure development in areas vulnerable to climate change impacts (i.e. by increasing premiums) and also by incorporating requirements for hazard-reduction actions into agreements (King *et al*. 2013). Indeed, insurance premiums continue to increase in the WTC region and are already inaccessible to many residents in the region, in large part because of the perceived risk of climate change-related weather hazards.

Rainfall variability: fresh water supply

Adaptation options to address the reduced availability of freshwater include increased use of water-saving devices, large-scale recycling and re-use programs, instigating behavioural change and encouraging domestic rainwater collection.

Maintaining adequate supply of fresh water for domestic, agricultural and industrial uses in parts of the WTC region is already constrained during the dry season and is likely to become more uncertain (DERM 2010). Although rainfall is not expected to decline, supplying uncontaminated freshwater will become more challenging, especially in coastal areas. Factors such as increased evaporation, increased rainfall variability and salt water contamination will impact on the availability of fresh water in the region (see Turton 2014). Factors such as sea water contamination will also impact on water supply by increasing corrosion of water distribution infrastructure.

Water conservation strategies are generally preferable to the construction of new large reservoirs, which are politically unpopular (McJannet *et al*. 2008) and which have a range of negative ecological impacts (Bouwer 2000). Water conservation strategies may include fitting water-saving devices for domestic and industrial use and facilitating behavioural change to conservative water use practices. Water conservation will result from improved irrigation efficiency and water harvesting techniques. Increasing local water storage capacity through increased use of domestic and farm rainwater tanks may also be an adaptation option to address greater variability in fresh water supply.

Water recycling and reuse is another adaptation strategy that will reduce the need for new water reservoirs or access to aquifers. Cairns Regional Council is already increasing their waste water recycling program to address existing and projected future shortfalls in fresh water supply. For example, the Marlin Coast Recycled Water Scheme is designed to supply recycled water through a dual domestic reticulation network to be used in toilet flushing and other non-potable uses (http://www.cairns.qld.gov.au/environment/water-and-waste/wastewater-management).

Higher temperatures: evaporative loss of water, heated industrial cooling water, heat stress in buildings and power failure

Evaporative loss of freshwater from storage compounds

Higher evaporative losses from water storage compounds may potentially be addressed using physical and chemical covers or by storing water in underground aquifers.

Rates of evapotranspiration are predicted to increase in all seasons in the WTC region (Turton 2014). This will lead to increased evaporative losses from dams, including large, public reservoirs which store water for municipal potable supply or for broad-scale irrigation, as well as private dams including large-scale reservoirs used in industry operations or smaller-scale on-farm dams. Increased evapotranspiration from catchments may also reduce runoff into dams and reservoirs. It will be very difficult to manage increased evapotranspiration from catchments or from large reservoirs such as Peter Faust and Tinaroo dams.

Adaptation options for new dams include ensuring that dam morphometric design minimises the ratio of surface area to volume and that water harvesting is maximised through appropriate design (e.g. Keyline systems). For new and existing dams, evaporative loss may be reduced by improving dam sheltering to reduce wind speed (Hipsey 2006) and by using physical covers or chemicals that form a film over the water surface (monolayers and surface films). There are economic and practical limitations on the use of physical and chemical covers, as well as a range of poorly known ecological impacts (NPSI 2006; McJannet *et al*. 2008). Physical covers include impermeable or modular plastic and shade cloth. Shade cloth seems to hold most potential for smaller dams, being relatively inexpensive, practical in many situations, and effectively reducing evaporation by up to 70% while allowing rainfall penetration (NPSI 2006). A web-based tool 'Ready Reckoner' has been developed to calculate water losses from farm dams and the economic value of different physical covers (Heinrich and Schmidt 2006).

The degree to which monolayers reduce evaporation requires more research, but it seems they may be most effective in smaller water bodies (McJannet *et al*. 2008), including irrigation channels (Land & Water Australia http://lwa.gov.au/projects/2636). A downfall of monolayers is that they need to be reapplied, every one to three days, especially if surface turbulence is high (McJannet *et al*. 2008), but this is a potential benefit in that they can be applied only when and if needed (Schache 2011). The health risks posed by monolayer or microlayers are also unknown (McJannet *et al*. 2008).

Alternatives to storage in open reservoirs include the use of closed storage tanks, as well as artificial recharge of underground aquifers (Brouwer 2000). This strategy, also known as 'water banking', has especially been used in parts of the world where rainfall is very seasonal, with rain water collected above-ground during the wet season, with any excess pumped into underground aquifers for extraction during the dry season. In parts of Europe excess surface water, desalinated water and treated effluent are used to recharge aquifers. This strategy is also one of the suggested methods of dealing with sea water incursion as a result of rising sea levels (see below). This method is not suitable where the water table is high, due to the risk of salinity or where aquifers are not suited to storage of large volumes of water.

Increased temperature of cooling water

Adaptation options for industry when cooling water temperatures are high include temporary shut-down, the development of new technologies, and switch to industries that do not require cooling water.

With increased average temperatures and increased frequency of heat waves, the temperature of industrial cooling water will increase and more frequently exceed threshold temperatures. Adaptation options include the development of new industrial processes that can tolerate warmer water or do not require as much cooling, the development of new technologies for cooling or temporary shut- down of facilities. This will impact mining operations in particular, which will also be affected by increased ambient temperatures in other significant ways (Mason *et al*. 2013). Plans for new industrial operations in the Mackay-Whitsunday region, near Cooktown and in the Herbert River catchment area should take into account potential constraints imposed by increased temperatures, the need to install technology such as heat exchangers, and the potential to partner with industries that could use waste heat (e.g. prawn farms).

Heat stress in buildings

Adaptation options for buildings in response to increased temperatures include improved design and upgrading, as well as the use of vegetation for shading and to provide green areas. It will be difficult to mitigate periods of severe heat-related health risk in some areas, especially where there is limited access to air-conditioning.

Prolonged exposure to high temperatures during heat waves will have serious impacts on discomfort and health, especially among older people and people with cardiovascular disease and pulmonary illnesses (Barnett *et al*. 2013). Planting vegetation to shade buildings, creating public 'green' areas, and using evaporative cooling may have localised cooling benefits (Barnett *et al*. 2013) but this process is less effective in very humid environments. Providing legislative support for new building design codes and retrofitting existing buildings with light-coloured roofing, ceiling insulation, protective coatings (e.g. ceramic paint) and window shading can make a substantial difference to heat stress experienced by occupants, particularly in regions where summers are warm or temperate (e.g. upland areas of the Terrain NRM region). However, while designing new buildings to reduce solar access in hot periods is a potential way of adapting housing to climate change impacts in some regions, analysis of modelled heat stress indices in different housing types with different degrees of adaptation shows that it will be very difficult to mitigate periods of severe heat-related health risk in regions with hot summers (i.e. most of Cape York and the Torres Strait region and lowland areas of the Terrain and Reef Catchments NRM regions) (Barnett *et al*. 2013).

In many of the most vulnerable regions of the WTC region, there is very limited domestic air-conditioning and public cooled places such as shopping centres are generally unavailable outside major urban areas. In situations where air-conditioning is available, this may offset some of the discomfort of high temperatures, although power outages during extreme heat weather and increases in household energy costs may mean this is not a viable option (Barnett *et al*. 2013). Note that the national electricity grid does not supply power to some of the areas that are most vulnerable to heat stress, including Cape York and the Torres Strait region, where dependence on diesel generators is high.

The prevalence of health problems that will be exacerbated by climate change impacts is higher among people in low income households (Barnett *et al*. 2013). In the WTC region, low income households are common, dominating more remote locations, and include many Indigenous families (see Chapter 6, this report).

Power failure during heatwaves

Heat waves may cause power failures because of the accumulation of resistance in transmission lines, which increases with temperature and demand (peak power demand typically occurs during heat waves). Demand may be able to be reduced to some extent by instigating behavioural change in residents as well as improvements in building design (e.g. see below), although there is a limit to how these adaptations will mitigate the discomfort experienced during heat waves. Within the WTC region, many of the areas most vulnerable to heat waves (i.e. Cape York, Torre Strait) are not on the national electricity grid and so will neither contribute to demand, nor benefit from improved supply from national grid.

Sea level rise: seawater contamination of freshwater supplies, impacts on power supply infrastructure, transport infrastructure, buildings and waste management systems

Sea level rise will lead to more frequent and permanent sea water inundation in coastal areas and the upstream extension of tidal reach, especially in combination with cyclonic storm surges (see Turton 2014). These processes will impact on most infrastructure sectors in the coastal zone and a suite of potential adaptation options may apply across sectors, including tourism infrastructure (see Chapter 5, this report).

Protective adaptation options for inundation from sea level rise are common across infrastructure sectors. These include the use of engineering techniques such as sea walls, dykes, storm surge barriers, beach nourishment and sand dune revegetation, which are intended to physically prevent sea water inundation and coastal erosion.

Coastal areas throughout the world have been protected from seawater inundation using ‘hard engineering’ structures such as sea dykes and storm surge barriers as well as ‘soft engineering’ approaches such as dune revegetation, beach nourishment and artificial reefs (Linham and Nicholls 2012). These protective measures are also suggested as adaptation options in relation to rising sea levels. There is considerable potential for unintended downstream effects such as altered patterns of beach erosion and accretion in other areas (Harman *et al*. 2014), especially with hard engineering measures. Soft engineering approaches (e.g. beach nourishment, sand dune revegetation) can have positive impacts additional to reduction in flooding, including the creation of habitat. However, the protective capacity of these measures will decrease with sea level rise over time, especially in area where these systems are confined by adjacent infrastructure. Beach nourishment in isolation will also tend to be an increasingly expensive means of providing protection due to increased severity of storm events and associated storm surge and erosion impacts.

In relation to risks to coastal infrastructure from sea level rise, community support in Australia tends to be highest for the option of protection (King *et al*. 2013) and at least in the short-term, retreat is likely to remain politically and economically unappealing in Australia (Fletcher *et al*. 2013; Harman *et al*. 2013).Protective options may potentially be effective in the short term, but, as noted, are likely to be expensive and will eventually be overcome by high levels of sea level rise (Wang *et al*. 2010b). Protective barriers such as sea walls may also have unintended consequences such as inhibiting the discharge of floodwaters, thereby exacerbating coastal flood events.

Adaptation options to accommodate inundation by sea water include the elevation of infrastructure in these areas, improved drainage, shut-down of infrastructure facilities during inundation and increased cycle of maintenance and repair. The relocation of infrastructure to elevated or inland areas is a Retreat adaptation option that is likely to be important for susceptible critical infrastructure (e.g. Cairns base and private hospitals).

These adaptation options apply to impacts from sea water inundation of infrastructure, including that associated with power supply, coastal buildings and waste management (below) and are also relevant to impacts of inundation from heavy rainfall across infrastructure sectors (see later section).

Seawater contamination of freshwater supply

Adaptation options for seawater contamination of freshwater supply include installation of tidal gates, desalination, switch to salt-tolerant crops, managed aquifer recharge, the relocation of operations upstream and a shift to localised collection and distribution of water, particularly rainwater.

Sea level rise will necessitate adaptation to freshwater contamination via sea water inundation into coastal surface water bodies, upstream extension of tidal range in coastal watercourses and seawater intrusion into ground water. The need for adaptation to sea level rise will be greatest in coastal areas of the mainland and islands and along coastal watercourses. Storm surge associated with tropical cyclones will exacerbate this problem.

Protective engineering options (see first section) may be used to prevent seawater inundation of coastal freshwater bodies. Tidal gates (hinged, one-way flaps across watercourses) may be used to prevent the inflow of tidal water into freshwater reaches of coastal watercourses. While installation of tidal gates on coastal watercourses may protect watercourses and surrounding floodplain areas from tidal inundation, such structures have been associated with the exposure of acid sulphate soils and changed composition of aquatic faunal communities (Heath and Windberg 2010). Research into the ecological impacts of tidal gates is required and legislation that regulates the design and installation of such engineering options will need to be developed.

Desalination of salt-contaminated water is a potential accommodative adaptation response to sea level rise. Desalinisation is generally expensive (McJannet *et al*. 2008) and is associated with a range of negative ecological and other impacts, as well as likely GHG emissions. Furthermore, desalination plants, like other critical coastal infrastructure, would need to have stand alone or backup power supplies that enabled continued operation in cases of damage to the grid network. Another potential adaptation option would be to switch to salt-tolerant crops (see Chapter 5, this report).

Sea level rise is predicted to lead to seawater intrusion into coastal groundwater. The Cape York NRM region has a relatively high dependence on groundwater due to the high seasonality and low reliability of surface water availability. Freshwater supply in this part of the region may be vulnerable to sea water intrusion, although sea level rise is predicted to be lower, at least on the Western Cape, than elsewhere in the WTC region (Turton 2014). Seawater intrusion also has the potential to significantly impact water supply for agriculture on coastal floodplains.

Managed or artificial recharge of underground aquifers involves pumping freshwater underground. This is used to replenish depleted aquifers and also to force back the salt water interface and may be a suitable adaptation strategy. Artificial recharge is already employed in areas such as the Burdekin Delta where over-extraction of groundwater has lead to seawater intrusion (Narayan *et al*. 2003). In South Australia, waste water is pumped into aquifers to reduce the discharge of nutrients and contaminants into waterways. However, managed recharge of aquifers will not necessarily restore water for extractive purposes, and also carries the risk of contaminating groundwater.

Sea water inundation and degradation of shoreline power supply infrastructure

The key messages relating to adaptation options for sea level rise (presented above) also apply to the inundation and degradation of power supply infrastructure by seawater.

Sea level rise will increase the exposure of coastal infrastructure to salt spray. In the case of power distribution networks, this will increase rates of corrosion of transmission wires, potentially leading to increased incidence of flashover. It is likely that there will be an increased need for maintenance and repair to networks in transmission networks exposed to salt.

Sea level rise, especially in conjunction with storm surge and heavy rainfall events, will lead to inundation of low-lying coastal power distribution facilities, such as sub stations. Adaptation options include the construction of defensive engineering structures (e.g. sea dykes), elevation of facilities, and the relocation of networks to less vulnerable areas. An additional adaptation option would be to develop backup power supply for when the mains power supply fails.

Increased coastal erosion associated with sea level rise will remove erodible shoreline areas where power transmission poles are currently located. If protective measures fail, relocation of the network away from the coastline appears to be the only adaptation option.

Subsurface networks, such as gas pipelines and underground power networks, will also be affected by seawater incursion and rising water tables resulting from sea level rise. In many parts of Cape York and in the Torres Strait region, small airports are critical for the transport of people, goods and services, especially in the wet season when the road network is closed for several months. Interruption of transport and freight distribution networks will have major, isolating and economic consequences for the region.

Sea water inundation of transport infrastructure, degradation of shoreline transport infrastructure

Adaptation options for transport infrastructure in response to inundation include shut-down during inundation events, technological adaptations, and increased reliance on local commodities. Retreat will not be possible where access to coastal areas (e.g. for sea ports) is required.

More frequent and permanent inundation of coastal transport infrastructure as a result of sea level rise will affect sea ports, airports, major roads and rail lines. Because most major settlement is in lowland coastal areas, major transport infrastructure is concentrated in the same areas that are most vulnerable to impacts from sea level rise. There are limited options for the relocation of transport networks away from vulnerable areas (Retreat). Although adaptation to these impacts will very likely require significant financial investment in strategies such as elevating infrastructure and constructing protective structures, these issues should be considered in regional planning processes.

Transport infrastructure is obviously critical to the mobility of local residents, as well as to trade, business and the tourism industry. The WTC NRM region currently depends on freight coming in from other regions, including for fuel, food and other commodities. Also, most major industries in the region depend on access to a freight distribution network to transfer goods nationally and internationally. Most major distribution networks are coastally-located and transport of products from mining, agriculture and other industries, especially across low-lying coastal land to sea ports, are vulnerable to inundation from both the sea and river floods.

Sea ports are particularly vulnerable to impacts from sea level rise. There are three bulk import/export sea ports in the WT NRM cluster region (Weipa, Mackay and Cairns and export ports at Hay Point, Mourilyan and Lucinda. Petroleum supply in the region depends on imports to the Mackay and Cairns ports. Smaller ports in the region (e.g. Lockhart River, Thursday Island) are also critical for goods supply and people transport, especially in the wet season. Most of the WTC NRM region around Cairns, Cape York and the Torres Strait depend on the supply chain in and out of Cairns where industrial fuel storage facilities are recognised to be vulnerable to inundation by seawater.

Increased coastal erosion resulting from sea level rise will remove the substrate for coastline infrastructure, such as roads. Engineering adaptations may provide protection, but relocation of infrastructure to less vulnerable parts of the landscape is likely to be the most pragmatic option.

Sea water inundation of coastal buildings and urban infrastructure

The key messages relating to adaptation options for sea level rise (presented above) also apply to inundation of coastal buildings.

'Hard' and 'soft' engineering adaptations have been used to reduce sea water intrusion, coastal erosion and flooding in coastal areas throughout the world (e.g. Netherlands and Bangladesh) and in Australia (e.g. Gold Coast: Linham and Nicholls 2012). However, the Australian system of land tenure, division of responsibility for implementation of adaptation measures, and the dispersion of a large number of at-risk communities across a long coastline may reduce the feasibility of this as a widespread response to sea level rise from climate change (Harman *et al*. 2013).

Options to accommodate impacts of sea level rise on coastal buildings include elevation and increased drainage. Retreat will involve relocation of communities to less vulnerable parts of the landscape. This strategy is being used in some parts of Australia (e.g. Byron Bay in New South Wales), but is generally an unpopular option for coastal residents. The Commonwealth of Australia (2009) present a useful summary of a suite of approaches to calculating the risk to coastal areas posed by sea level rise and extreme events (see below).

Sea level rise is also predicted to raise water tables in coastal areas, leading to freshwater inundation of subsurface infrastructure such as underground power reticulation (e.g. Cairns CBD), basements, underground carparks and swimming pools, as well as to structural damage and instability in above-ground buildings. This problem will be compounded by salination of the water table. Management of 'rising damp' is a problem throughout the world, and a suite of methods has been developed, including the use of electro-osmotic systems, injection of moisture barriers and installation of perimeter drains (Spennerman 2001).

Heavy rainfall: inundation, sedimentation and damage to infrastructure

Inundation of buildings

Adaptation options for buildings in response to heavy rainfall include incorporating structural features that reduce vulnerability to flooding.

Heavy rainfall events leading to flash flooding in floodplain and low-lying areas are likely to increase in the future (see Turton 2014). Coincidence with storm surges will exacerbate this flooding. In addition to the elevation of buildings and relocation to less vulnerable areas, design features such as breakaway wall sections of the lower areas of structures are potential adaptation options that will reduce loading during flooding (Linham and Nicholls 2012).

Dam sedimentation and failure

Adaptation options for dams in response to extreme rainfall events include integrated catchment management to reduce sedimentation and improved design standards.

Increased frequency and intensity of high rainfall events (including with cyclones) are predicted under climate change. This will increase sediment transport and the rate of sedimentation of dams, reducing their capacity and eventually their longevity (Wegner *et al*. 2013). Integrated catchment management actions that slow sediment transport are an adaptation option for increased rates of dam sedimentation. Increased sedimentation will increase surface area: volume ratios, compounding effects of increased evapotranspiration.

The likelihood of failure both of public and private dams will be increased with predicted changes in extreme rainfall events (Wegner *et al*. 2013). Improved dam standards that account for more frequent and intense rainfall events may be an adaptation option.

Sedimentation and debris transport and ports

Adaptation options for sea ports in response to increased sedimentation and debris transport during extreme rainfall events include more frequent dredging, improved sediment control and reduced harbour capacity.

Increased frequency of intense rainfall events will increase sedimentation and the transport of debris to ports and harbours. This will impact shipping and sea port operation. Improved sediment control measures in upstream catchment areas would be one option for trying to protect from this impact and it may be possible to make upstream sediment control (e.g. through revegetation) a condition of approval of any increased dredging operation. Increased dredging would be another potential adaptation to this impact, although removal of marine sediments may increase exposure to acid sulphate soils. Note that high flow events can also expose acid sulphate soils (Heath and Windberg 2010). Alternatively, seaward extension of sea port infrastructure is one option for adapting to increased sedimentation, as is reducing the capacity of harbours and ports to a smaller ship limit would be another adaptation option, although this would need to be integrated with export/import plans and is inconsistent with current proposals (e.g. expansion of Abbot Point terminal).

Inundation of waste management facilities

Extreme rainfall events are likely to cause flooding and failure of infrastructure in floodplain areas. During cyclonic events, these areas may be simultaneously impacted by storm surge and river flooding. Flooding of utilities such as waste water storage facilities and landfill sites in low-lying areas will potentially lead to point source pollution of surface and ground water and serious public health risks. Adaptation options for sea level rise such as the construction of levees (protection) and the elevation of sensitive elements (adaptation) and relocation to less vulnerable areas (retreat) also apply to inundation of waste management facilities.

More intense tropical cyclones: damage to infrastructure

Power supply

Potential adaptation options in response to extreme events include the replacement of wooden poles with stronger material, laying underground supply cables in areas not affected by seawater intrusion, improving mobile network coverage, improved systems in remote locations and transition to localised generation and supply networks.

More intense cyclones (Turton 2014) are likely to cause more damage to power generation and distribution networks, resulting in more frequent and prolonged power outages. Replacement of wooden poles (predominant in the WTC region) with steel may reduce damage, although transmission wires are still likely to be affected by strong winds. Increasing redundancy in the power supply system by encouraging local power generation (e.g. domestic solar or wind energy systems; micro-grid networks) is an obvious adaptation option for this impact. Transition to an underground power reticulation network would reduce the susceptibility of power supply to pole and wire damage, although in low-lying coastal areas, such subsurface infrastructure would potentially be susceptible to rising water tables, as described earlier.

Transport infrastructure

Adaptation options for transport infrastructure in response to extreme events include increasing freight storage capacity, and development of new technologies.

Extreme rainfall and wind speeds associated with more high-intensity tropical cyclones will cause damage to and inundation of transport infrastructure, and will lead to more frequent shut-down of transport networks. Shut-down periods are likely to increase with more intense cyclones. Increasing drain and stormwater capacity and elevating and relocating infrastructure where possible are also adaptation options. Increased redundancy in transport and freight networks will mean that distribution is not dependent on a single mode (Scott *et al*. 2013). Of relevance to mitigation of greenhouse gas emissions, road transport (car, trucks and light commercial traffic) accounts for almost 80% of Australian greenhouse gas emissions from transport and a modal shift to rail would substantially reduce emissions from transport (Stanley *et al*. 2011). For example, it may be possible to make use of existing cane rail infrastructure for local distribution, especially since it is needed for cane transport for only part of the year. Additionally, developing and strengthening local distribution networks of locally-produced food and other products will simultaneously reduce dependence on large-scale, vulnerable infrastructure as well as reducing transport emissions incurred in food distribution. Increased freight storage capacity may increase the ability of freight distribution infrastructure services to cope with delays due to shut-down. Development of equipment that is more resistant to impacts of extreme weather events (e.g. cranes that can tolerate higher wind conditions (Scott *et al*. 2013) would improve adaptive capacity in this sector.

Damage to buildings and urban areas

Adaptation options for buildings in response to damage from intense cyclones include upgrading pre-1980 buildings to current engineering standards and increasing the number of and access to cyclone shelters.

Intense tropical cyclones (i.e. category 3-5) are predicted to become more common in the WTC NRM region (Turton 2014), although the frequency of cyclones may decline. During intense cyclones, buildings can be damaged or destroyed by exposure to extreme wind gusts. Building standards introduced in the mid 1980s have increased the resistance of buildings to these forces. Upgrading pre-1985 buildings to current engineering standards is an important adaptive strategy, however this will probably be financially unrealistic for low-income households. Low income households have less capacity to adapt but are more vulnerable to negative impacts from extreme events, as well as to other impacts from climate change such as increased temperature because of less resistant and resilient housing location, design and materials.

There are currently few cyclone shelters in the region, and access to cyclone shelters is limited by poor roads and a lack of transport, especially in remote parts of Cape York and the Torres Strait. An adaptation option is to increase the number of and access to cyclone shelters that are engineered to protect against high intensity cyclones.

Storm surge associated with storms and cyclones already affects coastal areas within the WTC region. With climate change, these impacts are likely to increase in frequency and the area impacted is likely to increase in extent. Protection from this threat tends to be a popular option, as shown by community surveys in the Mission Beach area where there is strong support for protective work such as sea walls (King *et al*. 2013).

Sea walls have been used elsewhere in the region (e.g. Machan's Beach), but the small population size in other areas may make sea wall construction financially unrealistic. Such hard engineering protective options are also likely to alter patterns of sand erosion and deposition, with a range of ecological consequences as well as secondary implications for coastal infrastructure.

Higher sea levels will mean that the impacts of storm surge are felt further upstream of coastal watercourses. Flash flooding of floodplain areas during higher intensity high rainfall events will also result in more frequent inundation in these areas. Again hard engineering protective adaptation measures could include levees, bunds and drainage channels, while elevation of housing and other floodplain buildings may also be an option. Retreat strategies that involve shifting infrastructure and agriculture from vulnerable floodplain areas may include benefits in the form of ecosystem services payments to landholders who for example restore mangrove and wetland systems, providing protection to upstream and surrounding areas.

Key knowledge gaps

Better information about the following areas would improve the ability of NRMs to develop adaptation plans for their regions with NRM communities:

- A systematic assessment of the vulnerability of critical community-service infrastructure (e.g. hospitals, emergency management services, waste management infrastructure, major roads, bridges, airports, ports etc.), the flow-on consequences and potential adaptive options to protect, adapt or retreat
- A systematic assessment of the potential recipient/ refuge sites in a scenario of retreat from coastal and other vulnerable areas
- Study into the feasibility of renewable energy micro-grid networks, especially for areas currently dependent on diesel generators
- Assessment of the areas of freshwater likely to be subject to inundation or intrusion by sea or salt water
- Understanding of the required increase in water storage capacity given different projections for evapotranspiration and rainfall variability, together with potential consequences of salt contamination of current supplies
- Investigation into the industries likely to be affected by higher air and water temperatures and potential partner industries
- Assessment of the feasibility of reticulating power supply through underground networks, given potential for seawater intrusion and rising water tables
- Information about the ecological impacts and different design of tidal gates
- A directory of local producers and local distribution networks (e.g. the 'Taste Paradise' project in the Wet Tropics www.tasteparadise.com.au).

Summary of adaptation options by infrastructure sector

Potential adaptation options for the WTC region have been presented in relation to major climate change impacts. In this section, these same options are presented in brief summary tables (Tables 4.1–4.5) by infrastructure sector, because there may be instances when it is more useful to NRM groups to have the information organised in this alternative way.

Table 4.1 Major impacts of climate change on fresh water supply and potential adaptation opportunities.

		EXAMPLE ADAPTATION OPTIONS		
Climate change	**Major impacts**	**Protect**	**Accommodate**	**Retreat**
Increased temperatures	1. Increased evaporation of stored water	· Physical or chemical covers; · wind screening; · improved design.	· Increase water use efficiency; · water reuse and recycling; · storage in underground aquifers	Convert to local-scale water collection and distribution
	2. Heating of water for industrial uses		· Shut-down during high temperatures; · develop different technology.	Shift to industries that do not require cooling water.
Sea level rise	1. Seawater contamination of coastal groundwater	Artificial recharge	Desalination	Source fresh water from unaffected areas
	2. Sea water inundation of fresh water bodies in coastal areas	· Sea walls, dykes, storm surge barriers; · drainage channels; tidal gates	· Desalination; · Switch to salt-tolerant agriculture.	Source fresh water from unaffected areas
Extreme rainfall events	1. Dam failure, damage to distribution infrastructure		Improved design standards and capacity.	Deconstruct/ prohibit dams in vulnerable areas
	2. Increased rates of sedimentation of dams		Sediment control measures	Alternative storage (e.g. raised tanks)

Table 4.2 Major impacts of climate change on power supply and potential adaptation opportunities. Adaptation options that also potentially mitigate greenhouse gas emissions are marked **(M)**.

		EXAMPLE ADAPTATION OPTIONS		
Climate change	**Major impacts**	**Protect**	**Accommodate**	**Retreat**
Sea level rise	1. Increased deterioration rates of transmission network in coastal areas.		· Auxiliary power supplies; · Increase maintenance & repair	Relocate transmission network away from coastline.
	2. Inundation of coastal substations	· Sea walls, dykes, storm surge barriers; · tidal gates; · drainage channels.	Elevate facilities	Transition to local generation and distribution **(M)**.

		EXAMPLE ADAPTATION OPTIONS		
	3. Loss of infrastructure due to coastal erosion	Groynes, sea walls, breakwaters, beach nourishment.		Relocate transmission network away from coastline.
Increased variability in rainfall	1. Less predictability for hydroelectric power generation	· Divert water from elsewhere; · Increase capacity for excess storage.	Auxiliary power supplies	
Extreme events (more high intensity cyclones, heavy rainfall events, heat waves)	1. Increased frequency and duration of power outages		Auxiliary power supplies	Transition to local generation and distribution **(M)**
	2. Damage to distribution networks		· Auxiliary power supplies; · Replace wooden poles with steel; · Increase maintenance & repair	Transition to local generation and distribution **(M)**
	3. Increased transmission failure due to high resistance during heat waves		· Behavioural change to reduce demand during high temperatures; · Auxiliary power supplies	Transition to local generation and distribution **(M)**

Table 4.3 Major impacts of climate change on transport and freight distribution networks and potential adaptation opportunities. Adaptation options that also potentially mitigate greenhouse gas emissions are marked **(M)**.

		EXAMPLE ADAPTATION OPTIONS		
Climate change	**Major impacts**	**Protect**	**Accommodate**	**Retreat**
Sea level rise	1. More frequent or permanent inundation of roads, rail lines, sea ports and airports in coastal areas; increased corrosion and deterioration	· Sea walls, dykes, storm surge barriers, break walls; · dune construction; · channels; · levees	· Elevation; · closure on high tide events; · shift in export trade to climate-resilient commodities	· Relocate to less vulnerable locations; · increased localisation **(M)**
	2. Erosion of coastline	Groynes, sea walls, breakwaters, beach nourishment		Relocate to higher, more inland locations
Extreme events (more high intensity cyclones, heavy rainfall events, heat waves)	1. Sea port, airport, rail and road damage & shut-down due to high intensity cyclones		· Auxiliary freight and transport systems; · Increased storage capacity for freight goods; · Develop new technologies; · Increased maintenance and repair	Producer shift away from export market focus
	2. Increased sedimentation & debris in ports and harbours		Increased dredging	Shift to different mode of import and export freight

Table 4.4 Major impacts of climate change on buildings and potential adaptation opportunities

		EXAMPLE ADAPTATION OPTIONS		
Climate change	**Major impacts**	**Protect**	**Accommodate**	**Retreat**
Increased temperatures	1.Severe discomfort and heat-related health risk		· Increase use of air conditioning; · Retrofitting buildings (**M**); · Solar passive design (**M**); · urban greening (**M**)	Relocate to cooler locations
Sea level rise	1. Sea water inundation of housing in coastal areas and along floodplains	Sea wall, groyne, soft engineering	· Elevation of buildings; · increased drainage; · change emergency management practices	Relocate to higher, more inland locations
	2. Freshwater inundation of subsurface structures; structural damage		· Sump pumps; · perimeter drains; · waterproofing works.	Relocate to higher, more inland locations
Extreme events (more high intensity cyclones, heavy rainfall events)	1. more frequent destruction and inundation of buildings	Hard and soft engineering	·Upgrade pre-1980 buildings; ·increase the number of and access to cyclone shelters; ·Elevation of vulnerable housing	Relocate out of most exposed areas
	2. more frequent and extensive freshwater inundation in high rainfall events	Drainage channels, bunds	Elevation of vulnerable housing	Relocate out of floodplain and low-lying areas

Table 4.5 Major impacts of climate change on waste management and potential adaptation opportunities.

		EXAMPLE ADAPTATION OPTIONS		
Climate change	**Major impacts**	**Protect**	**Accommodate**	**Retreat**
Sea level rise & extreme events	1.Inundation of coastal sewerage treatment plants, solid waste facilities and stormwater management systems	· Hard and soft engineering · Sea walls, dykes, storm surge barriers; drainage channels; tidal gates	· Improved containment; · increased drainage capacity	Relocation out of vulnerable areas.

Summary and conclusions

There will be many impacts of climate change on infrastructure in the WTC region and these will be pervasive across communities. There are typically several adaptation options for given impacts, but most will have substantial economic, social, and ecological consequences. Optimal adaptation strategies will depend on community characteristics, including the distribution of risks through the community and an assessment of the importance of vulnerable infrastructure (Fletcher *et al*. 2013).

Adaptation will require co-ordination across different levels of government and will also involve industry and community. However, there is currently no integrated, overarching plan for adaptation of infrastructure to climate change impacts in Australia, although this is clearly needed (Infrastructure Australia 2011). Adaptation is often viewed as an incremental, iterative, ongoing process (Linham and Nicholls 2012), but there are also arguments for co-ordinating adaptation plans based on a rapid paradigm shift (Beyond Zero Emissions 2013).

It is striking that there are no identifiable protective adaptation options for several climate change impacts – that is, there is no known means of preventing the impact on infrastructure, only strategies that can adapt to these impacts to reduce the consequences. In the case of increased temperatures, more intense tropical cyclones and high rainfall events, impacts cannot be prevented and accommodation and retreat are the only available adaptation strategies. These will typically involve major structural, behavioural and cultural changes and high economic cost.

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5. Industry - adaptation pathways and opportunities in the Wet Tropics Cluster

James Langston and Stephen M. Turton

IN A NUTSHELL
• The main industries in the region have a high degree of dependence on the natural environment and hence are highly susceptible to climate change impacts. • Adaptation options for farmers are largely consistent with current 'best practice' management, although diversification is likely to be an important part of adaptation for primary producers. Ecosystem-based management of fisheries has potential as an adaptation pathway for this industry. There are limited adaptation options for the tourism industry. • Adaptation for the mining sector is complex and difficult and will require more site-specific challenges than other industries.

Precis

This chapter discusses some of the climate adaptation options and opportunities for key industries in the Wet Tropics Cluster (WTC) region. Specifically, this chapter considers potential options for adaptation to climate change impacts for tourism, grazing, agriculture (with cropping, horticulture and forestry), fishing and mining. This chapter is written for the NRM community and its key industries and is intended to provide a framework for considering options when developing potential climate adaptation pathways for the WTC region. The key messages associated with each of the topics addressed in this chapter are:

TOPIC	KEY MESSAGES
Tourism	114. Tourist destinations in the WTC region have limited options for climate adaptation due to predicted significant declines in the quality of key natural assets and limited diversification opportunities for the nature-based tourism sector. 115. Strategic adaptation decisions are constrained by uncertainties in regional climate changes, limited concern, lack of leadership and limited forward planning by the tourism sector.
Grazing	116. Improved land management practices resulting in enhanced stock and land condition are vital to increased system buffering capacity in the face of elevated climatic variability. 117. Land management regimes and agribusiness flexibility will need to be adjusted as the climate changes. 118. More widespread wet season 'spelling' rates will promote better quality pasture, and increase pasture regrowth rates. 119. Appropriate fire management, in conjunction with better grazing management regimes will

TOPIC	KEY MESSAGES
	reduce woody thickening. 120. Intensified agroforestry species will provide a wide range of benefits if utilised in grazing landscapes.
Agriculture, cropping, horticulture and forestry	121. There are opportunities for increased agricultural production and planting of climate-ready crops. 122. Many climate adaptation options for agriculture are similar to existing ‘best practice’ and good natural resource management, and therefore do not require farmers to make radical changes to their operations in the near term. 123. For the agricultural sector the imperative for NRM planning for climate adaptation should be proactive rather than reactive. 124. Information delivery on climate change, crop varieties and plant nutrition should be enhanced and regulatory agencies should introduce legal incentive for private agronomic services to provide the newest and best available data. 125. Adaptation to more extreme climatic events will be a significant challenge for long-lived crops and most forms of horticulture and forestry. 126. Diversification may be an effective adaptation pathway. 127. There may be some production benefits associated with higher levels of CO_2, but data is unclear and should be scrutinised as CO_2 is only one factor of the environmental conditions that needs integrated consideration.
Fishing	128. Ecosystem-based fisheries management provides a useful platform for the fishing industry to adapt to climate change. 129. Indigenous fishers and integrated management bodies should seek greater involvement with one another. 130. Certification for better-managed fisheries may provide niche markets to industry players. 131. Intensified aquaculture endeavours may be explored as an alternative to wild seafood production.
Mining	132. Local governments express more concern about climate adaptation for the mining sector than the mining industry itself. 133. Climate adaptation must be considered for the linked feeder systems (e.g. fly in fly out mines). 134. Climate adaptation in the mining sector requires addressing the site-specific challenges more so than other industries.

Introduction

The private sector in the Wet Tropics Cluster (WTC) region is largely dependent on a small handful of industries: agriculture, grazing, fishing, mining and tourism and many of these are small- to medium-sized enterprises. These industries are heavily reliant upon the natural environment, and so are vulnerable to the potential impacts of climate change (see review by Stoeckl *et al*. 2014). They each face different drivers of, barriers to– and the subsequent pathways towards–

effective planned adaptation.[1] Their adaptive capacity ranges from moderate to high, but many positively perceive their own capacities, which may in fact make them vulnerable to more extreme and frequent climate events. In addition they face major constraints at local and regional levels, especially when 'transformational' climate adaptation responses may be the only option (Chapter 1, this report). A recent report suggests that adaptation is a matter of changing management practices, technologies, institutions and expectations to fit the prevailing or projected future climate (Stokes *et al*. 2012). Adapting primary industries effectively may offset some of the negative impacts of climate change, and will possibly allow producers to take advantage of opportunities afforded by our changing climate (Stokes & Howden 2010). Incremental adaptation[2] measures exist in all the WTC industry sectors, but transformational measures will likely have to be considered in the longer term. Uncertainty about the degree of change will remain a barrier for transformational responses.

The private sector is recognised to have a strong role in delivering adaptation but it is also at risk of adaptive failures and maladaption.[3] In order to strengthen adaptive capacity, planned adaptations are necessary, as autonomous adaptation[4] on its own will likely be inadequate to sustain employment, income, and livelihoods. In order of perceived importance, the risks to businesses in addressing climate impacts are regulatory, physical, reputational and litigation risks. It is commonly understood that comparative advantages will accrue to businesses that take early action.

It is noted that there is a range of adaptation actions potentially available to Australian agriculture, with some strategies common across sectors – increased research and development (R&D), better training, the establishment of a framework to manage this transition and the development of appropriate policies – and others specific to individual types of agriculture. At present there is no cohesive framework in place to guide such a transition, but there are some examples of specific agricultural strategies, for example, some actions identified by Beer *et al*. (2013) for cropping/horticulture include:

- species change, including a switch to summer growing grains and herbage pulses
- variation in planting time
- better crop management, including the universal adoption of zero tillage, extended fallow periods and lowering plant populations
- nutrient management
- erosion management.

There are some inherent features of climate adaptation that make engagement on these topics particularly problematic. These features include – but are not limited to – the presence of climate change related misinformation and scepticism, behaviours of people and groups regarding how they handle uncertainty, and variation in different stakeholders' capacities for long-term planning. On the basis of these features and the related relevant literature, a number of psychological mechanisms have been identified that relate to adaptation engagement. The adaptation pathway (see Figure 1.5, Chapter 1 this report) may serve as a protocol for engagement with NRM stakeholders. The drivers will help promote progress along the pathway, and barriers indicate where opportunities for interventions lie (Gardner *et al*. 2009).

Engaging industry in discussion on climate change adaptation faces these barriers, however there are drivers that will enable progress towards enhanced adaptive capacity. CSIRO's (former) Climate Adaptation Flagship provides a valuable resource for industries and

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[1] Planned adaptations are proactive and can either adjust the system incrementally or transform it (IPCC 2014)

[2] Incremental adaptation: adaptation actions where the central aim is to maintain the essence and integrity of a system or process at a given scale (IPCC 2014).

[3] Maladaption: actions or inaction that may lead to increased risk of adverse climate-related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future (IPCC 2014).

[4] Autonomous adaptation: adaptation that does not constitute a conscious response to climate stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems (IPCC 2014).

the range of associated stakeholders. It presents best practice for engaging industries in finding ways to reduce vulnerabilities by enhancing their adaptive capacity, notably their Working Paper 3 (http://www.csiro.au/resources/CAF-working-papers#a1).

Climate adaptation is not something to be left to farmers, businesses, NRM groups, or governments alone. Everyone involved in primary industry, including policy makers, supply chains, Research and Development (R&D) providers, and enterprise managers – should all contribute to solutions by working in collaboration. For example, governments can ensure that water and drought policies accord with successful farm adaptation and do not impede it. R&D providers – working with farmers – can help facilitate effective climate adaptation options and technologies for the sector. These may include suitable crop varieties, improved water use efficiency standards, greater use of seasonal forecasting tools for improved decision making, or new farming or fishing methods. Not only do R&D providers help provide and guide choices, they should ensure that they are available and can be delivered when needed. There is a limitation here as R&D investment by government into innovation is decreasing, while privatisation is increasing. At stake here is potential diverted focus from system resilience into product penetration. Businesses need the skills, the financial assets, access to the best information and advice, and good incentives to make necessary changes. Climate adaptation will be most successful by considering the system-wide consequences of proposed adaptation measures at all social levels, at all points in the industry value and production chains, and in relation to other simultaneous challenges.

Consequently, there will be increasing demand for strong science–policy linkages, analysis of alternative governance models, and stronger focus on the institutional arrangements to support adaptation in all the NRM industrial sub-sectors (see Chapter 8, this report).

Industry-specific adaptation and opportunities

Tourism

Tourist destinations in the WTC region have limited options for climate adaptation due to predicted significant declines in the quality of key natural assets and limited diversification opportunities for the nature-based tourism sector.

Strategic adaptation decisions are constrained by uncertainties in regional climate changes, limited concern, lack of leadership, inadequate government policies, and limited forward planning by the tourism sector.

Future impacts of climate change on tourism have been evaluated for parts of the WTC region (Turton *et al*. 2010; Wilson and Turton 2011; Turton 2014a). The Great Barrier Reef (GBR) is expected to degrade under all climate change emission scenarios reducing its attractiveness as a global tourism icon (Marshall and Johnson 2007; Wilson and Turton 2011; Chapter 2, this report). Higher temperatures will place increasing stress on upland rainforest tourist destinations in the Cairns region, with extinctions likely for some key cool-adapted endemic vertebrate species (Turton 2014a; Chapter 2, this report). Sea level rise will result in pressures on coastal and island areas and any associated tourism infrastructure will be threatened (see Chapter 4, this report).

Australia has formalised climate adaptation strategies for tourism (Turton *et al*. 2010; Zeppel and Beaumont 2011). Institutions at various levels promote preparation for more extreme events and strengthening ecosystem resilience to maintain quality of tourist destinations, e.g. GBR (GBRMPA 2009). According to Reisinger *et al*. (2014), short investment, high substitutability and a high proportion of human capital compared with built assets give high confidence that the adaptive capacity of Australian tourism is high overall, except for destinations where climate change is projected to degrade core natural assets and diversification opportunities are limited, e.g. tourism relying on the quality of the GBR and upland rainforests in the WTC region (Wilson and Turton 2011; Turton 2014a).

Given that climate change adversely affects key tourism assets in the WTC region, and will continue to do so in the future, it is critical that forward planning be undertaken by the sector to ensure that adaptation strategies be adopted over medium-to-long times scales (Turton *et al*. 2010; Turton 2014a). Likewise, government agencies responsible for ongoing management of the WTC's globally significant world heritage properties (GBR, Wet Tropics and potentially Cape York) will also have to be considering adaptation strategies and options to strengthen their ecological resilience to climate change through management of anticipated environmental stress factors (see Chapter 2, this report). Adaptation to climate change in the tourism sector will need to consider actions at the operator, industry and local community levels (Turton *et al*. 2010). Adaptation options for tourism-related infrastructure are discussed in Chapter 4 of this report. Chapter 2 discusses adaptation options for terrestrial and marine biodiversity that provides the basis for the WTC's nature-based tourism industry.

There are a number of barriers to climate adaptation in the tourism industry (Turton *et al*. 2010). Firstly, there is a high degree of uncertainty and scepticism across the sector concerning climate change projections; this appears to be the main reason for the lack of action in the short term compared with other industries, e.g. agriculture. Secondly, communication and community involvement in climate adaptation is somewhat lacking in many tourist destinations, including those in the WTC region. Local tourism communities and the tourism industry need to be more heavily involved in planning and implementation of adaptation strategies at the grassroots level. Thirdly, one of the perceived limitations to adaptation within the tourism sector is the high proportion of small and medium enterprises (SMEs) that characterise regional tourism. Much concern revolves around the issue that these SMEs are operating on small overheads with little or no capital or capacity to implement major climate adaptation strategies.

The adoption of adaptation strategies and subsequent actions by the tourism sector in the WTC region will require the following (Turton *et al*. 2010):

- confidence that the climate really is changing and that increased variability in climate is part of the process
- motivation to avoid risk or take up potential opportunities
- demonstration of new technologies
- transitional and legislative support from government
- resources from government and private stakeholders
- effective monitoring and evaluation, given that climate change is a moving target.

Grazing

Improved land management practices resulting in enhanced stock and land condition are vital to increased system buffering capacity in the face of elevated climatic variability.

Land management regimes and agribusiness flexibility will need to be adjusted as the climate changes.

More widespread wet season 'spelling' rates will promote better quality pasture, and increase pasture regrowth rates.

Appropriate fire management, in conjunction with better grazing management regimes will reduce woody thickening.

Intensified agroforestry species will provide a wide range of benefits if utilised in grazing landscapes.

Heat stress is an impact that will reduce productivity, reproductive performance and enhance mortality under future climate scenarios. Increased thermal stress on livestock is very likely in the WTC region (Howden *et al*. 1999a) due to predicted increases in heat waves (Turton 2014b). However, there are opportunities here, as tick risks will decline due to excessively high temperatures. The control of ticks on beef cattle in northern Australia is based largely on host resistance that is acquired in response to tick feeding. Host resistance is most strongly expressed by the large majority of *Bos indicus* (zebu) cattle (Sutherst and Utech 1991). Zebu cattle are also more tolerant of extreme environmental conditions, so there may be adaptation opportunities in Zebu selective breeding for host resistance and increased heat tolerance (White 2003).

Graziers in the WTC region will have a comparative advantage in dealing with pests, weeds and diseases compared with more southern, sub-tropical and temperate regions of Australia. Most concerns in the grazing sector in Australia are of a southern spread of tropical pests and diseases into sub-tropical and temperate zones.

Key strategies for adaptation to climate change in the region include managing stocking rates and promotion of wet season spelling to maintain a high percentage of 3P grasses, i.e. palatable, perennial and productive. Overstocking and continuous grazing has led to a significant decline in 3P grasses on the better land types in the region (Shaw *et al*. 2007). Resilient enterprises in the future will rely more on business/herd recording and management systems that constantly improve breeder mortality rates, reproduction rates and annual live weight gains (Phelps *et al*. 2014).

Selective breeding for increased feed efficiency and/or reduced methane emissions appears to be one option eminently suited to northern Australia and hence parts of the WTC region where the grazing industry is important (Alford *et al*. 2006). Bortolussi *et al*. (2005) surveyed segments of the northern industry in the 1990s and found weaning rates varied between 50 and 80%. When this is coupled with low weaning weights of <0.3 of the maternal weight, it is clear that there is major scope for improvement in both weaning rate and weight (Henry 2012). Moreover, phosphorus supplementation may mean significant increases in productivity, leading to fewer cows required for the same number of progeny and a faster rate of turnoff.

Fire-vegetation models suggest that with appropriate stocking-rate management, fire can be used to manage woody plant cover whilst maintaining or improving live weight gain per hectare (LWG/ha) and hence profits in northern Australia. Active stock management such as reducing stocking rates, matching stocking rates to available forage and spelling, can be used to facilitate fire-use under lower rainfall. Under high rainfall there will be more opportunities to burn (including more risk of wildfire), but there may also be a greater need to burn more often as woody plant cover may increase in response to higher wet season rainfall and increasing levels of CO_2.

According to Meat and Livestock Australia (MLA), modelled results suggest that the implementation of fire has both economic and ecological benefits. There are opportunities in holding workshops with industry representatives for ‘best practices’ in implementing fire regimes matched with appropriate stocking rates. For example, it has been shown that there is an important role for fire management in parts of the WTC region for both ecosystem (Reside *et al*. 2014) and pastoral production (Stoeckl *et al*. 2014), but fire can only be implemented with appropriate stocking rates. Consequently, the management of grazing and fire are integrally related to the maintenance of productive and resilient grazing systems under climate change (Phelps *et al*. 2014).

Agroforestry systems with appropriate shade tree species have been shown to enhance microclimate effects on grazing productivity, and to mitigate surface water reductions (Neely *et al*. 2009). There is an opportunity to determine which tree species would be most appropriate for the WTC region for this practice, and what densities will benefit grazing lands the most.

Increasing the amount of carbon (C) sequestered as soil organic matter (SOM) can enhance rainfall effectiveness through increased infiltration and water-holding capacity and water source replenishment to withstand times of drought. This may be achieved through better fire management and appropriate stocking rates and through use of shade trees in the landscape. Bunching stock into large herds and moving them frequently will contribute to better pasture growth and nutrient content. Controlled grazing allows for more even distribution of dung and urine that can enhance SOM and nutrients for plant productivity. This has the knock on benefits of more quickly regenerating pastureland and improved livestock production. Other options include ‘improved’ grass and legume mixtures. They have a relatively large percentage of C sequestered in the fine root biomass, which is an important source of C cycling in the soil system (Mannetje *et al*. 2008). Thus, one of the most effective strategies for sequestering soil C is fostering deep-rooted plant species. Agroforestry species, specifically shade trees with deep root systems will have knock on benefits of reduced heat stress on the stock and improved water maintenance (Neely *et al*. 2009).

To avoid land degradation, management and adaptive strategies include:

- matching stocking rates to carrying capacity, e.g. through objective on-ground assessments, or future tools such as *PaddockGRASP* (http://www.longpaddock.qld.gov.au/grasp/)
- adopting moderate flexibility in annual stocking rate adjustments (increasing stocking rates by up to 10-20% and decreasing by up to 30-40% annually, with some regional variation), e.g. using forage budgeting tools such as the *StockTake* application (http://futurebeef.com.au/resources/workshops/sustainable-grazing-workshops/stocktake-balancing-supply-and-demand/)
- more widely implementing wet season ‘spelling’, e.g. based on regional best-practice guidelines
- reducing woodland thickening impacts through appropriate fire management.

These strategies are shown to lead to profitable enterprises in the long term under low and medium GHG emission scenarios.

The rotational spelling regime of a 6-month summer-season spell – every four years – is capable of improving pasture condition, carrying capacity and animal productivity in the spelled paddocks and overall property profitability under both current climate and future climates, providing stocking rates are appropriate to each climate. Land condition can be improved through combining wet season spelling with moderate stocking rates and not solely through low stocking rates that are often recommended. This may be a more acceptable approach to grazing industry in parts of the WTC region (Phelps *et al*. 2014).

Agriculture, cropping, horticulture and forestry

There are opportunities for increased agricultural production and planting of climate-ready crops.

Many climate adaptation options for agriculture are similar to existing ‘best practice’ and good natural resource management, and therefore do not require farmers to make radical changes to their operations in the near term.

For the agricultural sector the imperative for NRM planning for climate adaptation should be proactive rather than reactive.

Information delivery on climate change, crop varieties and plant nutrition should be enhanced and regulatory agencies should introduce legal incentive for private agronomic services to provide the newest and best available data.

Despite many challenges, potential benefits and fresh opportunities also arise from climate change for the agricultural sector. For example, it is likely that production of horticulture and pasture will increase due to projected higher temperature (Stokes and Howden 2011). Under elevated CO_2 in the atmosphere it is likely that plant growth and plant water use efficiency will increase (Lawler 2009; Stokes and Howden 2011). As different plants will respond in a different ways the competitive nature among plant communities may also be changed under elevated CO_2 levels; therefore some plants will be more resilient to climate change, including many weed species that may thrive. Planting crops that are drought tolerant, tolerant of higher temperatures and elevated atmospheric CO_2 levels (climate-ready crops) are likely to protect farmers from unexpected losses due to climate change (Stafford Smith and Ash 2011).

In the agriculture sector adaptations are adjustment made by farmers to their changing circumstances. It is expected that farmers will take decisions based on their own experience, observations, and available updated knowledge, such as planting of drought-resistant crops or trees (Stafford Smith and Ash 2011).

Climate change projections on a very fine spatial scale and in the short term – as well as focusing on seasonality and long term changes – will help farmers to plan well ahead of time. Information about suitable crop varities, plant nutrition and techniques such as precision fertiliser use and legume rotations will also be useful (Stokes and Howden 2011).

Adaptation to more extreme climatic events will be a significant challenge for long-lived crops and most forms of horticulture and forestry.

Diversification may be an effective adaptation pathway.

There may be some production benefits associated with higher levels of CO_2, but data is unclear and should be scrutinised as CO_2 is only one factor of the environmental conditions that needs integrated consideration.

There may be few incremental adaptation measures available to farmers that are at risk to extreme events – such as tropical cyclones – in long-lived crops and horticulture. Transformational adaptation measures include changing crops to types that can be harvested annually. This hastens the speed by which they can recover in the event of complete crop destruction. The forestry sector has begun withdrawing from the WTC region for this reason in response to recent tropical cyclone events (Turton 2012).

However, some crop systems (e.g. bananas) may benefit from protective agroforestry species. Crop damage by winds from extreme events may be minimised or prevented by the use of windbreaks. These can be natural or artificial. Properly oriented and designed wind-breaks are very effective in stabilising agriculture in regions where strong winds can potentially cause mechanical damage and impose moisture stress on growing crops. Windbreaks save the loose soil from erosion and increase the supply of moisture to the soil in the dry season.

Early harvests in anticipation of extreme events – such as cyclones – have proven effective in the past. This is more likely to be successful if crops are selected that mature frequently, and if safe storage areas are constructed. Irrigation canals and embankment of rivers in risk zones should be maintained and repaired to avoid breaching. Crop diversification may be necessary as a long-term measure to reduce the crop damage during the cyclone and storm season (Das 2005). This may include growing a variety of climate-ready crops in an area or geographically separating production of a single crop across the WTC region, e.g. bananas.

In the planning of relocation of crop lands, which may be necessary from coastal inundation from extreme events or sea-level rise, Geographical Information Systems (GIS) can be extremely useful tools in the analysis of flood-prone areas. Slope and aspect of regions - in addition to other data types – may provide opportunities to the best practice design of agricultural systems while also accounting for risk.

Table 5.1 shows climate adaptation options and priority ranking (1 as highest priority) for cropping and horticulture (Das 2005). It should be noted that the priority ranking is context-specific so may not necessarily represent priority ranking for the WTC region, but is nonetheless indicative of where future NRM investments in climate adaptation may be directed. Such investments may also be different at the regional compared with cluster levels.

Mulching the soil surface with organic matter for example will reduce the loss of water through evaporation. Kaolin clay applied to plants, usually for pest and disease control, has been demonstrated to reduce the effects of water and heat stress though results have been variable so further studies are needed (Das 2005).

Table 5.1 Climate adaptation options and priority ranking for cropping and agriculture.

ADAPTATION OPTIONS	Priority ranking
Temperature increase. Determine climatic thresholds to plant growth and product quality.	1
Re-assess location in regional terms to optimise reduction of climatic risk.	1
Invest in conventional breeding and biotechnology to address future adaptation capacity.	1
Tailor seasonal climate forecasts to horticultural requirements	2
Develop and modify markets for new crops and crop schedules	3
Change crop production schedules to align with new climate projections	3
CO_2	
Ascertain the crop-specific interactive effect of increased CO_2, temperature and water use.	1
Determine the effect of CO_2 on pests, diseases and weed species.	1
Rainfall	
Integrate catchment management and climate change projections to assess future water availability.	1
Constantly benchmark irrigation management to increase efficiency.	1
Pests and diseases	
Geographically sensitive pest and disease risk assessments using projected climate data.	2

Source: after Das (2005)

Autonomous adaptation is a particularly important category because farmers have traditionally adapted their methods in response to changes in climate and other drivers. Historically, new techniques have diffused through the industry, with innovative farmers being the first to introduce new techniques, and others adopting these approaches once they are seen to be successful. Farmers tend to be responsive in the short term by altering cropping patterns and management practices but may find it more difficult to focus on medium- to long-term changes in climate (Kingwell *et al*. 2013).

Fishing

Ecosystem-based fisheries management provides a useful platform for the fishing industry to adapt to climate change.

Indigenous fishers and integrated management bodies should seek greater involvement with one another.

Certification for better-managed fisheries may provide niche markets to industry players.

Intensified aquaculture endeavours may be explored as an option for wild seafood production.

Ecosystem-based fisheries management (EBFM) is a useful holistic tool that may provide benefits to many stakeholders in the fisheries sector as they adapt to climate change and other drivers. EBFM takes into account interrelationships among exploited fish stocks, non-target species, the environment and human action. Adaptation options in the EBFM suite include developments in by-catch reduction. Improved targeting practices will have the dual benefit of minimising impacts on non-target species, and they will provide potential alternatives to spatial closures to protect species of interest. Multi-species fisheries should continue to develop species-specific fishing equipment and targeting practices to improve future adaptability. Species-specific equipment will allow individual species to be targeted, without impacting other species that may be in decline due to climate change, and therefore their protection from fishing (Stokes *et al*. 2010).

Adaptation strategies to cope with a permanent change in distribution of key species include improvements in locating stocks of fish, changes in home port to minimise economic costs associated with transport of harvested catch, and zoning of fishing habitats to minimise unwanted species interactions (e.g. Hobday and Hartmann 2006; Hobday *et al*. 2009: in Stokes *et al*. 2010).

Indigenous fishers will be supported by greater involvement with integrated management bodies. They would benefit by supporting a reduction of fishing pressure on species impacted and of concern. Fishers – Indigenous and recreational – will be affected by changes in the biophysical environment due to climate change. Adaptive strategies are about advocating that regulations for vessel and shore-based safety measures are adhered to. Adaptive strategies would also include the support of increased use of ocean forecasts. Both Indigenous and recreational groups should become active in fisher education to increase awareness and monitor environmental changes. There may be opportunities for business in new regions, and for longer seasons in the same regions. For example, game fishing targets 'warm-water species', so southward movements due to ocean warming may be an advantage with regard to longer fishing seasons, and increased availability to the southern areas of the WTC region (Hobday *et al*. 2007b; Hobday 2010).

Certification initiatives such as the Marine Stewardship Council have been successful for industrial players, putting them at a comparative advantage in the market. This has been evident in several developed countries including New Zealand, the USA and Australia (Gulbrandsen 2009).

Mining

Local governments express more concern about climate adaptation for the mining sector than the mining industry itself.

Climate adaptation must be considered for the linked feeder systems (e.g. fly in fly out mines).

Climate adaptation in the mining sector requires addressing the site-specific challenges more so than other industries.

Hodgkinson *et al*. (2010) indicate that though every stage of mining is potentially influenced by climate change, the direct production stage is most at risk. Other research has suggested that all parts of the supply chain are at some degree of risk, with ports, rail lines, bridges and roads subject to extreme weather conditions (Stoeckl *et al*. 2014). Some risks may be dealt with by simply strengthening existing infrastructure or building new infrastructure to higher standards (see Chapter 4, this report).

Fly-in fly-out (FIFO) mining practices impose human capital risks with respect to climate change. Extreme weather events may prevent workers attending the mine and/or impede workers leaving the mine in the case of flood, fire or cyclone. Moreover, the impacts of disruption in mine schedules may be felt throughout the feeder settlement systems, including metropolitan and non-metropolitan places distant from the areas of the mining production sites. Fundamentally, a long term disruption to mining production may challenge the incomes of these and many other rural households, placing their economic sustainability at risk.

A survey of mining companies' adaptive capacities indicated that in general, local governments expressed greater concern than do the companies. While 45 percent of local government authorities in mining areas were undertaking climate adaptation activities, only around 15 per cent of mining companies were doing so. Regarding barriers to climate adaptation, the reasons given for not undertaking preparatory action differed greatly between governments and mining companies. Mining company respondents typically claimed uncertainty around climate change impacts and political/regulatory settings, were inhibiting their investment into enhancing adaptive capacity. Government respondents most often nominated financial assets and human capital to be the main inhibitors towards investing in enhanced adaptive capacity.

Regarding factors that could assist climate change adaptation, both government and companies identified the need for better climate change projections and specific advice about adaptation options and solutions. It is also evident that the information most valued for assisting adaptation is that which is organisationally specific, locally relevant, and technical in nature (Loechel *et al*. 2013).

Summary of adaptation options for industry

Table 5.2 Major climate change impacts and potential adaptation options for industry. Adaptation options that also potentially mitigate greenhouse gas emissions are marked **(M)**.

		EXAMPLE ADAPTATION OPTIONS		
Climate change	**Major impacts**	**Protect**	**Accommodate**	**Retreat**
Increased temperatures, sea level rise, more variable rainfall, more extreme events (intense cyclones, heatwaves, heavy rainfall)	1. Less reliable growth of grasses for livestock		· Managed, flexible stocking rates; · Widespread wet season spelling of pastures; · Selective livestock breeding for increased feed efficiency and reduced methane emissions **(M);** · Phosphorus supplementation; · 'best practice' fire management regimes; · agro-forestry to mitigate surface water reductions; · enhanced carbon sequestration of soil **(M)**; · improved grass-legume mixes.	Relocated livestock production from unsuitable areas.
	2. Increased thermal stress on livestock during heatwaves		· Selective breeding of species with higher heat tolerance (e.g., Zebu cattle).	
	3. Changed growing seasons, reduced suitability for some crops.		· Variation in planting times; · New, 'climate ready' crops (e.g., tolerant of drought, high temp., high CO_2, salt); · zero tillage; · mulching or application of Kaolin clay to plants to	Relocate cropping from unsuitable areas e.g., coastal lowlands impacted by salt water inundation.

EXAMPLE ADAPTATION OPTIONS				
			reduce water and heat stress; · extended fallow periods; · lower planting densities.	
	4. Long-lived horticulture crops especially impacted by extreme events.	Construct windbreaks (natural or artificial) around crops.	· Harvest early in anticipation of extreme event; construct safe storage. · Maintain irrigation canals and embankments to minimise inundation; · Shift to annually-harvested crops.	Relocate production to less impacted regions or separate geographically.
	5. Changes in numbers, distribution and interrelationships among fish stocks.		· Ecosystem-based fisheries management; · Shift location of home port for fishing vessels; · Zone fishing habitats to minimise unwanted species interactions; · Take advantage of longer seasons e.g., for 'warm-water species'.	
	6. Degradation of core natural tourism assets such as the Great Barrier Reef and mainland coastal areas.			Develop tourism industries in less-impacted areas.
	7. Risk of disruption and damage in every stage of mining production, including all parts of the supply chain.		Strengthening or building stronger infrastructure.	
	8. Risk caused by long-term disruption to economic sustainability of workers' households and			

		EXAMPLE ADAPTATION OPTIONS		
	feeder settlement systems.			
Increased temperatures & Co_2	1. Increased plant growth		· Take advantage of increased productivity of horticulture and pasture; · Manage changed competitive interactions (e.g., advantaged weeds)	

Summary and conclusions

The agriculture, tourism and mining industries – all of which are crucially dependent upon the region's natural resources – sustain the private sector in the WTC region. Climate change is likely to have a profound effect upon the region's natural resources and may thus – by extension– have a profound effect upon these industries and the region's economy. They each face different drivers of, barriers to - and the subsequent pathways towards - effective planned adaptation. Their adaptive capacity is moderate to high but faces major constraints at local levels, especially when transformational adaptation responses may be the only option.

Adapting primary industries effectively will not only offset negative impacts of climate change, but will allow producers to take advantage of opportunities afforded by our changing climate. Incremental adaptation measures exist in all the WTC industry sectors, but transformational measures will likely have to be considered in the longer term. Uncertainty about the degree of change will remain a barrier for transformational responses. The private sector is recognised to have a strong role in delivering adaptation but it is also at risk of adaptive failures and maladaption.

Adaptation is not something to be left to farmers, businesses, NRM groups, or governments alone. Everyone involved in primary industry, including policy makers, R&D providers, and enterprise managers – should all contribute to solutions by working in collaboration. Climate adaptation will be most successful by considering the system-wide consequences of proposed adaptation measures at all social levels, at all points in the industry value and production chains, and in relation to other simultaneous challenges. Consequently, there is will be increasing demand for strong science–policy linkages, analysis of alternative governance models, and stronger focus on the institutional arrangements to support adaptation in all the industrial sub-sectors.

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6. Adaptation pathways and opportunities for Indigenous peoples

Rosemary Hill and Pethie Lyons

IN A NUTSHELL
• Climate change impacts in many Indigenous communities in the WTC are compounded by pervasive issues of justice and well-being resulting from historical disadvantage, as well as by the remoteness and challenging environmental conditions associated with many communities. Effective adaptation strategies will address this context. • Indigenous people have an inherently high capacity for resilience through their traditional, adaptive knowledge systems. Formulating suitable adaptation pathways requires Indigenous-driven approaches that engage different Indigenous people and groups, their knowledge systems within their unique context, and builds synergies with scientific and other practitioners' knowledge. • Improved land tenure security, governance and technical skills can contribute to the formulation of successful adaptation pathways for Indigenous people. Cultural brokers are likely to be important in enabling genuine engagement in formal adaptation planning processes.

Precis

The culture, history and geography of Indigenous peoples in the Wet Tropics NRM cluster region underpin both high resilience and high vulnerability to the impacts of climate change. This chapter addresses the issues and options for generating adaptation pathways and opportunities that take account of this context, with some Case Examples (Boxes 6.1–6.4) from the Wet Tropics cluster region. We discuss how to support Indigenous knowledge and culture in adaptation, and the conditions, methods and tools that enable these to be integrated into policy, land-use and land management decisions. We synthesise findings about how to simultaneously build desirable resilience and reduce vulnerability by addressing barriers to adaptation, and monitor outcomes. We conclude with some international and Australian Case Examples.

The key messages associated with each of the topics addressed in this chapter are:

TOPIC	KEY MESSAGES
Indigenous vulnerability and resilience	114. Indigenous culture and knowledge influence the application of impact-specific, disaster risk-reduction and adaptation-planning measures and outcomes (e.g. sea walls, housing designs). 115. Generation of adaptation pathways and opportunities with Indigenous peoples benefits from linking vulnerability-reducing and desirable resilience-building responses in a joint

TOPIC	KEY MESSAGES
	approach.
Indigenous knowledge systems as the basis of adaptation	116. Indigenous peoples' knowledge systems are typically adaptive and provide a primary basis for generation of adaptation pathways and opportunities. 117. While Indigenous groups frame and perceive climate change based on their world views, collaboration with science based on ethical processes supports adaptation strategies that integrate different types of knowledge.
Indigenous culture as the context of adaptation	118. Recent Indigenous cultural change in Australia is towards a general resurgence of traditionally-derived culture—and in NRM, towards increasing formal involvement of Indigenous peoples and their culturally-based knowledge systems. 119. Indigenous culture impacts on all three areas required for successful adaptation: knowledge-based technologies; decision-making tools; and adaptation institutions. 120. Strengthening 'traditional ways' and building cultural cohesion are identified as key adaptation pathways for some Indigenous groups. 121. Institutions engaging on climate adaptation require intercultural skills to understand and work with perceived risks to culture that shape the capacity and will of Indigenous groups to adapt.
Integrating Indigenous knowledge and culture into policy, land-use and land management decisions for adaptation	122. Integration of Indigenous knowledge and culture into policy, planning and management can be supported by: – Indigenous governance and co-governance; co-management that engages power-sharing; and cognisance of social contexts – Intercultural "knowledge-bridgers/brokers" that undertake joint agenda setting and knowledge co-production – Indigenous-driven and cultural planning frameworks that recognise interlinkages between people, place, plants, and animals; and bridge scales by considering issues across the whole of an indigenous people's territory – Visual and spatial tools including: seasonal calendars; maps of cultural sites, use and occupancy and incorporating art; narratives; and cultural keystone species.
Building adaptive capacity through reducing vulnerability	123. Adaptation planning that prioritises respectful Indigenous partnerships and explicit commitment to address issues of justice and well-being can reduce vulnerability arising from barriers posed by colonial history. 124. A sustainable development approach, that addresses wider social and economic needs (e.g. infrastructure, health services) can reduce vulnerability arising from socio-economic disadvantage. Comprehensive Community Planning is an interesting Canadian First Nations example.
Building adaptive capacity through strengthening desirable resilience	125. Indigenous peoples seek adaptation pathways that focus on empowering communities to identify and implement their own responses to climate change. 126. Building sustainable local economies through climate adaptation opportunities (e.g. carbon credits) requires secure land tenure and rights to carbon to foster desirable resilience. 127. Regionally specific capacity-building strategies are required to support Indigenous organisations to gain the governance, technical and other capabilities that enable

TOPIC	KEY MESSAGES
	brokering across cultures and scales to support desirable resilience. 128. Long-term collaboration with Indigenous groups on structural transformation can help address the deep sources of ongoing inequities and build desirable resilience.
Monitoring adaptation pathways with Indigenous peoples	129. Participatory development with Indigenous peoples of monitoring and evaluation based on program logic, indicators and criteria, can support effective use of these approaches and link them to Indigenous knowledge systems, as shown in the Our Country Our Way Guidelines. 130. Indigenous holistic concepts of monitoring through close observation over time can be supplemented by scientific surveys and technologies like Cyber-tracker. 131. Integrated monitoring approaches that measure health across social, environmental, economic and cultural domains can support the more holistic Indigenous concepts of adaptation.

Introduction

Indigenous engagement in Natural Resource Management (NRM) improves health outcomes for both people and country, and Indigenous roles in managing country provide an important avenue for adaptation pathways in the context of climate change (Hilbert *et al*. 2014). Australian Indigenous peoples have distinctive sources of both resilience and vulnerability to the impacts of climate change—resilience based on their unique knowledge, cultural practices and customary institutions, and vulnerability from their socio-economic and historical disadvantage. This vulnerability is heightened for some Indigenous groups due to their remoteness and the inhospitable and fragile environments they occupy. In this chapter we provide a literature-based synthesis of issues and options for generating adaptation pathways and opportunities that take account of this context. The review we provide responds to two drivers:

- "Climate change impacts and issues for Indigenous peoples" as identified in the earlier science synthesis report (Hilbert *et al*. 2014) which related to:
  - Indigenous knowledge and climate change
  - Indigenous communities and climate change
  - Cultural practices and climate change
- The priority information needs for science to underpin adaptation and pathways as identified by the Wet Tropics Cluster NRM groups (Table 6.1).

Climate adaptation has evolved into a jargon-rich, multi-disciplinary research and practice arena, often burdened, but also enriched, by debate and confusion over meanings (Preston and Stafford-Smith 2009). Parsons (2012) provides a useful and simple (but not simplistic) framework through which to consider adaptation strategies with Indigenous peoples. This framework identifies four essential strategies:

1. Impact specific adaptation: for example, in relation to the impacts of sea level rise, adaptation options include seawalls, raised houses, beach replenishment, and relocation
2. Disaster risk reduction: for example, in relation to heat wave disasters, adaptation options include early warning systems, social networks, housing design, improvements to household and workplace infrastructure
3. Mainstreaming: for example, incorporating climate change adaptation into local government policies and community plans
4. Vulnerability reduction: for example through community based adaptation—community-led process, enhancing livelihood options, increasing access to information and services, preventing and

managing conflict over scarce resources, incorporating local values, prioritises, and needs into decision-making.

In this report, adaptation options for Indigenous peoples in response to specific impacts and disasters (such as sea level rise and cyclones) are considered in the relevant chapters including Biodiversity (Chapter 2), Infrastructure (Chapter 4) and Industry (Chapter 5). Indigenous communities across the Wet Tropics Cluster face many such impacts relevant to NRM including: coastal erosion; changes to availability and seasonality of plant and animal species; extreme weather events including cyclones, floods, droughts and heat waves; changes to fire regimes including through changed fuel loads, fire weather conditions and other factors. The emerging NRM frameworks for disaster risk reduction and mainstreaming adaptation through plans and policies, addressed in Chapters 9 and 10, also have relevance for Indigenous peoples and communities in response to these factors.

Here we provide a lens through which Indigenous-specific considerations can be incorporated into the impact-specific, disaster-risk reduction and 'mainstreaming' adaptation pathways. We do this by identifying how Indigenous knowledge, culture and socio-economic contexts influence adaptation outcomes. We also focus attention on the fourth strategy identified by Parsons (2012) as "reducing vulnerability" through the perspective of the recent vulnerability-resilience model for building adaptive capacity (Maru *et al*. 2014). The chapter addresses the majority of priority needs identified by the NRM groups, but we found little information on identifying "what aspects of community culture support adaptation and what aspects impede adaptation" (Table 6.1).

In the remainder of this chapter we: first present the linked vulnerability-resilience model; second the influence of Indigenous knowledge and culture on adaptation pathway-generation; third the approaches to integrate Indigenous knowledge in policy; and fourth, methods to reduce vulnerability and build desirable resilience. We include Case Examples drawn from the Wet Tropics Cluster region throughout, and also provide a final section that presents national and international Case Examples.

Table 6.1 Priority science needs related to Indigenous peoples and adaptation pathways and opportunities from Wet Tropics Cluster NRM groups, and relevant sections in this chapter.

PRIORITY SCIENCE NEEDS FOR THE CHAPTER IDENTIFIED BY THE NRM GROUPS	RESPONSE
Specific communities/aspects	Four boxes with case examples from specific communities in the Wet Tropics Cluster included.
• building general community resilience	Included in the *Building desirable resilience* section; introduced in the section on *Indigenous vulnerability and resilience a linked approach.*
• building sustainable local economies	As above
• identifying key drivers of change to culture	Included in the *Indigenous culture as the context of adaptation* section
• identifying what aspects of community culture support adaptation and what aspects impede adaptation	Little information available; some material on the limitations of Indigenous knowledge-derived processes included in the *Building desirable resilience* and *Indigenous knowledge* topics
• improving cultural knowledge integration into policy, landuse and land management decisions	Included as a separate topic
Local, regional, national, international examples/case studies	Included as a separate topic
Key considerations/principles for monitoring whether particular actions have intended adaptation outcomes	Included as a separate topic
Barriers to potential adaptation actions. Potential strategies to surmount barriers or enable adaptation	Included in a separate topic
Local, regional, national, international examples/case studies	Included in the *Reducing vulnerability* section

Indigenous vulnerability and resilience: a linked approach

Indigenous culture and knowledge influence the application of impact-specific, disaster risk-reduction and adaptation-planning measures and outcomes (e.g. sea walls, housing designs).

Generation of adaptation pathways and opportunities with Indigenous peoples benefits from linking vulnerability-reducing and desirable resilience-building responses in a joint approach.

The linked model of building adaptive capacity through vulnerability-reducing and desirable resilience-building responses in a joint framework provides the foundation for understanding adaptation pathways in the context of Indigenous peoples (Figure 6.1). Here we consider resilience as the capacity of a system to absorb disturbance and still maintain its same controls and key structure and functions, and refer to "desirable resilience" where this characteristic of persistence supports desired social goals and values (Maru *et al*. 2014). We recognise that "desirable resilience" sometimes includes transformational change. Resilience approaches often look at links between longer-term drivers or slow variables and rapid changes, such as flooding or change in political leadership. Vulnerability analysis focuses on human agency and hazards, actor- and issue/impact- based analysis usually with much shorter timeframes (Nelson *et al*. 2007).

Attributes of desirable resilience in the context of Australian Indigenous societies include their experience and knowledge of environments and environmental change. Governance systems arising from rights and interests of country imbue the sense of cultural confidence, self-determination-based independence and community self-reliance in the face of variability and uncertainty. The many faces of current vulnerability correspond to symptoms of the loss of this self-determination-based independence and community self-reliance, associated with the history of colonialism and hostile policy settings producing the contemporary context of socio-economic disadvantage and chronic poor health. These conditions occur even where interventions have resulted from well-intentioned social and economic policies to support 'development' (Howitt *et al*. 2012; Maru *et al*. 2014).

Strategies to build adaptive capacity with Indigenous peoples and communities through this linked resilience-vulnerability perspective require two complementary approaches:

1. Reducing vulnerability through addressing its immediate causes and the barriers faced by Indigenous communities from the context of colonialism and persistent socio-economic disadvantage
2. Increasing desirable resilience through strengthening the influence of relevant attributes of including knowledge and culturally-based governance systems, and self-determination based independence and community self-reliance.

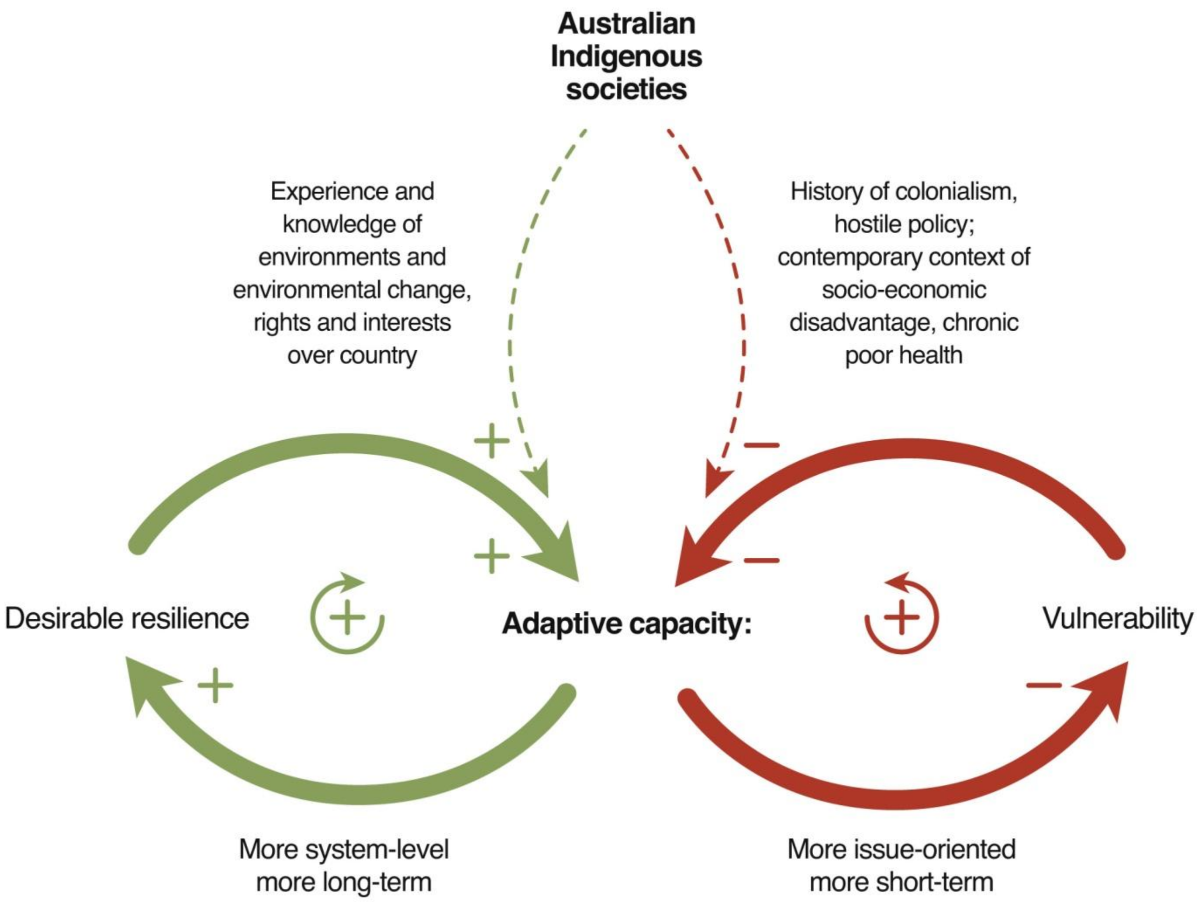

Figure 6.1 Linked vulnerability-resilience model for adaptive capacity: Australian Indigenous societies

Box 6.1 Poruma (Coconut Island) case example from the Torres Strait

Poruma (Coconut Island) and adaptation pathways in the Torres Strait

Torres Strait Climate (http://torresstraitclimate.org/) is a web-site promoting knowledge sharing and raising awareness about impacts and adaptation for climate change in the region. In January 2014, they reported that king tides have again swept across the low-lying islands in the Torres Strait, flooding homes, roads and other infrastructure. "Poruma residents gathered at the seafront this month, calling on all levels of government to protect their island from coastal erosion and flooding. They held placards, some of which read "Help" and "What about us", indicating a desperate cry for urgent action. While king tides are an annual occurrence in the Torres Strait, residents are finding it harder and harder to deal with. Federal and state government funding for the Torres Strait Coastal Protection Works (Seawalls) Project is still pending, leaving many residents concerned about the next king tide." They summarised their message as "We are part of Australia and our people are Australian citizens so please help us." While the Australian Government confirmed $12 million in funding for the Seawalls Project in February 2014, work is yet to begin on the construction and repair of seawalls in the affected islands.

Indigenous knowledge systems as the basis of adaptation

Indigenous peoples' knowledge systems are typically adaptive and provide a primary basis for generation of adaptation pathways and opportunities.

While Indigenous groups frame and perceive climate change based on their world views, collaboration with science based on ethical processes supports adaptation strategies that integrate different types of knowledge.

Indigenous knowledge systems are based on their management, observations and experience with their environments and with environmental change, accumulated over time (Berkes *et al*. 2000). These systems are typically adaptive, so responses such as adjusting the times for carrying out traditional burning (in response to changed humidity and rainfall for example) are already occurring (Head *et al*. 2014). For indigenous groups, indigenous knowledge and its use provides an important foundation for adaptation, resilience and natural resource management (Nakashima *et al*. 2012; Parry *et al*. 2007; Petheram *et al*. 2010). Indigenous knowledge is place based and prioritises elements in the community that sustain local livelihoods and well-being (Herman-Mercer *et al*. 2011; Nakashima *et al*. 2012).

Indigenous knowledge and skills can be strengthened through collaborative arrangements that actively engage indigenous groups to develop their strategies for change, as co-researchers or co-managers of natural resources, through the integration of different types of knowledge for mutual enrichment. Strengthening traditional knowledge of the past, through inter-generational knowledge transfer programs, and its use and inclusion with science, supports traditional resource management institutions, and cements the evolving culture of the group (Adger *et al*. 2013; Nakashima *et al*. 2012; Petheram *et al*. 2010). Adaptation for some groups is contextualised in terms of strengthening 'traditional ways', requiring continued access to country to sustain and transfer Indigenous knowledge, as well as engaging other types of knowledge (Memmott *et al*. 2013; Wiseman and Bardsley 2013).

Indigenous peoples recognise that knowledge partnerships are critical to developing climate change adaptation pathways. Trusting information on climate change provided by 'experts' and allowing knowledge contributions from local Indigenous community members were matters identified by some respondents to a recent national survey as necessary components of the relevant knowledge needed for a carbon offset adaptation pathway (Robinson *et al*. 2014). Some Australian Indigenous peoples describe their approach as the 'two-toolkit' way to look after country, combining the best of Indigenous and western scientific knowledge and decision-making (Green and Minchin 2012; see also Aak Puul Ngantam case example in Box 6.2). While Indigenous communities are keen to have their knowledge taken on board, participants at a national meeting about Indigenous knowledge for climate change adaptation highlighted the troubling history where their information has been taken without proper permission, been inappropriately transmitted, and without benefits flowing on to communities. The legal regimes for protecting Indigenous knowledge are deficient, and new legislation is needed to properly protect Indigenous knowledge. In the mean time, collaborations need to be based on cultural protocols and clauses in contracts that protect intellectual and cultural property rights (Griggs *et al*. 2013). Ethical Guidelines set out the research collaboration processes required (AIATSIS 2012).

For example, the Ltyentye Apurte Rangers in Australia recently worked with a group of CSIRO scientists to bring climate science knowledge into their work, based on ethical research processes. They collaborated to develop presentations of the science of climate change and its likely impacts on country in central Australia. These presentations consisted of English language powerpoint slides that were presented in Arrernte and English by the Rangers, and were very well received by their community audiences. People reported hearing about climate change often on the TV but not understanding what it was about. Work is currently underway to bring some changes into their Ranger work plans for management of erosion, which is rapidly increasing in response to more frequent and higher intensity rainfall events (Mooney 2014).

Indigenous culture as the context of adaptation

Recent Indigenous cultural change in Australia is towards a general resurgence of traditionally-derived culture—and in NRM, towards increasing formal involvement of Indigenous peoples and their culturally-based knowledge systems.

Box 6.2 Aak Pauul Ngantam Cape York case example

Wik and Kugu people and adaptation pathways in Cape York Peninsula

Aak Puul Ngantam (APN Cape York), based in Aurukun, formed a partnership with team of researchers from the University of New South Wales and the University of Western Sydney to support generation of climate adaptation pathways. The project supported field trips to film Wik and Kugu traditional owners going back to country. The interview process has been developed in partnership with Wik and Kugu people, via the APN steering committee and Traditional Knowledge Recording Project. The interviews offer a rare insight into Wik and Kugu people's connection with their country, their memory of what it used to be like, and how these changes relate to their perception of their own well-being. APN supports a 'two-toolkit' approach to looking after country, combining the best of indigenous and western scientific knowledge and decision-making. The goal of the climate change project is show how cultural practice and knowledge of country still remains with these Wik and Kugu Elders and consider how it may be relevant to climate adaptation policies. Options include encouraging the return to living and working back out on country, and the re-investment in families returning to live for some of the year on their outstations, where the connection to country can continue to be strengthened (Green and Minchin 2012).

Indigenous culture impacts on all three areas required for successful adaptation: knowledge-based technologies; decision-making tools; and adaptation institutions.

Strengthening 'traditional ways' and building cultural cohesion are identified as key adaptation pathways for some Indigenous groups.

Institutions engaging on climate adaptation require intercultural skills to understand and work with perceived risks to culture that shape the capacity and will of Indigenous groups to adapt.

Indigenous cultures are highly dynamic and in the Australian context exist within a postcolonial frame in which the nation-state has overarching sovereign power (Smith and Hunt 2008). Nevertheless, the main trend in Aboriginal cultural change over the last decade has been towards a resurgence of traditionally-derived distinctive culture. Key drivers of this general change include the formation of alliances made possible by the advent of land rights and native title, an Aboriginal cultural turn amongst Aboriginal and non-Aboriginal people, and changing (more community-oriented) approaches to regional development (Jones and Birdsall-Jones 2013). In the NRM context, increasing formal involvement by Indigenous peoples is one of four stand-out trends over the last decade (State of the Environment Committee 2011). Six drivers underpin this trend: customary obligations; Indigenous leadership to secure their NRM roles; recognition of Indigenous rights to country; markets for NRM services; increased co-management arrangements; and increased levels of investment (Hill *et al*. 2013b).

Cultural change is also resulting in loss of Indigenous knowledge due to policies of assimilation that prevented transmission of language and traditions, and western/modernity industrialisation-driven changes to daily practices of production of food/clothing/shelter (Nawrotzki and Kadatska 2010). Many languages in Australia are highly threatened and ongoing attrition of Indigenous knowledge threatens the adaptive capacity of Indigenous communities (Hill *et al*. 2013b).

Understanding and action on climate change adaptation are always influenced within the cultural values and practices of a society and community (Adger *et al*. 2013). However, the influence of culture is particularly strong for Indigenous peoples and communities, where culture impacts on all three areas recognised as critical to successful adaptation to climate change (Figure 6.2).

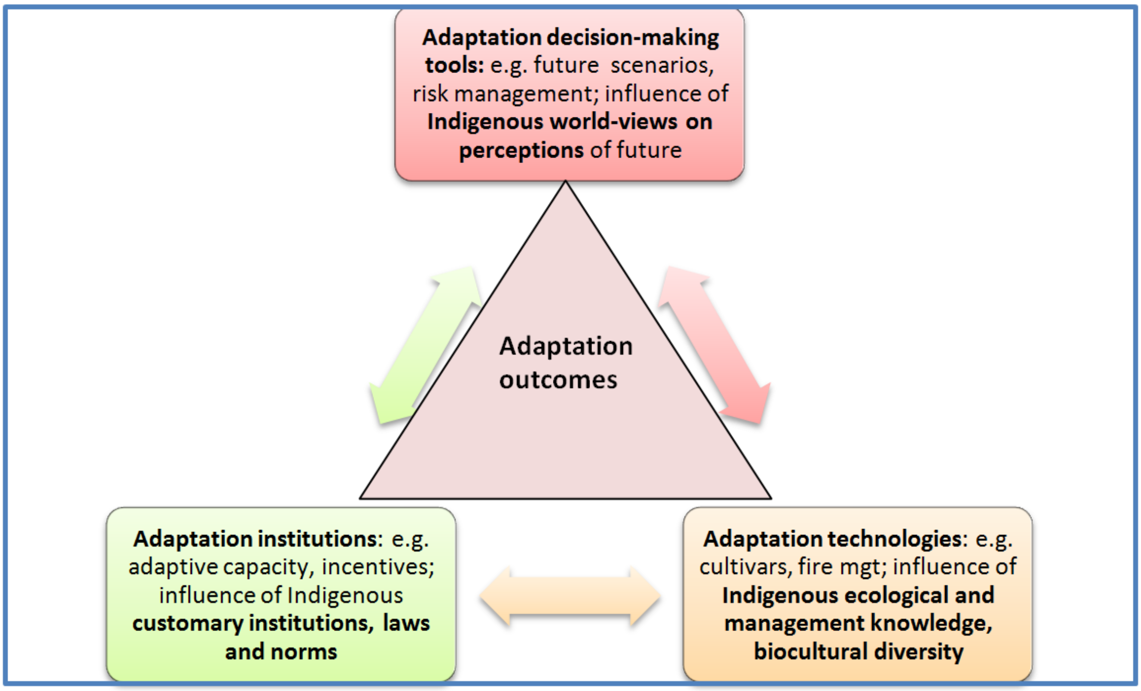

Figure 6.2 Adaptation outcomes and Indigenous cultural influences.

Source: Adapted from Stafford-Smith and Ash (2011)

Adaptation decision-making relies on tools that enable people to evaluate options and make choices—for example, future scenarios of change and risk management models. For many Indigenous peoples' perceptions of change and their meaning have their context in Indigenous world-views (the Dreaming) that supersede and parallel Western scientific discourses of hazard and risk (Veland *et al*. 2013a). For example, changes are related to people's loss of respect for a living environment and weakened awareness of their intricate co-existence with the elements of nature, rather than to climate. Adaptation institutions, the formal and informal rules that determine the decision-making processes, in the context of NRM are strongly influenced by customary institutions for governance—that determine, for example, which people are responsible for decision-making over specific areas of land (Davies *et al*. 2013). Australian Indigenous peoples maintain culturally-based governance systems with distinctive features include an emphasis on networks, nodal modes of leadership within these networks, and dispersed distribution of powers among self-defined social groups (Smith and Hunt 2008). Adaptation technologies relate to the development of specific solutions (technical and other) generally tied to specific threats, such as the adoption of new cultivars that will grow in hotter conditions. Again in the context of NRM, Indigenous peoples' specific solutions are highly influenced by the knowledge of practices such as fire management, and by their management of "biocultural diversity". This term denotes that biodiversity and cultural diversity share common links which developed over time through mutual adaptation and possibly co-evolution (Hill 2013).

Institutions and organisations engaging indigenous groups on climate adaptation will therefore require intercultural platforms and skills to understand and work with perceived risks to culture that will shape the capacity and will of groups to adapt (Adger *et al*. 2013; Bassett and Fogelman 2013). While adaptation is a necessity in the face of climate change, negative consequences for communities can result when the cultural context is not central, and changes underway are narrowly defined within a science or economic argument (Adger *et al*. 2013; Wiseman and Bardsley 2013).

Box 6.3 Bana Yaralji case example from wet tropics country

Kunawarra clan and adaptation pathways in wet tropics country

Bana Yaralji Corporation in south-east Cape York works on behalf of the Kunawarra clan to look after their rich, bioculturally diverse country. Marilyn Wallace and Bana Yaralji have pioneered efforts to effectively integrate Aboriginal lore and ecological knowledge into wider national and international climate change mitigation and adaptive management strategies. Together with the United National University Traditional Knowledge initiative, they produced an Indigenous Perspectives on Climate Change film entitled 'Walking on Country with Spirits'. In this film, Marilyn highlights how the seasons are getting hotter, the country is transforming and traditional foods are disappearing. Marilyn attended UNU hosted Indigenous Climate Change conference in Alaska and presented their film at the Indigenous Perspective on Climate Change Film Festival at the National Museum in Copenhagen at the time of the Conference of the Climate Convention. The groups has established a Climate Change Walk to educate community members and visitors, is seeking to establish an Indigenous Climate Change Watch and facilitate a culturally informed strategy for climate change adaptation and mitigation in the northern Wet Tropics World Heritage Area (Wallace 2012).

In the context of contemporary Australia, many groups are widely scattered across the continent, and not engaged on a daily basis with their country. Arabana people, for example, are scattered around the country. Nevertheless, they have withstood the pressures of colonisation and remained culturally strong with a resilient sense of identity, no matter where they live (Nursey-Bray *et al*. 2013). They came together from all across Australia to Port Augusta to consider climate change, and collectively agreed on an adaptation program based on improving cultural cohesion and strength (Nursey-Bray *et al*. 2013). The Kunawarra clan of the wet tropics similar seek culturally-based adaptation (Box 6.3).

Integrating Indigenous knowledge and culture into policy, landuse and land management decisions for adaptation

Integration of Indigenous knowledge and culture into policy, planning and management can be supported by:

- **Indigenous governance and co-governance; co-management that engages power-sharing; and cognisance of social contexts**
- **intercultural "knowledge-bridgers/brokers" that undertake joint agenda setting and knowledge co-production**
- **Indigenous-driven and cultural planning frameworks that recognise interlinkages between people, place, plants, and animals; and bridge scales by considering issues across the whole of an Indigenous people's territory**
- **visual and spatial tools including: seasonal calendars; maps of cultural sites, use and occupancy and incorporating art; narratives; and cultural keystone species.**

The integration and use of Indigenous knowledge and culture to inform environmental policy, land use and land management is a growing global phenomenon (Robinson and Wallington 2012). However, the interactions between scientific, practitioner and Indigenous knowledge and cultural systems encounter many challenges in practice, and particularly in the context of climate change (Bohensky *et al*. 2013; Head *et al*. 2014). Several conditions have been found to influence integrative goals in the Australian Indigenous context. Integration is supported by: Indigenous governance and co-governance over knowledge integration; evolution of co-management towards a degree of power-sharing; cognisance of the social contexts of integration, and involvement of inter-cultural "knowledge bridgers" (Bohensky and Maru 2011; Hill *et al*. 2012). Integration into planning is supported by frameworks that bridge scales by considering values and issues across the whole of an indigenous people's territory.

New frames that respond to interlinkages of stewardship between people, place, plants, and animals help integration. Examples include: "Anpernirrentye", traditionally-derived worldview of Arrernte Aboriginal people which views plant resources through the lens of dreaming, country and people, each with multi-dimensional inter-related components (Walsh *et al*. 2013); and the "Ngurra-kurlu Framework for Walpiri Indigenous Ecological Knowledge" which centres on country, law, language, ceremony and skin (Holmes and Jampijinpa 2013).

The Kuku Thaypan Fire Management Research project, the Importance of campfires and Firesticks is a collaboration involving Indigenous people from Cape York mentoring with New South Wales people. This approach provides a leading example of an innovative frame to assist knowledge transfer of Indigenous fire management (Box 6.4). The principle of recognition of roles, responsibility, respect and reciprocity apply across the frame for knowledge of fire in three components, each with multiple inter-linked parts: knowing what it is; knowing what it does; and knowing how to do it (Standley and Felderhof 2011).

Box 6.4 A co-generative poster outlining the innovative Indigenous led methodology applied through the Kuku Thaypan Fire Management Research Project and documented by the Importance of Campfires research and its mentorship to the NSW Firesticks project. The poster highlights the interconnected knowledge frame of the Kuku Thaypan Elders as it applies to fire management: knowing what it is; knowing what it does; and knowing how to do it.

Source: Standley and Gothe (2011)

Specific tools also help integration of Indigeous knowledge and culture in NRM. Ecological calendars developed through cross-cultural collaborations can effectively correlate climate, astronomy, resource availability, and cultural practices. Robinson and Wallington (2012) describe mapping and narrative tools applied to resolve uncertainties about feral animal management in Kakadu National Park. They reinforced the need for "boundary agents" (bridgers/brokers), people with the capacity to communicate equitably across knowledge systems. Davies *et al.* (2013) also highlight the key role played by brokers in the development of IPA management plans that integrate knowledge. Brokers ensure participation in agenda setting and joint knowledge production; bring Indigenous and non-Indigenous staff together for interactions between knowledge systems; and support production of collaboratively built knowledge outputs (e.g. feral animal impact assessment data). "Boundary work" by bridgers/brokers can help efforts to translate across knowledge systems and across the knowledge-action divide, even when consensus is difficult to achieve (Robinson and Wallington 2012). Cultural keystone species that are also of high ecological significance to science-based NRM can play a strongly catalytic role in supporting integration of Indigenous knowledge and culture in to policy, planning and practice (Butler *et al.* 2012).

Building adaptive capacity through reducing vulnerability

Adaptation planning that prioritises respectful Indigenous partnerships and explicit commitment to address issues of justice and well-being can reduce vulnerability arising from barriers posed by colonial history.

A sustainable development approach, that addresses wider social and economic needs (e.g. infrastructure, health services) can reduce vulnerability arising from socio-economic disadvantage. Comprehensive Community Planning is an interesting Canadian First Nations example.

Reducing vulnerability with Indigenous peoples requires both addressing aspects of material welfare, and aspects of cultural and spiritual welfare. Much of the focus on climate science and adaptation is based on the assumption that climate change is important only when it affects our material welfare (Adger *et al*. 2011). Consideration of cultural, spiritual and non-material well-being is not addressed (Adger *et al*. 2013; Adger *et al*. 2011). The danger for Indigenous groups is that this approach to climate adaptation and the focus only on technical solutions will ignore the cultural and spiritual dimensions of well-being, an action that mirrors colonial policies and programs for change (Bird *et al*. 2013; Cameron 2012). For Indigenous nations, the impacts of colonisation remain current and real, and are their primary concerns in their increased vulnerability to climate change (Veland *et al*. 2013b). Indigenous groups continue to be burdened by a colonial past that has not been addressed nor compensated (Howitt *et al*. 2012). Assessments of vulnerability and adaptation to climate change that do not incorporate and respect the indigenous perspectives can entrench patterns of racialised disadvantage and marginalisation and set in train future vulnerabilities and disasters. Climate risk assessment, preparation, and recovery that prioritises partnerships based on recognition, respect, and explicit commitment to justice is recommended as an appropriate means to reduce vulnerability arising from colonial history (Howitt *et al*. 2012).

Over-arching issues of Indigenous disadvantage, poverty and welfare, were identified as of more concern than climate change in a Northern Territory and in South Australia, highlighting the importance for adaptation pathways that address material welfare (Petheram *et al*. 2010; Wiseman and Bardsley 2013). Historical disadvantage that sustains social and political marginalisation, disease and health-impacts on wellbeing, are concerns that have more immediate impact and will be exacerbated the impacts of climate change (Low-Choy *et al*. 2013). Addressing these challenges suggests a sustainable development approach (Reyer *et al*. 2012; Robinson 2004) that considers wider social and economic needs of Indigenous groups. These include needs for improved housing, water, energy, sewerage and transport infrastructure, educational opportunities, health and recreation services and for conditions that attract educators, health workers and other skilled people to work with Indigenous peoples in remote contexts (Hilbert *et al*. 2014). Comprehensive community planning approaches that establish a vision for Indigenous societies across all these domains are proving highly effective with First Nations in British Columbia and are worthy of attention here (Andre Grant, Centre for Appropriate Technology, pers. comm. 2013). Based on experiences of a number of First Nations with this approach, the Canadian Government has supported development of a Comprehensive Community Planning Handbook.

Building adaptive capacity through strengthening desirable resilience

Indigenous peoples seek adaptation pathways that focus on empowering communities to identify and implement their own responses to climate change.

Building sustainable local economies through climate adaptation opportunities (e.g. carbon credits) requires secure land tenure and rights to carbon to foster desirable resilience.

Regionally specific capacity-building strategies are required to support Indigenous organisations to gain the governance, technical and other capabilities that enable brokering across cultures and scales to support desirable resilience.

Long-term collaboration with Indigenous groups on structural transformation can help address the deep sources of ongoing inequities and build desirable resilience.

Participants at a national Indigenous climate adaptation workshop identified that responses to climate change should come from within each community, who are in position to determine the best solutions for their unique needs, interests, and circumstances. Solutions imposed externally are likely to be ineffective, inappropriate or unsustainable. However, Indigenous knowledge by itself is not sufficient to address all the requirements for adaptation. Communities need support to identify and generate adaptation pathways including being able to:

- access good information and research that enables the necessary skills for communities to understand what climate change means for them and determine the best adaptation options
- establish meaningful input to regional and national policy and decision making processes affecting their lands
- develop opportunities for knowledge sharing between Indigenous communities in Australia and overseas (Griggs *et al*. 2013).

Indigenous people now hold rights and interests over more than half the Australian continental land mass (Hill *et al*. 2013b). As a result, many Indigenous communities are well situated to generate adaptation pathways based on local economies that provide greenhouse gas abatement and carbon sequestration benefits from their lands. In addition, access and connection to traditional country sustains the Indigenous knowledge systems that form the basis of desirable resilience.

However, Indigenous participation in carbon economy schemes are limited by land tenure arrangements and the extent of rights over carbon ; geographic and biophysical factors; low levels of requisite technical, human and financial resources; and lack of appropriate recognition of Indigenous knowledge and cultural responsibilities. Regionally specific capacity-building strategies are needed to enable Indigenous people to participate in emerging carbon offset activities and the generation of associated ecosystem services. For example, 94% of Indigenous organisations in a recent national snapshot reported lack of requisite governance, technical, human and financial resources to engage in adaptation economies (Robinson *et al*. 2014).

Capacity building of indigenous organisations, with a view of these agencies providing a central point for coordination across levels and scales government could potentially position them in a more active role across a wide range of issues – social, economic, ecological, physical infrastructure, communications. Pooling funding processes to support innovative solutions and experimenting with resilient organisational structures offer possibilities of addressing the concern of lack of funds and fragmented funding (Memmott *et al*. 2013; Wiseman and Bardsley 2013). While the capacities of Aboriginal corporations differ, it is important recognise that some have survived and adapted to changing policy and funding arrangements to potentially be major players in building desirable resilience (Memmott *et al*. 2013). However the lack of authority of these corporations, such as rangers not having the legal capability to act on illegal activities, limits their potential effectiveness (Bird *et al*. 2013). Advocacy by Indigenous groups for community-driven strategies for sustained and effective adaptation outcomes also seek improved governance capacity and responses (Memmott *et al*. 2013; Petheram *et al*. 2010).

If we are to genuinely engage indigenous groups in climate adaptation programs, and act on the increasing impact of climate change, long-term collaboration with indigenous groups on structural transformation is required (Bassett and Fogelman 2013). Transformative change aims to address the long-term adaptation and future conditions rather than short-term adjustment responses within the current context (Park *et al*. 2012). Transformative change calls for active participation of Indigenous groups in defining the role of institutions, governance, and 'development', the pathway for adaptation and what is accepted as transformative change, and the capacities important for managing and responding to risk events (Bassett and Fogelman 2013; Park *et al*. 2012). For Indigenous groups, their strong attachment to place can strengthen their capacity to adapt (Marshall *et al*. 2012), and addressing adaptation of place will also mean addressing the non-climate drivers of indigenous disadvantage (Green *et al*. 2009; Low-Choy *et al*. 2013; Petheram *et al*. 2010).

Monitoring adaptation pathways with Indigenous peoples

Participatory development with Indigenous peoples of monitoring and evaluation based on program logic, indicators and criteria, can support effective use of these approaches and link them to Indigenous knowledge systems, as shown in the Our Country Our Way Guidelines.

Indigenous holistic concepts of monitoring through close observation over time can be supplemented by scientific surveys and technologies like Cyber-tracker.

Integrated monitoring approaches that measure health across social, environmental, economic and cultural domains can support the more holistic Indigenous concepts of adaptation.

Result Based Management, the Logical Framework Approach and the accompanying logframe are the most common monitoring and evaluation approaches used for adaptation (Lamhauge *et al*. 2013). The Australian MERIT system which operates in the NRM domain is based on these methods. The inherent scientific and reductionist approach MERIT is somewhat at odds with the more holistic approaches to NRM management and monitoring by Indigenous peoples based on their culturally-derived knowledge systems. However, case-management approaches by the Australian government teams that support Indigenous Protected Area and Working on Rangers in capacity-building have resulted in effective adoption of these methods by Indigenous organisations (Hill *et al*. 2013b).

Guidance on how to implement MERIT in NRM contexts with Indigenous peoples is provided in Our Country Our Way: Guidelines for Australian Indigenous Protected Area Management Plans (Hill *et al*. 2011). Participatory workshops can help groups think through the Program Logic, a one-page "roadmap" or diagram to illustrate the rationale behind the adaptation pathway. It sets out the link from actions to short, medium and long term changes, and how these will lead to the achievement of the long term goal or vision for adaptation.

These Guidelines also discuss how traditional monitoring of country through close observation can be supported by fauna/flora surveys conducted with science partners to establish a more comprehensive baseline data. Cybertracker systems can be used to collect data when out on country. Other monitoring programs use a traffic-light based assessment of the health of the main targets and uses indicators to measure change over time. Some Indigenous people have updated paintings to show how their country is changing. In New Zealand, a cultural health index for streams is based on Maori concepts of country (Maclean 2010). In the wet tropics, Indigenous peoples have identified "linked cultural and biophysical indicators" across six categories, with associated sub-categories, indicators and criteria attached to cultural significance (Cullen-Unsworth *et al*. 2012). More recently, participatory monitoring of co-management of coutnry that use health indicators across results, structures and processes is proving useful to underpinning a more holistic measure across social-economic-cultural-environmental domains (Hill *et al*. 2013a).

Case examples

ARCTIC

Hunting in the Arctic

The indigenous people at Sachs Harbour are coping with changed seasonal patterns by: modifying the timing and location of their seasonal hunting and fishing activities; diversifying their harvests; and closely monitoring sea ice conditions (Berkes 2008).

In the Arctic, narwhal co-management arrangements across multiple levels of governance are supporting knowledge sharing and the use and integration of indigenous knowledge and science (Armitage *et al*. 2011). This arrangement is reinvigorating traditional knowledge, practice and governance and is building adaptive capacity of the groups involved (Armitage *et al*. 2011; Ford *et al*. 2010). Wage income is also an important part factor of household adaptive capacity in Inuit communities (Ford *et al*. 2010).

Arctic: The arctic reindeer herders use of the polar view initiative (McLean 2010)

The polar view initiative in the Arctic provides reindeer herders with satellite-based snow maps. Snow is of paramount importance for reindeer herding because its quality determines whether reindeer are able to access the pastures that lie beneath it for much of the year. The project explores ways that satellite observations can help herders by gathering information on snow and snow change and providing this to herders to assist them to make decisions about winter pasture quality and potential migration routes.

ASIA

Housing and weather extremes (McLean 2010)

Traditional housing techniques are changing in Bangladesh and the Philippines in response to typhoon flooding. Communities are re-designing and adjusting their homes to be flood resistant. These changes include use of low cost materials, local labour, skills and knowledge. Changes include the construction of an attic for storage, joining of bamboo and timber to form joists for homes that increase the flexibility of homes during typhoon winds, and houses built on raised platforms (McLean 2010).

Use of Local knowledge in disaster management (McLean 2010)

In Bangladesh flooding submerges 60 percent of the land. This also damages agricultural land, property and results in loss of life. Coping mechanisms of villages include raising homes, planting of catkin reeds to reduce erosion, shelter in elevated grounds, reducing food intake, fuel and food storage as well as re-location.

MALDIVES

Sea level rise and safer islands strategy (McLean 2010)

The Maldives is one of the most vulnerable nations to predicted impacts of sea level rise from climate change.

More than 85% of the nation lies less than 1.5m above average sea level. More than half the populated islands have been affected by recent swells and storms. The Maldives government development the 'Safer Island Strategy' that includes re-settlement from smaller vulnerable islands to larger island and improved coastal defences. The larger islands will provide safe shelter as well as basic and emergency services before or after a disaster, with a long-term view of supporting re-located inhabitants of the small vulnerable islands.

CARRIBEAN (Adger 2003)

A strong positive relationship between government and local stakeholders in the Buccoo Reef Marine Park facilitated a new institutional design, conflict resolution strategies and the joint development of a new management plan for the marine park. The strong stakeholder networks are a critical resource to cope with extreme weather conditions, where individuals involved in disaster planning are also working closely with the marine park to promote management of the protected area.

NEW ZEALAND

Cultural health index for streams and waterways (McLean 2010)

The Maori monitoring of New Zealand wetlands project uses indigenous indicators to assess how Maori see their environment changing. A method was developed with Maori organisations for their people to use to assess the change in their environment and prepare a report for their state of environment report that is delivered to their local and central governments. Maori concepts underlie the monitoring indicators.

Consultation with Maori on Climate change (McLean 2010)

In 2007 consultation was held with Maori people across the country to discuss climate change issues and options. It was acknowledged that climate change is an urgent issue that requires action, both for future generations and to restore the environment Participants also made clear their desire for more and better information. The principle of partnership was highly regarding in developing policies that will affect Maori.

AUSTRALIA

Ranger programs in Northern Australia

(www.indigenousclimatechange.com.au/casestudy7.aspx, accessed 5 April 2014).

The ranger programs in northern Australia, in Broome, Maningrida and Ngukurr (Northern Territory), and Wujal Wujal (Queensland) are supporting indigenous adaptation in those communities. Rangers are managing climate and environmental threats of bushfires, coastal erosion, feral animals and weeds, loss of biodiversity through strategies that use both traditional and western knowledge.

Re-introduction of traditional fire management in Northern Australia

(www.indigenousclimatechange.com.au/casestudy11.aspx, accessed 5 April 2014).

Also in northern Australia, a partnership between NAILSMA and the University Nations University, and the Australian Government on a savannah fire management and sustainable livelihoods project is seeing the re-introduction of traditional-style patch burning. The practice has reduced the intensity of late dry season fires and emissions. Other benefits delivered through the project were increased use of cultural and social tradition and increased capacity to adapt to climate change.

TUMRA between Great Barrier Reef Management Authority and Girringun Aboriginal Corporation (Zurba 2009)

The Traditional use of Marine Resources Agreement (TUMRA) between the Great Barrier Reef Marine Authority (GBRMPA) and the Girringun Aboriginal Corporation (GAC) in Northern Queensland demonstrated increased consideration and inclusion of indigenous knowledge into a co-management approach. Increasing dialogue and the incorporation of indigenous knowledge and perspective has strengthened the co-governance of arrangement for a more adaptive resource-use community.

Summary and conclusions

Generating adaptation pathways and opportunities with Indigenous peoples in the Wet Tropics cluster region requires recognition that culture, history and geography underpin both high resilience and high vulnerability to the impacts of climate change. Indigenous knowledge systems are highly adaptive and provide the foundation for developing adaptation pathways and opportunities. However, many Indigenous organisations and communities report lack of technical skills and knowledge to take account of the contemporary context of climate change policy that shapes their opportunities, and seek better understanding of the science of climate change. Regionally-specific capacity building and knowledge co-production projects can help to address this gap. At the same time a number of approaches, methods and tools are necessary to ensure that Indigenous knowledge and culture are integrated into mainstream adaptation polices, programs and practices. These include support for Indigenous governance and co-governance, cultural brokers, the use of Indigenous-driven and cultural planning approaches, and visual and spatial tools including cultural mapping and seasonal calendars. Cultural keystone species have been found to play a catalytic role in knowledge integration (Bohensky *et al*. 2013; Hill *et al*. 2013b; Maru *et al*. 2014; Robinson *et al*. 2014). Many Indigenous communities already face liveability challenges across infrastructure issues including transport, energy, water, sewerage, industry, housing. Integration of Indigenous knowledge and cultural considerations into the adaptation strategies for these sectors is vitally important.

Integrated approaches that support sustainable development to address current socio-economic barriers are central to climate adaptation for Indigenous peoples. Comprehensive community planning processes underway with First Nations in Canada provide a good example of how to do this, and are worthy of consideration. Indigenous peoples in Australia emphasis the need for community-driven adaptation that empowers their roles and responsibilities. However, many structural factors are encountered as barriers by Indigenous peoples in generating these pathways, including limitations to tenure and rights over carbon. Long-term partnerships that address these deep structural sources of disadvantage are needed to build Indigenous adaptive capacity. Indigenous peoples' emphasis on integrated approaches that link adaptation across social, economic, environmental and cultural domains challenges our usual more reductionist approaches to monitoring and evaluation. Nevertheless, participatory knowledge/action projects are demonstrating how program logic-based approaches can be linked with Indigenous knowledge to generate effective holistic measures

Specific adaptation actions have not been identified in this Chapter, as these will be negotiated through the participatory processes facilitated by NRM groups and other stakeholders. Effective adaptation pathways and opportunities will be different for different Indigenous people, communities and groups across the Wet Tropics cluster. Application of the approaches, tools and methods synthesised in this chapter provide an opportunity to support beneficial approaches across this diversity by tailoring to the context. Indigenous roles in managing country provide a key avenue for adaptation pathways that contribute positively to health and well-being of people and natural resources across the cluster. Table 6.2 provides an example from the Upper Georgina River Basin (UGRB) of the key strategies, actions and outcomes identified as part of an adaptation planning process involving Aboriginal people from five communities in the UGRB and the Aboriginal Environments Research Centre (AERC, University of Queensland) (Memmott *et al*. 2013). While the Upper Georgina strategies have been developed in very different geographical, climatic and community contexts to those present in the WTC region, many issues are common to Indigenous peoples across regions, as reflected in the planning themes (i.e., land management, housing and settlements, enterprise development; Table 6.2). We commend this and the other examples and adaptation approaches provided in this chapter as useful entry points for Indigenous peoples and communities in developing practical adaptation pathways.

Table 6.2 Key climate adaptation strategies, strategic actions and outcomes identified by Aboriginal communities in the Upper Georgina River Basin (UGRB) (Source Aboriginal Environments Research Centre). *Reproduced with permission from Memmott et al. (2013).*

ADAPTATION STRATEGIES	STRATEGIC ACTIONS	KEY OUTCOMES	BARRIERS
1. Anticipatory Adaptations/ Preparedness for Climate Change			
1.1 UHRB Aboriginal communities to work together in building climate change adaptation (CCA) strategies.	Establish a UGRB CCA Group.	Co-ordinate preparedness and anticipatory adaptation activities at a regional level.	Potential issues regarding who funds the formation of this group.
1.2 Appropriate regional climate change planning processes required.	Consult with Aboriginal community members and Government/NGO agencies.	Develop further the Regional Climate Change Management Plan. Develop a Disaster Management Plan for each community.	Lack of funding and cross-jurisdictional issues.
1.3 Better regional climate change preparedness communication processes needed.	Establish a regional CCA social media program.	Co-ordinate local communities and State, Federal and non-Government agencies re. practical climate change adaptation ideas, both for chronic change and acute weather response.	Lack of funding and cross-jurisdictional issues disrupting good communication outcomes.
1.4 Management of response and recovery processes during and after an extreme weather event.	Link with the Australian Red Cross (ARC).	Become the conduit between local communities, State, Federal and non-Government agencies re. disaster management co-ordination.	Potential issues with communications protocols, roles and responsibilities during such events.
1.5 On-going CCA research in the UGRB region required.	Continue communicating with Aboriginal climate change protagonists in the UGRB region.	Seek further funding to continue current research.	Lack of funding options prevents this from happening.
1.6 Appropriate regional and local CCA programs need to be implemented.	Consult with Aboriginal community members and Government/NGO agencies.	Develop a primary and secondary schools education program.	Lack of funding.
1.7 Appropriate regional and local CCA training programs need to be implemented.	Consult with Aboriginal community members and Government/NGO agencies.	Develop a regional Emergency Management Queensland/TAFE training program.	Lack of funding.
2. Land and Riverine Management			
2.1 Managing culturally and environmentally significant places.	Documentation and mapping of culturally and environmentally significant places.	Establish a set of cultural places and plant and animal habitats for monitoring and protection and	Access to knowledgeable Aboriginal people and availability of suitably skilled people to record knowledge

ADAPTATION STRATEGIES	STRATEGIC ACTIONS	KEY OUTCOMES	BARRIERS
	Protection of culturally significant places and plant and animal habitats. Negotiation over land and river use with regional stakeholders including pastoralists and mining companies.	implementation of program. Build the capacity of Aboriginal representatives and their involvement in environmental management.	as well as funding for Aboriginal Knowledge recording, archiving and retrieval. Accessing funding. Availability and willingness of knowledgeable Aboriginal people and regional stakeholders to meet, discuss and lobby effectively.
2.2 Education about Aboriginal land and river management and climate change in the region.	Lobby local government for visitor interpretation and history of land management.	Develop a range of educational resources in collaboration with the Aboriginal community on land and river management, Aboriginal Knowledge and climate change in the UGRB for use in local and regional schools and in the wider community.	Availability and application of appropriate teacher training and educational resources for schools as well as for the wider community.
2.3 Training and employment of local Aboriginal rangers.	Create further opportunities and programs for Aboriginal ranger training in the UGRB region.	Support local Aboriginal groups to gain access to ranger training programs in the UGRB region.	Funding for all aspects of locally-based ranger training programs and availability of suitable trainers and mentors.
3. Housing and Settlement Program			
3.1 Improve adaptive capacity of individuals.	Increase employment in local service delivery.	Aboriginal provision of infrastructure, services and housing construction.	Aboriginal participation and initial costs.
3.2 Integrated settlement design.	Aboriginal participatory planning.	Utilise local knowledge in settlements planning.	Upfront cost.
3.3 Bioclimatic housing.	Low-energy housing case study.	Aboriginal participation in design, planning and construction, with teams of qualified building consultants, experienced in cross-cultural design.	Costs and complexity.
4. Enterprise Development Opportunities			
4.1 Ecosystem restoration works in relation to carbon farming initiatives relevant to the region.	Investigate Aboriginal environmental management processes.	Develop a regional carbon farming enterprise and mining land rehabilitation enterprise.	Complex land use agreement process between local pastoralists and UGRB Aboriginal communities. Lack of will by mining companies to support such

ADAPTATION STRATEGIES	STRATEGIC ACTIONS	KEY OUTCOMES	BARRIERS
			an agreement.
4.2 Environmental disaster management and clean up.	Investigate environmental disaster management processes.	Develop an environmental land rehabilitation enterprise.	Lack of will by mining companies to support such an enterprise.
4.3 Emergency road repair.	Investigate infrastructure and disaster management processes.	Develop an infrastructure and disaster response enterprise.	Lack of funding opportunities to support such an activity.
4.4 Weed eradication programs.	Investigate Aboriginal environmental management processes.	Develop an environmental land rehabilitation enterprise.	Complex land use agreement process between local pastoralists and UGRB Aboriginal communities.
4.5 Feral animal hunting.	Investigate Aboriginal environmental management processes.	Develop an environmental land rehabilitation enterprise.	Complex land use agreement process between local pastoralists and UGRB Aboriginal communities.
4.6 Patchwork burning programs.	Investigate Aboriginal environmental management processes.	Develop an environmental land rehabilitation enterprise.	Complex land use agreement process between local pastoralists and UGRB Aboriginal communities.

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7. Social adaptation: minimising impacts through enhancing adaptive capacity

Nadine A. Marshall

IN A NUTSHELL
• The actual impacts of climate change on communities will be strongly influenced by the capacity of individuals and industry sectors to detect and respond to the associated challenges. This capacity is currently relatively low in some primary industry sectors. • Adaptive capacity is related to i) risk assessment and management; ii) adaptive planning; iii) financial and psychological buffers; & iv) the level of interest and proactive behaviour. • Strengthening communication, trust and social support networks will build community adaptive capacity.

Precis

Adaptive capacity can be a major influence on what social and economic impacts actually eventuate. This chapter aims to inspire NRM planners within the Wet Tropics Cluster to consider strategies to enhance adaptive capacity across scales: within individual landholders such as cattle graziers and farmers, within agricultural industries and within the NRM organisations themselves. The chapter introduces and defines the concept of adaptive capacity, describes what successful adaptation might look like, refers to case studies within the region, and offers suggestions to enhance adaptive capacity. The key messages associated with each of the topics addressed in this chapter are:

TOPIC	KEY MESSAGES
What does successful adaptation look like for landholders?	132. Adaptive success depends on maximising productivity during any one season and minimising impact on the future ability of the land to produce.
What is adaptive capacity?	133. Adaptive capacity is the ability to respond to challenges through learning, managing risk and impacts, developing new knowledge and devising effective approaches. 134. Enhancing adaptive capacity is not about providing additional resources. 135. Adaptive capacity can be measured through assessing; i. how people assess risks and manage for uncertainty, ii. extent of planning, reorganising, experimenting, iii. financial and psychological buffers, and iv. the level of interest and extent of proactive behaviour.
How can adaptive capacity	136. At all scales, adaptive capacity can be enhanced through better networks, increasing

TOPIC	KEY MESSAGES
be enhanced?	environmental awareness, recognising and responding to feedbacks, developing strategic/business skills, developing an interest in science and technology and fostering a culture of shared learning. In sum: any action would likely lead to adaptive capacity. 137. Adaptive capacity can be enhanced by NRM organisations through facilitating workshops, partnerships, communications and monitoring. Topics to share with landholders include identifying potential adaptations, and pressing for ambitious co-funded management actions to be progressed by industry groups 138. Education of the next generation of leaders is vital to enhance adaptive capacity of the region. Mentoring, job placement, training in adaptive thinking and scenario development, recognising environmental feedbacks developing strategic/business skills, developing an interest in science and technology and fostering a culture of shared learning are all be important.

Introduction

Managing the climate and its impacts on natural resources is not a new challenge. Ever since the inception of agriculture some 4-10,000 years ago, human civilisations have had to contend with 'good' years and 'bad' years. In addition to more recent economic, social and environmental demands humans must now also contend with climate change in which rainfall patterns and mean temperatures in particular are likely to be significantly altered and unprecedented in human history (Howden *et al*. 2007). Climate change acts to push natural resource systems and those dependent on them towards their thresholds of tolerance, testing whether they can absorb the impacts and adapt (Marshall *et al*. 2012).

Primary industries and enterprises, which include the sectors of agriculture, forestry, fisheries and tourism, are especially vulnerable to climate change because they are dependent on resources that are highly climate-sensitive (Fleming and Vanclay 2010, Stokes *et al*. 2010, Chapter 5, this report). Resource dependency can make resource-users especially sensitive to changes that occur in the resource as a result of climate change. However, while resource dependency may describe the sensitivity of people to climate change and the likely associated impacts, adaptive capacity can be a major influence on what impacts actually eventuate (Marshall *et al*. 2013b).

Adaptive capacity also becomes important to meet the demands of an ever-increasing human population. Industries and enterprises dependent on climate sensitive resources must enhance their productivity without compromising their capacity to be productive in the future if they, and the communities dependent on them, are to be sustained (Marshall *et al*. 2012). Recognising and enhancing adaptive capacity becomes increasingly important for resource-dependent industries facing significant climate change, and for the communities dependent on them (Kelkar *et al*. 2008). Defining adaptive capacity and exploring ways to enhance adaptive capacity for adaptive success are the main aims of this chapter.

What does successful adaptation look like?

Adaptive success depends on maximising productivity during any one season and minimising impact on the future ability of the land to produce.

Success not only depends on maximising productivity during any one season, but also on minimising impact on the future ability of the land to produce (McKeon *et al*. 1990, Anderies *et al*. 2002). Of particular concern is that degradation processes within the region are especially accelerated during drought periods, especially on the grazing lands (Briske *et al*. 2010). In drought situations, which are becoming more 'normal', cattle producers for example need to know when to alter stocking rates, when to supplement feeding, when to agist (move livestock to other properties), when to burn and when to alter water supplies if they are to be successful (Hansen 2002, Marshall *et al*. 2011). If stocking rates are too high at the onset of drought, for example, soil sustainability will be diminished and the productivity of future years will be impacted. Yet, different strategies are used by different people to different effect. Successful people and successful organisations are those that do not necessarily subscribe to what everybody else is doing, but are able to listen to feedbacks (environmental, economic, social), and experiment, learn, plan, reorganise, refine, monitor and reflect.

The capacity of farmers, fishers, foresters and graziers to individually undergo climate adaptation and succeed may be vital to the success of their respective industries and regions: in most situations a critical mass of individuals will need to adapt for regional or industry-wide adaptation to occur. Yet, not all individuals or organisations will have the same capacity to adapt; some are likely to face considerable barriers that make embarking on their own too challenging, consequently reducing the chances for regional and/or industry adaptation success (Chapter 5, this report). Primary producers that can anticipate or effectively react to climate change events including climate extremes are more likely to adapt to new climate conditions and be successful (Reed *et al*. 2007). Some people, some organisations are likely to do better than others (Adger 1999, Adger *et al*. 2009). In fact, a recent study of cattle producers across Northern Australia suggested that only 15% of the industry were well positioned to meet the challenges of the future. An aim of this chapter is to inspire NRM planners within the Wet Tropics Cluster to consider strategies specifically to enhance adaptive capacity across scales within the region.

What is adaptive capacity?

Adaptive capacity is the ability to respond to challenges through learning, managing risk and impacts, developing new knowledge and devising effective approaches

Adaptive capacity is the ability to convert resources (natural, physical, financial, human, social) into useful adaptation responses (Brooks and Adger 2004, Smit and Wandel 2006). This might translate, using commercial fishers in the Great Barrier Reef as an example, as the ability of fishers to recognise that they need to reorganise themselves as they are no longer able to continue fishing in the places that they know well. Fishers that plan and experiment with new ways of running their fishing business such as investing in alternative fishing gear, acquiring new skills through learning or forming a cooperative and increase profit yields to compensate for travel further afield are more likely to be successful in the future than fishers whom have always been able to remain viable in the past and assume that they can continue on as always despite conditions becoming untenable (Marshall and Marshall 2007).

Adaptive capacity describes the ability to respond to challenges through learning, managing risk and impacts, developing new knowledge and devising effective approaches. A key ingredient is the flexibility to experiment and adopt novel solutions (Olsson and Folke 2001, Olsson *et al*. 2004a). In ecosystems, adaptive capacity is related to genetic diversity, biological diversity, and heterogeneity within landscapes (Carpenter and Gunderson 2001). In social systems, adaptive capacity can be a conscious or inadvertent characteristic, enhanced by the existence of institutions and networks that learn and store knowledge and experience, and create flexibility in problem solving without compromising the ability to cope and adapt to future change (Armitage 2005).

Enhancing adaptive capacity is not about providing additional resources

Adaptive capacity is not just about the possession of resources. Given equal resources, not all individuals, communities or NRM groups will be equally able to convert resources into successful adaptation strategies. The presence of resources; be they natural, physical, financial, human, or social, does not guarantee that adaptation will succeed. Resources will certainly be important in climate adaptation processes; given all other aspects are similar, a person with more resources is better able to experiment with their options for the future, but the *capacity* to cope and adapt to change and its translation into a tangible strategy, can occur irrespective of the resources available. Readers familiar with capacity investment in adaptation in developing communities will know that financial aid does not always assist with adaptation, and can indeed result in cases of maladaptation.

Adaptive capacity can be measured through assessing; i) how people assess risks and manage for uncertainty, ii) extent of planning, reorganising, experimenting, iii) financial and psychological buffers, and iv) the level of interest and proactive behaviour.

The capacity of individuals to adapt to a range of change events has been assessed using a variety of approaches. For example, Brown *et al*. (2010) use self-assessments, while Frank *et al*. (2011) refer to socio-cognitive frameworks. Grothmann and Patt (2005) apply the Model of Private Proactive Adaptation to Climate Change. In this chapter, we offer an established framework based on longitudinal data sets for operationalising adaptive capacity that was initially developed within the Great Barrier Reef region and that may be useful to NRM planners in the Wet Tropics Cluster. Here, adaptive capacity is regarded to be determined in large part by the characteristics and circumstances of resource users and by their capacity to take advantage of other opportunities; these 'preconditions' are summarised into four dimensions including: (i) how risk and uncertainty are perceived and managed, (ii) the development of skills for planning, learning, reorganising and experimenting, (iii) the degree of financial and psychological flexibility, and (iv) the level of interest in and willingness to proactively undertake change (Marshall and Marshall 2007).

These dimensions were developed with commercial fishers in Queensland and have been tested within a range of communities, resource-dependent industries and nations (Cinner *et al*. 2009, Marshall *et al*. 2010c, Marshall 2011, Sutton and Tobin 2011). Commercial fishers were originally asked to respond to 75 statements about various and generic change events and indicate how strongly they agreed or disagreed with each statement. Responses clustered into the four dimensions described above. Fishers and cattle producers across northern Australia are currently being monitored through time. We describe the four dimensions of adaptive capacity here:

1. **The perception of risk and managing for uncertainty:** How individuals and organisations perceive the risks associated with change and manages for uncertainty is key in determining their ability to cope and adapt. Some will find ways to plan that are consistent with the range of likely futures and possible desired outcomes. This necessarily involves a degree of uncertainty, but need not be a barrier to planning (Adapt NRM 2014). How risk is managed reflects individual and cultural differences in experiences, knowledge, beliefs, values, attitudes and judgements as well as differences in abilities to plan and execute plans (Ritchie *et al*. 2004).
2. **The ability to plan, learn and reorganise:** This component reflects the capacity to anticipate the future. The capacity to plan, learn and reorganise in the face of change is dependent on novelty, creativity, experimentation, learning and planning (Harris *et al*. 1998, Colding *et al*. 2004, Olsson *et al*. 2004b). Without it, any response to climate changes will be reactive and there will be less opportunity for input from others (Marshall *et al*. 2010b, Marshall *et al*. 2010d).
3. **The ability to cope with change:** In social systems, the ability to cope is a measure of the proximity to emotional and financial thresholds. All change is expensive and people that have a financial buffer or access to credit are better able to absorb the costs of change. Examples of emotional or psychological barrier to adaptive capacity include health, divorce, death in the family or trauma. A serious emotional issue can significantly undermine the best laid intentions. NRM planners may already know that suicide is the main killer of men living in rural Australia, and recent research has observed that more suicides occur during drought periods. This, together with knowledge that domestic violence is the biggest killer of women in rural Australia, indicates the extreme emotional conditions under which rural people can live and work (Berry *et al*.

2011a,b). Regardless of how adaptive people are on all other dimensions, this dimension can significantly outweigh all others in determining adaptive success. NRM organisations may wish to consider the level of community support networks that exist within their region.

4. **The level of interest in change:** This dimension of adaptive capacity corresponds with the degree to which the system is capable of 'self-organisation'. Individuals that have a higher level of proactive interest in adapting to the requirements of the future usually have a higher related financial, social and/or emotional flexibility. An interest in adapting is necessary for individuals to identify the consequences, impacts and possible responses ("adaptation options") to climate change (Howden *et al*. 2007, Bohensky *et al*. 2010, Marshall 2010).

Whilst measures of self-assessments can be useful, they can also be severely limiting. People unaware of their own personal limitations and limitations imposed upon them by the environment may feel completely competent to assess their own level of adaptive capacity and identify their own needs. In one example based in America and Sweden, 80% of car drivers rated themselves above average on a number of characteristics related to their driving skills (McCormic *et al*. 1986) suggesting that people can be unaware of the reality of their own capacity. Similarly, in a recent study in the Burdekin region, graziers' were found to positively perceive their own capacity to cope and adapt to climate variability. This perception may, in fact, make them vulnerable to more extreme and frequent climate events in the future. Climate change is likely to seriously challenge the skills, experience and judgement of resource-users, and unless they use novelty, creativity, experimentation, learning and planning in approaching this change, they are unlikely to cope and adapt (Hiedanpaa 2005).

How can adaptive capacity be enhanced?

Case-study research suggests that there are several characteristics of people that are associated (correlated) with higher adaptive capacity. These include: possessing creativity and innovation for identifying solutions or adaptation options; testing and experimenting with options; recognising and responding to effective feedback mechanisms; employing adaptive management approaches; possessing flexibility; being able to reorganise given novel information; managing risk and, having necessary resources at hand. We describe some of these below.

At all scales, adaptive capacity can be enhanced through better networks, increasing environmental awareness, recognising and responding to feedbacks, developing strategic/business skills, developing an interest in science and technology and fostering a culture of shared learning. In sum: any action would likely lead to adaptive capacity.

The adaptive capacity of societies is partly determined by their ability to act collectively (Adger 1999, Osbahr *et al*. 2008). This ability is often embedded within the concept of social capital. Social capital and community empowerment reflect the level of social interaction, social networks and social relations that exist within a community (Putnam 1993, Worthington and Dollery 2000, Adger *et al*. 2002). They help to explain the ease with which change events are accepted and incorporated into people's lives. Those with stronger, more informed and more effective networks are regarded as being more resilient to generic change events than those with weaker ties (Mitchell 1974, Flora and Flora 1993, Putnam 1993). Communities with increased stocks of social capital typically have reciprocal networks of community interactions and increased social trust that are directed towards mutual benefit. Social capital includes knowledge and mutual obligation, and is developed through social learning. The level of social capital within a community provides some indication of the capacity for a community to cope with change and adapt (Marshall 2011).

Social networks could be used within each of the NRM regions to develop social capital around climate adaptation. To derive most benefit from the capital developed within a community, it will be important to: (1) build landholder adaptive capacity; (2) facilitate the activity of forums for building relationships between stakeholders and demonstrating the value of a cooperative ethic; and (3) educating stakeholders about climate change adaptation and create an awareness of the benefits of engaging other stakeholders (Brunckhorst 2002, McAllister *et al*. 2005).

Adaptive capacity can be enhanced through increasing environmental awareness

Climate change awareness is an important factor influencing the capacity of primary producers to cope with and adapt to climate changes (Marshall *et al*. 2013a). Climate change awareness is the extent that primary producers accept, understand, relate to, and prioritise climate change as a driver of change within their system. Climate change awareness might also be managed to support adaptation processes. Marshall *et al*. (2013a) sought to understand the influence of a primary producer's climate change awareness on their capacity to adapt to climate change risks. They suspected that primary producers could be limited in their capacity to adapt from the outset if they failed to see the need to adopt novel climate adaptation strategies. Their results indicated that primary producers in Queensland that have higher climate change awareness also have a higher capacity to adapt on at least three dimensions of adaptive capacity.

Education of the next generation of leaders is vital to enhance adaptive capacity of the region. Mentoring, job placement, training in adaptive thinking and scenario development, recognising environmental feedbacks developing strategic/business skills, developing an interest in science and technology and fostering a culture of shared learning are all be important.

Environmentally educated and aware resource-users tend to be more flexible and supportive of resource-protection strategies (Marshall *et al*. 2007). They can develop identities such as 'land steward' or 'marine steward', which makes them less dependent on traditional resource management practices, and more willing to adapt new practices that enhances not only their own resilience to change, but that of the environment. Marshall *et al* (2013) asked marine-based tourism operators for their level of interest in learning more about marine sustainability (Marshall *et al*. 2010a). They found that adaptive capacity can be enhanced through developing environmental awareness.

Adaptive capacity can be enhanced through recognising and responding to feedbacks

Like active adaptive management increases the adaptive capacity of a system, recognising and responding to environmental and social feedbacks through experimenting with different strategies, learning from strong feedback loops and incorporating new information into the design of new strategies will contribute to greater potential for adaptive success (Gunderson *et al*. 1995, Folke *et al*. 2002a, b, Olsson *et al*. 2005).

Educating landholders within the NRM regions of the Wet Tropics Cluster to recognise land degradation and to respond appropriately is a vital influence on enhancing their adaptive capacity.

Adaptive capacity can be enhanced through learning to manage for uncertainty.

Uncertainty can be managed and accommodated for in planning and should not be seen as a barrier to action, as inaction has been shown to be more detrimental than assessing risk and making decisions based on that risk calculation. Below we outline some different types of uncertainty and where they come into the planning process, as well as basic ways in which they can effectively be tackled in planning (These types of uncertainty are listed in the Adapt NRM 2014 brochure).

1. Natural variability – " the ecological conditions, and the spatial and temporal variation in these conditions, that are relatively unaffected by people, within a period of time and geographical area''
2. Observation/Data error - Observation error is the failure to properly observe, measure or estimate processes and quantities. It results both from imperfect methods of observation (or simply not measuring key factors) and from sampling error, i.e. the statistical differences between a sample of individuals and the population that the sample is meant to represent

3. System uncertainty - our system understanding is limited by the understanding of all the links – thus, even with complex models, any projections (qualitative or quantitative) will have uncertainty
4. Inadequate communication - Inadequate communication relates to the difficulty of effectively conveying information between scientists, managers and stakeholders. When communication is ineffective, information is lost, which can manifest itself as uncertainty
5. Unclear objectives or lack of goal setting - Unclear management objectives are ones that are expressed vaguely, not fully conceived, scaled improperly, or difficult to quantify
6. Outcome uncertainty – when actions not implemented properly; Outcome uncertainty can be referred to as ‘‘implementation error’’ or ‘‘implementation uncertainty’’ because it is commonly associated with differences between a management goal and the implementation of the management plan. A typical example in fisheries is when actual catches of a fished stock are not equal to the model-derived allowable catch limit. Outcome uncertainty can be especially critical to NRM because it undermines the ability to determine whether management actions and recommendations are truly working—that is, if models and other tools recommend policy X, but the resource users instead implement practice Y, then the research and management communities cannot conclude that policy X was either effective or ineffective, because it has not actually been implemented yet.

Adaptive capacity can be enhanced through better planning.

We highly advise that NRM planners be aware of the “Adapt NRM” guide associated with this project. This guide provides a ‘checklist’ for NRM planning frameworks. The framework is built around five common stages or planning components; (i) assessment, (ii) strategic planning, (iii) implementation planning and action, (iv) monitoring, and (v) reflection. These are built into an iterative process – necessary because the most effective responses to climate change problems may not be known and outcomes may only be achieved after trying a range of options, assessing the responses and making appropriate changes. From this a series of self-reflective questions are posed to assist NRM planners to discuss the ways in which planning to adapt to climate change may need to be done differently compared to what might have been done traditionally.

Strategies to enhance adaptive capacity

Adaptive capacity can be enhanced by NRM organisations through facilitating workshops, partnerships, communications and monitoring. Topics to share with landholders include identifying potential adaptations, and pressing for ambitious co-funded management actions to be progressed by industry groups.

All four dimensions of adaptive capacity are important in endowing adaptive success on individuals, organisations and industries. Fortunately, all dimensions can be managed or learned and adaptive capacity be enhanced. There are surprisingly few research studies that describe case studies in which interventions have been successful, so here we present some ideas that NRM planners within the Wet Tropics might want to consider.

1. Practice active adaptive management. Adaptive capacity can be strengthened through practising active adaptive management. Active adaptive management can help to increase adaptive capacity through experimenting with different strategies, learning from strong feedback loops and incorporating new information into the design of new strategies
2. Hold NRM workshops (or provide learning opportunities) for landholders. Risk, uncertainty, strategy, planning, experimenting, learning and financial buffers are all critical factors for adaptation. These factors can all be learned. Providing opportunities for landholders to explore these factors within their own working lives may prove to be a useful strategy. The study of these

factors with colleagues may also stimulate an interest in adaptation and pro-active behaviour. In these ways, NRM workshops addressing adaptive capacity may address all dimensions simultaneously

3. Partner with community services. Psychological or emotional buffers relating to health issues or financial crises need to be explicitly addressed. Developing partnerships with counselling services for example for advice and support may assist to develop adaptive capacity on the third dimension
4. Communicate about climate change. Extension services, communication outputs, community discussions on local radio are some ideas that NRM planners may consider to develop an interest in change, and encourage proactive behaviour
5. Assess adaptive capacity within your region. Design and administer very simple surveys and collect data to inform you of the current status of adaptive capacity within your region. By monitoring the adaptive capacity of your landholders, stakeholder organisations, and your own organisation, you may be able to evaluate if and when you can devote fewer resources specifically to adaptation planning. Partnering with scientists can be a great way to monitor adaptive capacity, particularly to get started and to reduce the work load
6. Involve people in the strategy to enhance adaptive capacity. Many research studies have shown that meaningful involvement in the decision-making process is essential to foster feelings of satisfaction, understanding, trust and confidence in the future. These feelings are necessary for a successful transition to adapting to change – and in particular policy change (Becker and Carper 1956). Kallstrom and Ljung (Kallstrom and Ljung 2005) convincingly argue that people must be satisfied with their situation in terms of control over decisions in order for social sustainability and environmental goals to be achieved. They believe that by participating in decisions regarding the future, and by taking part in the public debate, day-to-day life becomes more meaningful and social identities are strengthened around the resource itself. In contrast, resource users that do not have the opportunity to be meaningfully involved in the process tend to feel that policy changes, at least, are 'unfair', 'unnecessary', 'wrong', 'immoral' and/or 'illegal', where some people do well out of them, and others do poorly. If people feel confident about their future and the future of the resource, then they are more likely to positively assess the risks associated with change and their ability to cope: both of which are important in maintaining adaptive capacity.

Summary and conclusions

Humans can influence the impacts that climate change might have through adaptation: through building the capacity of people to adjust to plausible future climate scenarios. Whilst human communities may be sensitive to changes in the climate that affect the resources upon which they depend, their vulnerability may be moderated by the extent of their adaptive capacity. The specific challenge faced by people living in the Wet Tropics Cluster region will be to ensure community security and build the productivity and profitability of their resource-based industries and enterprises where possible without degrading the natural resource services on which they depend. People, industries and organisations that tend to display higher levels of adaptive capacity and success often are better able to manage the risks associated with change, can plan, experiment, reorganise, and learn, are more likely to have financial and psychological buffers and are more proactive. We know this from a range of case-studies, many of which occur locally.

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8. Emerging planning frameworks for climate adaptation

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IN A NUTSHELL
• To achieve adaptation at larger scales, individual local adaptation actions will need to be guided by strategic planning at higher scales that includes vision-setting, strategy development and the monitoring of outcomes. Commitment to cohesive implementation of agreed adaptation priorities from all institutions involved in planning will be critical. • The current system of adaptation planning in the WTC has some healthy and some less healthy aspects, although the overall likelihood of success in adaptation to climate change is currently precarious. International, national and state planning frameworks are in relatively poorer health, with a limited strategic focus on supporting adaptation. • Community ownership of strategic adaptation planning and the implementation priorities at the regional scale is essential and the process must be adaptive.

Precis

This chapter focuses on the more strategic activities that lead people in the regional community to decide how they want to respond to climate change. Such strategic activities include analysing, prioritising and deciding upon the best course of action. *Planning for climate adaptation* (usually seen to include the setting of visions and objectives, the determination of key strategies and the monitoring of broad outcomes) encompasses the strategic activities involved in the system of governance for climate adaptation. Planning occurs at all scales from global to the business, property, family and even individual scales. Applying a rapid appraisal technique, this chapter analyses the system of planning for climate adaptation as it relates to the achievement of adaptation outcomes within the Wet Tropics Cluster. It finds that some aspects of the system are healthier than others, and identifies several actions that regional NRM bodies may consider (either collectively or individually) to enhance adaptation outcomes by improving the planning system within the cluster.

TOPIC	KEY MESSAGES
Effective Planning Systems For Climate Adaptation	139. Within climate adaptation systems, there needs to be a focus on improving strategic (planning-oriented) practices such a vision and objective setting, strategy development and outcomes monitoring at various scales.
Opportunities for the Next Generation of Climate Adaptation at the Cluster and Regional Scales	140. As a whole, the practice of planning for climate adaptation within regions, including within the Wet Tropics Cluster, can benefit from several new opportunities in, and approaches to, planning practice. Their adoption will be critical in mobilising climate adaptation efforts within regions.

TOPIC	KEY MESSAGES
Key Adaptation Planning Components Within the Wet Tropics Cluster	141. Strategic aspects of adaptation planning are happening through diverse and separate planning activities at the international, national, state, cluster, regional, local and business scales. The relative health of all of these planning activities needs to be considered in strengthening the governance system for adaptation.
How Healthy is the Adaptation Planning System?	142. There are several key areas of adaptation planning reform that may be within the realm of reasonable influence for regional NRM bodies in the Wet Tropics.

Introduction

In climate adaptation work, much attention is often paid to local practice-based actions that can, if individually accumulated, lead to climate adaptation at landscape scale. These local efforts represent the implementation and delivery end of the governance system for climate adaptation. Equal attention also needs to be applied to thinking about best practice approaches and the design of the more strategic components of the system; that part where future visions and objectives for climate adaptation are set, where the key strategies for delivery are determined and where the overall achievement of these objectives are monitored. In effect, this part of the system is what we may refer to as the *planning system for climate adaptation*. This system involves multiple institutions and players, has complex legislative foundations and operates differently at different scales.

A new Australian innovation in climate adaptation is joined-up planning among clusters of natural resource management (NRM) regions likely to experience similar climate-related changes. There are 8 different clusters across the Australian landscape, each consisting of several NRM groups. Hence, the Wet Tropics Cluster (one of these 8 national clusters) represents an important scale for strategic thinking and action associated with climate adaptation. In addition to being likely to experience similar climate change impacts, the Wet Tropics Cluster also has many related biophysical and social characteristics (e.g. cyclone exposure). Consequently, the Cluster has several consistent governance arrangements for planning which operate at a range of scales. Together, these elements make it worth considering common approaches to mobilising Cluster-level efforts to enhance adaptation.

This paper aims to explore the key principles that need to be operating for an effective planning system for climate adaptation to function at any scale and the challenges for this current generation of planning as it relates to climate adaptation. It then goes on to explore the current nature of this system within the Wet Tropics Cluster and makes some key recommendations about the actions that regional NRM bodies and other key players can take in enhancing the functionality of the system.

Effective planning systems for climate adaptation

Within climate adaptation systems, there needs to be a focus on improving strategic (planning-oriented) practices such as vision and objective setting, strategy development and outcomes monitoring at various scales.

If we view societal governance as the "intentional shaping of the flow of events so as to realise desired public good" (Parker and Braithwaite 2003, p. 119), then it becomes clear that governance is not a hierarchical concept, or one driven by some form of authoritative leadership (Thomas and Grindle 1990). Instead, it needs to be viewed as a wider set of processes of bargaining and negotiation among differing interests in society, leading to particular system outcomes; often with a mix of public and private good implications (Dovers 2000, Emerson *et al*. 2011). With this understanding, we can identify and analyse those parts of the system focused on or delivering climate adaptation outcomes, or the *governance system for climate adaptation*.

The globe's wider governance system for climate adaptation (and significant sub-systems within it) is poly-centric and multi-themed. This system is not orchestrated by any one player, and no one individual or institution is in charge per se, rather it is the impact of a vast array of interactions among many independent decisions that determine system outcomes (i.e. measurable progress towards climate adaptation within society) (Kemp and Parto 2005, Lockwood *et al*. 2010). To analyse complex governance systems (such as the climate adaptation system) and its consequence for outcomes, Dale *et al*. (2013b) developed an analytical framework that can be used to explore the health of the overall system *or* to enable a focus on key system components. Their approach aimed to enable analysts to more powerfully contextualise their work and improve key components at different scales within any governance system that might be at risk of failing. This means effective planning efforts for climate adaptation, no matter how small or at what scale, could be reformed to benefit the wider system for climate adaptation.

This thinking makes it clear that the failure of a particular institutional arrangement (e.g. involved in climate adaptation) to deliver its outcomes needs to be understood in the context of a fuller understanding of the wider governance regime (Paavola *et al*. 2009). Indeed, Dale *et al*. (2013b) suggest the need to be explicit about four key things in any systemic governance analysis:

- **Thematic aspects of governance:** Understanding that key governance themes (e.g. environment, social and economic) can't be separated, and comprise various domains (e.g. climate, water, biodiversity) and subdomains (e.g. climate mitigation vs. climate adaptation)
- **Polycentric aspects of governance:** Understanding that within any theme, domain or sub-domain of governance, different governance activities tend to play out at different spatial scales, and these scales operate in a polycentric (not hierarchical) fashion (Ostrom 2010)
- **Structural aspects of governance:** The concept of structure offers an account of the parts a system comprises. Generally, well defined structural components with a particular role in the system may be considered to be inter-related via an inter-connected hierarchy. Different structures may indeed be represented as a network; with outcomes from one structural component continually informing outcomes from the others. Often, the social sciences refer to structures within society as being represented by or manifested through institutions (e.g. governments, corporations, families, etc.) or alliances of institutions with particular roles
- **Functional components of governance:** Apart from ensuring the key structural elements of our governance systems are in place (i.e. the things that need to be done and by whom), it is equally important to consider how well things are working within and across these structural elements within the system (or how functionally sound they are).

Based on the above, and drawing on the policy/planning literature (e.g. Althaus 2008), the following describes the standard structural components of governance systems:

- *Vision and objective setting:* Setting higher level visions/objectives
- *Analysis (research and assessment):* Research and assessment to underpin decision-making
- *Strategy development:* Determining the best, most well informed strategies for securing visions and strategic objectives. This requires the application of an appropriate solutions mix (i.e. balancing market-based, suasive, regulatory, collaborative and capacity building approaches) within strategy development
- *Implementation:* Implementation and delivery of broader visions, objectives and strategies
- *Monitoring, evaluation and review:* Monitoring, reviewing and evaluating implementation.

Such structural considerations can be applied to evaluation of any theme, domain and sub-domain of a governance system or to a system as an integrated whole. At the local level, for example, many different institutions are involved in *implementing* climate adaptation, including family farms, corporations, local government, voluntary groups, Indigenous communities, etc. Hence at a particular local scale, whether they are operating as a weak network or strong alliance, they can all be considered as a part of the overall structural arrangements for the *implementation* of different aspects of climate adaptation at the local scale and hence, they collectively and actively contribute to the success or failure of this agenda.

Alternatively, in functional terms, great integration of effort in *vision and objective setting* structures in relations to climate adaptation, for example, can be undone by poor integration of effort within strategy development and implementation structures. Considering this provides a focus for analysing how the system works (i.e. its functionality), against all the key structural elements of the system. Dale and Bellamy (1998) suggest there are three cornerstone functional elements of healthy governance systems within our globe's over-arching governance system. These are:

- *Knowledge application to improve governance systems:* Improving the functionality of any particular governance system requires coordinated and integrated use of knowledge derived from multiple epistemologies and approaches (Pahl-Wostl *et al*. 2007, Emerson *et al*. 2011, Leys and Vanclay 2011)
- *Securing connected effort within governance systems:* Power relationships primarily drive connections within and between structural components of any governance system. Indeed, many governance systems often consist of many highly isolated activities (or silos) within and between different structural components of the system (Margerum 1995). In respect to climate adaptation at the national scale, for example, several institutions in a particular nation may be actively setting national visions and targets without ever connecting; at best duplicating effort and at worst working at cross-purposes
- *Improving the decision-making capacity of system participants:* Anything that develops the decision-making capacity of institutions (e.g. agencies, communities, corporations, families, etc.) and individuals operating within a governance system will improve the system's vitality (Dorcey 1986). Consequently, attention to improving the capacity of all system participants is needed to understand and to have access to information, to raise motivations to engage well, to secure access to the appropriate technical and financial resources needed, to secure a clear mandate and to raise the capacity needed to negotiate well within that mandate.

The above considerations underpin the analytical tools that we use in this chapter to unpack the climate adaptation governance system as it relates to the Wet Tropics Cluster. Importantly, however, we are particularly focused on the strategic end of the climate adaptation system's structural picture; more strategic level planning activities at a range of scales that involve *vision and objective setting*, *analysis*, *strategy development* and the high end *monitoring of outcomes*.

Opportunities for the next generation of climate adaptation at the cluster and regional scales

As a whole, the practice of planning for climate adaptation within regions, including within the Wet Tropics Cluster, can benefit from several new opportunities in, and approaches to, planning practice. Adoption of these sorts of opportunities and approaches will be critical in mobilising climate adaptation efforts within regions.

In this chapter section, we explore new opportunities for the meaningful application of improved strategic planning within clusters and regions for securing climate adaptation. These are intended to help inform new planning directions that the Commonwealth, state and territory governments, other sectors and regional NRM bodies may consider over the coming years. We also consider possible new directions in light of emerging Australian Government and regional NRM body needs, current planning developments at the

State level and the emerging planning practice literature. The findings have been drawn from and adapted from implications specifically considered for regional NRM bodies in Dale *et al*. (2013a) and are consistent with Commonwealth guidelines for this current generation of regional NRM planning being conducted across the nation.

A focus on landscape resilience

The need to prepare for emerging new global pressures requires a higher order focus on building landscape resilience, particularly in the face of climate change (Gunderson *et al*. 2010). The focus of regional planning practice over the last decade, however, has been based on more linear/rational target setting approaches with several limitations. More resilience-based thinking is required as:

- Climate change pressures facing our natural resources are so global and intense, that transformational change, rather than incremental thinking, is required (Ostrom 1999)
- The dynamic interplay between natural assets (e.g. between water, biodiversity, carbon stocks/flows and productive capacity) needs to be made more explicit if we are to secure greater resilience in our landscapes (Plummer and Armitage 2007)
- A focus on understanding "thresholds of concern" in natural systems will be required, whereas a more linear approach might result in managers fiddling around the edges of potentially devastating changes in the health of our landscapes.

A strong impetus is emerging to move away from rational models of planning and move towards more adaptive approaches better informed by resilience thinking. Importing resilience thinking as a foundation for adaptation planning enables a robust, systems-based and scientifically informed debate about ecological thresholds and the transformational changes required to avoid them or to adapt to them if they occur (Cash and Moser 2000, Vogel *et al*. 2007). The implications for planners working within regions include a shift to building collaborative planning alliances focused on jointly determining priorities, mobilising implementation and reviewing progress. The first generation of Australian NRM plans, for example, tended to focus more on the production of a static strategic document rather than on creating the social foundation for ongoing collective regional action.

Adaptive planning: collaborative, evidence-based continuous improvement

One of the greatest promises of Australia's regional NRM planning system was that it was established through a bilaterally agreed planning framework; it seemed that a genuine, continuously improving and adaptive planning effort could begin with almost indefinite time horizons (Dale *et al*. 2008, Lockwood and Davidson 2010). This promise was curtailed when the Australian Government retreated from initial commitments to progressive regional NRM planning from 2008 onwards (Robins and Kanowski 2011). While regional NRM planning effort may have floundered in the intervening years, most states and regional NRM bodies themselves continued progressing improved planning, but on a more ad hoc basis. Importantly, in part through an emerging new approach to regional NRM planning and through the introduction of the Carbon Farming Initiative (CFI), the Australian Government is now re-embracing genuinely long term continual-learning approach to regional NRM planning (Dent *et al*. 2012, Clayton 2013). This is an important opportunity, but one still yet to be fully scoped, agreed and collaboratively resourced across Australian state, territory, local governments and regional NRM body spheres of influence. Other forms of adaptation planning occurring within regions (e.g. strategic land use planning) also tend to be less focused on continuous improvement. Further, the opportunity to progress learning-based planning approaches can and should be married with more resilience and transformation-based approaches to planning (Brunner 2010).

Overtly collaborative decision-making and monitoring

Early regional NRM plans did have strong community ownership and buy-in, including formal accreditation by two levels of government (Farrelly 2005). At the time of their development, however, the approach focused on temporal sign-off rather than explicit and durable institutional commitment to ongoing collective action. Ongoing community and government legitimacy behind regional NRM plans has consequently declined in many regions (Robins and Kanowski 2011). Adaptation planning within regions needs to revisit collaborative decision-making about thresholds, transformative changes, management and implementation priorities and become more focused on securing ongoing commitment from all parties to the integrated alignment of effort, informed by resource condition monitoring against thresholds and targets (Healy 1995, Pahl-Wostl 2009, Pahl-Wostl *et al*. 2010). In particular, this also refers to the need for strong community ownership of regional land use planning and the integral link between this and regional NRM planning.

A strong evidence base and community/science partnerships

Adaptation planning within regions can benefit from stronger and more durable science/community partnerships. This means building a more integrated synthesis of scientific input (e.g. between social and biophysical sciences), best managed through well structured, durable relationships between the science community, regional NRM bodies, land use planners, stakeholders and governments at regional scale (Ozawa 1991). The climate sciences, however, also need to be better integrated into the wider range of adaptation planning activities within regions at various scales. Community acceptance of the emerging science is critical and new science developments need to be able to be easily adapted into decision making as it unfolds (Ozawa 1991). The Australian Government's Stream investments under the Regional NRM Planning for Climate Change Fund, for example, aim to achieve this science-planning integration outcome and have wider application. In the Wet Tropics cluster, this can integrate well with planning for the setting of science priorities (see Crowley *et al*. 2014).

Monitoring and evaluation to review thresholds

Adaptation planning within regions is generally under-resourced with regard to monitoring, though many regional NRM bodies have tried within these limitations to establish robust monitoring frameworks to support learning-based approaches (Eberhard *et al*. 2009, Lane *et al*. 2009, Robinson *et al*. 2009). A stronger focus on establishing simple but collaborative and durable monitoring frameworks in regions is required, avoiding key thresholds (Robinson *et al*. 2009). Real consistency and connectivity needs to emerge, however, between accounting approaches at the national, State and regional scales (e.g. see Wentworth Group 2008).

Improved spatial analysis to guide the carbon market

Not all first generation regional land use and regional NRM plans were able to progress strong spatial analysis to identify particular parts of the landscape where:

- High value assets and or spatial threats associated with the way that climate change affects those assets (e.g. high risks of salinity rising in water tables)
- Government, community and market-driven investments might deliver the most strategic and effective land use outcomes for the least cost
- Particular land uses/management practices need to be avoided/supported.

This problem was not fatal to planning within regions, but was a feature of the embryonic status of the process. Some regions had much more historical spatial data and scientific analysis to draw upon than others (Robins and Dovers 2007). Indeed, regional NRM planning sparked an increase in cross-regional and cross-State data enhancement and sharing of knowledge (Robinson *et al*. 2009). Improved spatial analysis is reliant on maturation of the planning process, the emergence of collaborative alliances, progressive development of the science and community engagement to enable further analysis and enhanced spatial prioritisation. In particular, the link between the emerging CFI and guidance offered by next generation plans presents an opportunity in this regard.

Better contextualising targets through improved spatial analysis would be beneficial first start in areas such as improving biodiversity and landscape connectivity (Bryan and Crossman 2008). In the future, at the very least, this would allow those developing CFI methodologies and projects based on particular NRM practices to target their efforts in those parts of the landscape that will deliver the best outcomes for improved landscape scale resilience in the face of climate change.

Defining regional practices frameworks

Regional NRM plans tend to be the planning activity within regions most likely to identify and classify management practices in particular industries and land uses that lead to enhanced climate adaptation, including target setting for practice improvement (Vella *et al*. 2011). There are, however, often poorly contextualised and insufficiently standardised approaches across the nation. This can change, for example, with the CFI concept enabling a renewed national focus on a wide range of land management practices that deliver positive Greenhouse Gas Abatement (GGA) outcomes and that avoid perverse landscape outcomes across the nation. Revised legislation related to the CFI will encourage a relationship to regional NRM plans.

Challenges associated with market-based GGA approaches are connected with regionally differentiated landscape management approaches across Australia, and different regions have their own needs, opportunities and constraints when it comes to practice improvements. Responses to climate change also require regionally or even site-specific technical solutions and management approaches (van Oosterzee 2012). Turning these diverse management conditions into a standardised approach, based around national GGA targets and delivered through regional CFI projects provides a governance challenge. In this space, NRM plans, with their capacity to unify stakeholder and scientific knowledge around practice improvement, provide a particularly important opportunity to address local and national needs. Other practices, such as decreasing property risk to cyclone damage, equally need to be benchmarked into planning activities within regions.

Connectivity with broader regional and regulatory planning instruments

Working with relevant regulatory processes such as State or Local Government land use, water resource or vegetation management planning is an important factor in enhancing the ability for regional NRM plans to fulfil their potential in the delivery of good NRM outcomes, particularly for carbon sequestration and biodiversity management (Pannell 2004). While this is a longer-term desired outcome, this new generation of NRM planning presents a renewed opportunity to better align Australian Government policy, regional NRM plans and better-informed regulatory processes. This would enhance and clarify the regulatory NRM responsibilities of state and territory governments, but enable voluntary regional NRM plans to maintain their wide community support.

The current Green Paper on the development of northern Australia envisages a new focus on regional approaches to landscape scale planning (Department of Prime Minister and Cabinet 2014). Additionally, there is an opportunity to ensure regional NRM planning effectively interfaces with Regional Roadmaps that are developed by Regional Development Australia (RDA) Boards (e.g. see Regional Development Australia 2014). These are important developments in the better integration of social, economic and environmental issues at regional scale that may be supported to some degree by the Queensland government. Many regional NRM bodies have already actively integrated their planning and operational efforts with those of RDA Boards and their emerging Roadmap development processes. In the FNQ&TS Region, for example, the strategic priorities of the region's four NRM Bodies directly informed the development of that region's Roadmap (Regional Development Australia 2014). The RDA Board itself sees the strengthening of the regional NRM model and planning approach as being a key strategy in the region's overall development, and particularly important for climate change adaptation processes. A clearer and consistent framework for the integration of next generation NRM plans, Regional Roadmaps and other (particularly local government planning activities) is a logical process improvement, consistent with broader adaptive planning principles, bringing a combined NRM and regional economic and social development perspective to the issue of resource management, land use and climate change adaptation.

Social and community development and building regional GGA literacy

First generation regional NRM plans focused on improving the condition and trend of a region's natural assets but weakly referred to the region's social and community assets (Robinson *et al*. 2009). This was largely driven by a biophysical sciences bias in funding provided for regional NRM planning. Many regions sought to more fundamentally integrate social and environmental issues in their planning processes, rather than just exploring the social and economic impacts of their proposed targets and actions. Next generation NRM plans have the opportunity be more actively focused on viewing social and community resilience alongside ecological resilience concepts. They can also view their regional communities and institutions as important assets requiring integrated effort and investment (Bohnet 2010). This will be a significant challenge as clearer concepts of community resilience to climate change are only just emerging in the literature (see Chapters 6 & 7 of this report), and effective integration between the biophysical and social planning domains remains limited in practice.

Key adaptation planning components within the Wet Tropics Cluster

Strategic aspects of adaptation planning are happening through diverse and separate planning activities at the international, national, state, cluster, regional, local and business scales. The relative health of all of these planning activities needs to be considered in strengthening the governance system for adaptation.

This chapter section outlines the key components of the climate adaptation planning system as it currently operates at various scales. While this section considers a broad range of planning activities from global to property scales, it is aimed to view this through the lens of more regional-scale adaptation planning activities within the context of the Wet Tropics cluster and NRM regions.

International and national scale

At the international scale, a clear governance framework for strategically progressing global climate adaptation has not yet emerged. In terms of cross-governmental international action, climate adaptation tends to be being progressed as a bundle of secondary bargaining issues in the over-all *UN Framework Convention For Climate Change* negotiations (Pielke *et al*. 2007). Because the significant need to focus on reducing greenhouse gas emissions is all-important, to date, these negotiations tend to be focussed on setting climate mitigation targets and strategies (Pielke *et al*. 2007; United Nations 2014). Climate adaptation issues, however, have tended to be raised by less developed nations in an attempt to ensure equity between those nations that have previously experienced the benefit of carbon-intensive development (Stern 2006, Heyward 2007, Jakob and Steckel 2014). Many of these nations are near Pacific neighbours to northern Queensland.

Adaptation governance systems, however, have benefited from the science integration mechanisms that have emerged internationally to inform global discussions. Keogh (n.d.) shows that significant international investment has been directed at research agencies investigating the changing global atmosphere, the causes of those changes, and the likely climatic implications. Keogh (n.d.) suggests that much of this science has been assimilated into publications produced by the Inter-governmental Panel on Climate Change (IPCC), first established by the United Nations in 1988. Since that time, the IPCC has produced several integrative reports that have identified a growing scientific consensus that human activities are resulting in increased concentrations of greenhouse gases more than they would otherwise (IPCC 2013, IPCC 2014). This scientific work has been complemented by international exploration of the impacts of climate change (Parmesan and Yohe 2002, Beyene *et al*. 2010). While conservative at the time, Stern (2006), for example concluded that the potential future economic impact of global warming may be in the order of 5–20% of global Gross Domestic Product (GDP) annually by the latter half of the twenty-first century.

The international community's focus on mitigation compared to adaptation, however, does not mean that global institutions of other kinds are not progressing climate adaptation planning and implementation activities. Few of these activities, however, have had much impact on Australia's interests and obligations with respect to climate adaptation.

At the national scale, some significant approaches to strategically progressing climate adaptation issues were emerging prior to December 2013. In particular, these included:

- Encouragement of adaptation planning and implementation activities at various scales within the context of the National Greenhouse Gas Abatement Strategy and later, the Australian Government's Clean Energy Package (CEP). These frameworks indirectly (e.g. improving the energy resilience of communities) or directly (e.g. supporting the next generation of regional NRM plans) support climate adaptation (see Clayton 2013)
- Via funding and support of strategic knowledge building activities with respect to climate adaptation via the National Climate Change Adaptation Research Facility (NCCARF) and National Environment Research Program (NERP) programs
- Some strategic approaches to climate change adaptation thinking within various Australian Government portfolios (e.g. within the design of drought relief arrangements, etc.)
- Funded support for government aligned think-tanks aiming to raise awareness of climate change and need for proactive adaptation (e.g. the Climate Commission)
- Emerging climate adaptation advocacy within independent national think-tanks (e.g. The Climate Institute) or peak bodies.

Following the change of Government in late 2013, there has been a significant reworking of these key adaptation planning structures at the national scale, with significant implications for climate adaptation in states and regions. Consequently, key developments of national significance include:

- The shift to a direct action approach to dealing with regard to mitigation. Like the CEP, the Direct Action approach can have some significant indirect climate adaptation benefits, but it is more important to note the retained interested in the role of regional NRM planning, the continuation of the CFI and the emergence of new direct action strategies
- A current review and likely rebuild of knowledge building activities with respect to climate adaptation via the NCCARF and NERP research hub processes
- Some continuation of strategic approaches to climate change adaptation thinking within a limited number Australian Government portfolios (e.g. drought relief)
- The shift from government to more civil-society based investment in policy think-tanks (such as the crowd-funding of a revamped Climate Commission) with civil society itself seeking to raise awareness of climate change and the need for proactive adaptation
- Continuing climate adaptation advocacy within national think-tanks (e.g. The Climate Institute) or peak bodies.

The above processes, it should be noted, have tended to have quite limited impacts on state level planning activities with respect to climate adaptation. There is no bilateral framework for taking forward either a climate mitigation or adaptation agenda. There is, however, slightly more impact on regional adaptation planning through the now direct (non-bilaterally negotiated) Australian Government influence over the regional NRM planning and delivery system. Similarly, and consequently, there has been a significant shift in Queensland's state level approaches to climate adaptation planning since the change of government in early 2013. Key changes have included:

- The abolition of the Queensland Office of Climate Change and a greater shift to disaster preparedness and response via the Queensland Reconstruction Authority. More strategic climate adaptation planning that was occurring under the Office of Climate Change has tended to transition towards making contributions to disaster preparedness arrangements
- Before 2013, Queensland's planning system was increasingly being called upon to progress climate adaptation issues (e.g. via Regional Land Use Planning and Coastal Plans). Significant reforms in these areas are likely to see more focus on disaster preparedness, and a streamlining of the system via State Planning Policy and Local Planning Scheme levels
- The Local Government Association of Queensland (LGAQ) remains strongly committed to encouraging and supporting councils across the State to consider climate adaptation issues within their corporate plans, community plans and planning schemes
- Peak bodies and think tanks in Queensland generally do not have a cohesive policy agenda with respect to progressing climate adaptation thinking, but are contributing some effort.

Cluster and regional scale

At the cross-regional scale, it is important to note that an alliance of Regional Development Australia (RDA) Boards across Northern Queensland have identified climate change and the need for adaptation as a significant strategic issues facing the future development of Northern Queensland (Regional Development Australia Fitzroy and Central West, Mackay Whitsunday, Townsville and Central West and Far North Queensland and Torres Strait 2013). The LGAQ is also an important player within this alliance. With limited resources, this alliance is initially focused on major infrastructure issues associated with development (e.g. the Bruce Highway), but the alliance is quite clear that even such infrastructure-focused activities have major climate adaptation benefits.

Within the far northern component of the wider north Queensland region, RDA FNQ&TS has a Roadmap process and plan that identifies climate adaptation as very significant strategic issues for the region. Informed by social resilience benchmarking (see Dale *et al*. 2011), this approach is progressing towards some consensus about high level adaptation priorities for the region, and during 2014/15, it is intended that this strategy will under-pin structured negotiation regarding climate adaptation and disaster preparedness across governments and within state and federal budget cycles. Critical issues being raised and addressed in this context include, for example:

- Reducing infrastructure vulnerability
- Insurance reform
- Natural Disaster Relief and Recovery Arrangements reform
- Improved disaster preparedness systems
- Building business and property-level resilience
- Protection of key natural assets (Wet Tropics and Great Barrier Reef (GBR)).

With respect to the state's statutory planning responsibilities and the link that should be made to climate adaptation, it is worth noting that consideration of climate adaptation strategies was emerging within Strategic Regional Land Use Plans being developed by the state (e.g. Mackay, Isaac and Whitsunday and the Far North Queensland Regional Plans (Queensland Department of Local Government and Planning 2009, 2012). The plans, however, tended to focus solely on the development of a fixed urban footprint, and their continued use and status is likely to be reviewed and reconsidered. Similar current regional statutory planning efforts in Cape York are also focused on strategic land use planning versus climate adaptation.

In terms of landscape scale adaptation, this current revamped generation of regional NRM planning represents the most cohesive approach to climate adaptation planning within the Wet Tropics Cluster. The link to strategic climate science within the Wet Tropics Cluster is also clear, though most planning activities are likely to be completed before the middle of 2015. Specific attention to climate adaptation planning within the economic development and human services sectors are very limited. Some consideration to climate adaptation planning within the tourism and agriculture sectors is emerging, though not yet in a cohesive fashion. Additional regional scale research related to climate change is also occurring through NERP funding via the auspices of the Reef and Rainforest Research Corporation (RRRC). These efforts are closely connected to the Wet Tropics Cluster, and it is likely that this work will strongly influence the next generation of NERP funding (due mid 2015).

At the sub-regional effort, specific attention needs to be paid to the climate adaptation planning efforts emerging in the Torres Strait. This work has been broadly underpinned by a NERP-funded project being delivered by CSIRO (Project 11.1 - Building resilient communities for Torres Strait futures). As a consequence, during July 2014, the Torres Strait Regional Authority undertook a major workshop that will see this roll into a long term adaptation planning process.

Local government scale

There has been much realignment in local government opportunities to progress climate adaptation planning in the last two years:

- Both the Whitsunday and Far North Queensland Regional Organisations of Councils are aware of climate change risks, but have not been yet able to progress cohesive strategy development to support local government-led adaptation planning. The Cape York and Torres Regional Organisation of Councils is only just emerging at this stage
- Corporate Plans are high level strategic direction setting documents for councils that have the capacity to be used to help position and mobilise climate adaptation issues, but few Council Corporate Plans within the region identify climate adaptation as a significant challenge. In short, the culture of corporate planning activity tends to be focused on the strategic business of councils and to have a broader focus on service delivery issues, but there is nothing to stop them being used effectively to drive major adaptation efforts
- Until recently, Community Plans were a legislative requirement for councils, and over the last five years, there has been significant council-scale activity on this front. Community-scale planning activities were regularly identifying the need for climate adaptation and disaster preparedness as a significant community priority. The state government, however, no longer requires the development of Community Plans
- Council planning schemes (including specific recognition of State Planning Policies and Regional Land Use Plans) remain the key vehicle through which strategic climate adaptation effort is progressed within councils within the Wet Tropics Cluster. More often than not, this effort is generally restricted to a broad spatial recognition of the potential disaster-related risks, and these are subsequently factored into future land use planning considerations.

Local area and catchment scale

While there are few statutory or other programmatic obligations requiring climate adaptation planning at the catchment or local scale in the Wet Tropics Cluster, there are a number of initiatives at those scales that can potentially be used to great effect for such purposes. Currently at the Wet Tropics Cluster level, such planning related activities include:

- *Water Resource Plans (WRPs):* WRPs developed under Queensland's *Water Act 2000* do need to (and often do) consider the implications of climate change when deciding how to allocate water for environmental and consumptive purposes. This is relevant to the Gulf, Wet Tropics, Mackay Whitsunday and Cape York water resource planning processes
- *Catchment Plans:* Several community groups have taken a leadership role, often with support from Regional NRM Bodies, in catchment scale planning that has the capacity to address climate adaptation issues. Water Quality Improvement Planning being carried out across the Great Barrier Reef (GBR) catchments represents one such planning effort

- *River Planning*, often undertaken by River Improvement Trusts, is often specifically focused on reducing the flooding impact of various river systems within the Cluster Area, and hence explicitly needs to consider climate change predictions within the region. Such planning, however, is not cohesively undertaken across the Wet Tropics Cluster
- In biodiversity terms, experiments in local area planning have been strategically applied in biodiversity hot spot (e.g. Terrain's Mission Beach Habitat Network Action Planning) within the Cluster area, enabling another form of local-scale adaptation planning (see Hill *et al*. 2010).

Business and property scale

There is an increasing literature on understanding the resilience of companies, families, and individuals to climate change (e.g. effort at the business and property scale). Strategic planning effort (e.g. vision and objective setting and strategy development) is just as crucial at business and property scale as it is at the regional, state and national scales. Indeed, there is some anecdotal evidence that many businesses and properties are not well prepared for risks associated with climate change-related events. Despite this, wider policy and programmatic efforts to increase support for building resilience and enabling people to plan to undertake adaptation actions are quite fragmented, but still need to be considered. Within the Wet Tropics Cluster, some include:

- programs, often run through regional economic development organisations and state agencies aimed, in a general way, at increasing business resilience
- programs, often run through not-for-profit human service providers, local councils and state agencies aimed, in a general way, at increasing family and individual resilience
- a fragmented offering of support (combined with some regulatory obligations) for the development of property management plans at property scale
- some emerging consideration among insurance providers that strategic risk assessments might enable or facilitate cheaper insurance premiums within northern Queensland.

How healthy is the adaptation planning system?

There are several key areas of adaptation planning reform that may be within the realm of reasonable influence for regional NRM bodies in the Wet Tropics.

While the above section outlines the current arrangements for adaptation planning as they relate to the Wet Tropics Cluster, this section applies a rapid appraisal technique adapted from Dale *et al*. (2013b). Dale *et al*. (2013b) aim to analyse the combined impact of both structural and functional aspects of governance systems on overall system outcomes. This technique is particularly useful in undertaking rapid appraisal of governance systems, and it can enable a focus in on either the more strategic (planning) or implementation (delivery) aspects of governance. The technique also enables an integrated assessment of governance in terms of how it operates across various scales. In this instance, we are specifically exploring the governance domain of climate adaptation and within that context, we focus on strategic planning aspects of this system related to the Wet Tropics Cluster. Doing so, however, requires us to contextualise climate adaptation planning activities at scales above and below the Wet Tropics Cluster, inclusive of state, national and international scales.

The technique enables the rapid appraisal and description of both structural and functional aspects of the climate adaptation planning system, and then by considering a simple rating of risk, it enables an informed discussion about the health or otherwise of the system. This is useful, as it helps discussion about whether the system is likely to deliver genuine adaptation outcomes. While Table 8.1 outlines the guiding analytical prompts used to describe the system, Table 8.2 outlines the very specific criteria used to assess the risk of the system failing to deliver the required climate adaptation outcomes. The results are not intended to deliver definitive measures, but provide a simple basis for an informed discussion about the health (or otherwise) of the system.

Table 8.1 Typical analytical points of inquiry applied in describing the system of planning for climate adaptation as it relates to the Wet Tropics Cluster.

FUNCTION/STRUCTURE	DECISION-MAKING CAPACITY	CONNECTIVITY	KNOWLEDGE USE
Visioning and Objective Setting	• Do capacities exist to set higher aspirational or condition targets? • Do the relevant stakeholders have the knowledge, financial, human and infrastructure resources required? • Do key institutions involved have strong corporate governance/ continuous improvement systems?	• Are relevant stakeholders actively connected to decision-making? • Are visions and objectives aligned to higher and lower scale visions and objectives? • Are collaborative frameworks for setting visions and objectives well designed? • Are there frameworks for bargaining and negotiation over setting visions and objectives?	• Are all forms of information available for vision and objective setting? • Are traditional and historical knowledge sets being applied? • Are appropriate decision support tools in place to support scenario analysis?
Research and Assessment	• Are there strong research and analysis capacities in place to inform other structural components of the system? • Are there strong environmental, economic and social research and analysis capacities in the system?	• Are there strong collaborative linkages between research institutions? • Are there effective research brokerage and communication arrangements between research provider and end user stakeholders? • Are collaborative arrangements in place to integrate social, economic and physical research?	• Are there systems in place for long term research synthesis and knowledge retention? • Are there broad research priority setting exercises that need to be refined? • Are all forms of information available for system decision making?

FUNCTION/STRUCTURE	DECISION-MAKING CAPACITY	CONNECTIVITY	KNOWLEDGE USE
Strategy Development	• Do capacities exist in the system to set clear strategic targets? • Do relevant stakeholders have the knowledge, financial, human and infrastructure resources available to make the decisions required? • Do the key institutions involved have strong corporate governance and improvement systems?	• Are all relevant stakeholders connected to strategy decision-making? • Are strategies aligned to visions and objectives? • Are strategies aligned to higher/lower scale strategy development? • Are collaborative frameworks for setting strategies well designed? • Do strategies integrate an appropriate solutions mix?	• Is there social, economic and environmental knowledge relating to the assessment of the efficacy of key strategies? • Are decision support tools available to scenario test alternative strategies?
Implementation	• Are there capacities to implement a broad mix of strategic solutions? • Do the implementation players have the financial, human and infrastructure resources to implement plans? • Do the key institutions involved have strong corporate governance and improvement systems?	• Are there effective partnership and integration arrangements between policy and delivery systems? • Do different components of the solution mix collaborate? • Are there effective research brokerage arrangements to support implementation?	• Are there research efforts to inform continuous improvement in implementation? • Are local and traditional knowledge sets informing implementation? • Are effective data sets concerning implementation being managed and retained?
Monitoring, Evaluation and Review	• Are there effective monitoring and evaluation capacities in the system? • Are there collective monitoring alliances in place? • Are there defined and independent evaluation capacities in the system? • Are there reporting capacities to enable high levels of accountability?	• Are there integration arrangements between objective setting and monitoring systems? • Are evaluative and review mechanisms linked to long term monitoring? • Are monitoring and reporting systems able to influence strategic processes and the allocation of resources?	• Are social, economic and environmental outcomes from the system being monitored? • Are monitoring and evaluation data being retained into the long term?

Once characterised in structural/ function terms (using Table 8.1), the climate adaptation system can then be assessed in terms of its health, determining how likely it would be that the system would deliver climate adaptation outcomes enabling communities to adapt in the face of climate change. The rating rules applied in determining system health at various scales are outlined in Table 8.2.

Table 8.2 The rating scale applied in determining the health of the climate adaptation planning system

HEALTH RATING	DECISION RULE
5	The planning system is in excellent overall health and will not to fail to deliver its intended system outcomes.
4	The planning system is in good overall health and is not likely to fail to deliver its intended system outcomes.
3	The planning system's health is on a knife's edge and could fail or succeed in delivering its intended system outcomes.
2	The planning system is in poor overall health and likely to fail to deliver its intended system outcomes.
1	The planning system is dysfunctional and will fail to deliver its intended system outcomes.

Assuming that the intent of the climate adaptation planning system is to support nations, states, regions, councils, communities and businesses to adapt, based on the application of the guides in Table 8.1 and Table 8.2, our broad first cut assessment of the system is outlined below in Table 8.3.

In summarising the key results emerging from this analysis, it is worth noting that while there are some parts of the system that are in relatively good health (e.g. at the catchment scale), while overall, most parts of the system remain at the suggested ratings, they are not likely to deliver the climate adaptation responses needed at different scales that would enable communities to prosper under the climate change projections currently expected for the Wet Tropics (e.g. increased frequency of intense cyclones, deeper wet and dry cycles, increased sea level rise, etc.). In particular, insufficient leadership and action at the international, national and state levels are delivering ineffective outcomes at regional and local scales, particularly in the important fields of land use planning. Some real steps in adaptation at the business and property scale are tending to emerge where major climate-related disasters have already sparked adaptation actions at that scale. While positive, these efforts represent responsive rather than proactive approaches to climate adaptation.

Table 8.3 A summary of structural/functional analysis of planning systems for climate adaptation at various scales with an influence in the Wet Tropics Cluster

ADAPTATION PLANNING SCALE	STRUCTURAL CONSIDERATIONS	FUNCTIONAL CONSIDERATIONS	OVERALL HEALTH RATING
International Scale	• Overall international strategic framework for climate change management remains focused on mitigation versus adaptation, though adaptation issues have increasingly emerged in international negotiations. • No clear global climate change adaptation framework, plan and associated strategies. • Some key strategic areas of global policy and strategy reform exist. • No clear international global frameworks for monitoring national improvements in climate resilience at all scales.	• International capacity for strategic approaches to climate adaptation are fragmented and generally too centralised for effective engagement. • Some research and development funding arrangements support climate adaptation exist, particularly in developing countries. • Some strong areas of cross-national cooperation exist that are focused on supporting climate adaptation among near neighbouring countries.	2.5
National Scale	• Overall national strategic framework for climate change management remains focused on mitigation versus adaptation. • No clear national climate change adaptation plan and associated strategies. • Some key strategic areas of significant policy and strategy reform exist (e.g. emerging new support for regional NRM planning effort, drought relief reform, etc.). • No national frameworks for monitoring improvements in climate resilience at all scales.	• National capacity for strategic approaches to climate adaptation are fragmented and generally too centralised for effective engagement. • Decline of NCCARF arrangements and centralisation of NERP structural arrangement have potentially weakened national policy effectiveness. • Some Australian capacity is focused on supporting climate adaptation among near neighbouring countries. • Systems for national management of key data sets (climate, water, biodiversity, etc.) have improved, but are tend to be fragmented by sector.	2

ADAPTATION PLANNING SCALE	STRUCTURAL CONSIDERATIONS	FUNCTIONAL CONSIDERATIONS	OVERALL HEALTH RATING
State Scale (Queensland)	• State strategic approach and activities in disaster preparedness and response has dramatically improved following several disastrous climate events since 2006. • Strategic effort on broader scale adaptation has not yet fully emerged and is represented by a fragmented set of strategic efforts (e.g. insurance reform). • State has no strong strategic policy focus on landscape-scale climate adaptation. • No framework for state level monitoring of moves towards improved resilience to climate change or climate disasters.	• Capacity in some aspects of climate adaptation have improved (e.g. disaster response systems) while others have fragmented and declined (e.g. landscape scale NRM and land use planning policy frameworks). • Low levels of connectivity between disparate climate adaptation efforts (e.g. disaster response, insurance reform, business resilience building). • Data and information systems for flood, cyclonic and storm surge events have dramatically improved, while state investment in social adaptation has declined in recent years. Knowledge building effort is focused in disaster preparedness versus adaptation.	2
Cluster Scale	• Coordinated strategic approach to regional NRM planning is emerging, as one fully integrated Wet Tropics Cluster planning effort not necessary at this level. • Emerging monitoring and evaluation of impact of regional scale adaptation planning in improving climate adaptation outcomes, including social resilience benchmarks emerging within FNQ&TS region.	• Strong interconnectivity between FNQ and Mackay Whitsunday regions at strategic level through northern Queensland strategy approach. • Coordinated and combined approach to regional NRM planning well connected across the Cluster through collaborative effort among regional NRM bodies. • Much increased science-knowledge base through Wet Tropics Cluster and ongoing NERP investments. • Some stronger Cluster scale planning in context of Wet Tropics and GBR World Heritage Planning.	3

ADAPTATION PLANNING SCALE	STRUCTURAL CONSIDERATIONS	FUNCTIONAL CONSIDERATIONS	OVERALL HEALTH RATING
Regional Scale	• Higher level strategic and effort alignment approach to regional scale adaptation via RDA framework in FNQ&TS and linked to Mackay Whitsunday region. • Revitalised strategic approaches to landscape scale adaptation planning in NRM field, but decline in such activity from a regional land use planning viewpoint. • Limited monitoring and evaluation of impact of regional scale adaptation planning in improving climate adaptation outcomes, though social resilience benchmarks are emerging within FNQ&TS region.	• Improved strategic capacity in regional NRM planning has been undermined by a weaker state/federal mandate concerning role of regional NRM plans. • Potential to better integrate regional NRM adaptation with regional land use planning has declined. • Knowledge base for regional NRM and land use planning has dramatically improved through Wet Tropics Cluster grouping, NERP-funded Reef and Rainforest Research Centre RRRC efforts and improved spatial information layers.	3
Local Government Planning	• Limited local government strategic focus on climate adaptation in corporate plans/ planning schemes. • With limited higher level policy vision for climate adaptation, adaptation strategies generally limited to infrastructure and high risk land uses. • Implementation limited to high risk infrastructure and land use regulation delivery mechanisms. • No clear framework for monitoring increased resilience to climate change.	• Community and corporate plans and planning schemes now disconnected. • Regional NRM plans now have more limited on planning scheme influence. • Regional Land Use Plans increasingly influence planning schemes, but less focused on climate adaptation. • Local government planning still poorly linked to regional climate science.	2

ADAPTATION PLANNING SCALE	STRUCTURAL CONSIDERATIONS	FUNCTIONAL CONSIDERATIONS	OVERALL HEALTH RATING
Catchment River and Local Area Planning	• Water Quality Improvement Planning and Water Resource Planning set a strong strategic framework for quality and quantity issues associated with climate change. • Strong delivery mechanisms exist through Resource Operating Plan and Reef Rescue/ Reef Plan implementation models. • More effective monitoring arrangements regarding quantity and quality issues have emerged in recent years, • Strategic and delivery framework for systemic improvements in rivers to minimise disaster risk and maintain river health remain limited. • Strategic approaches to Local Area Planning in biodiversity hotspots show great potential, but implementation and monitoring may be limited by more centralised governance models on NRM programs and R&D frameworks.	• Strong research and development frameworks for water quality and quantity issues have emerged throughout the cluster area. • Similar capacities exist with respect to Local Area Planning and biodiversity. • Capacities for integrated social and development planning at catchment/ mill scale are improving, but suffer from lack of dedicated support frameworks. • Connectivity between Water Resource Planning, Water Quality Improvement Planning, Catchment Planning and River Improvement Planning and local Land Use Planning remains fragmented. • Capacity of regional NRM bodies and local councils to undertake such planning over longer timeframes has diminished recently due to centralisation of NRM programs.	3
Business and Property Scale	• Some major cyclonic events in the Wet Tropics have forced significantly improved strategic approaches to business and property-scale adaptations. • Overall, key strategic planning and subsequent implementation for supporting business and property-scale adaptation remains under-developed. • Very limited monitoring of business and property-scale strategic approaches to climate adaptation in Wet Tropics Cluster.	• Capacity for business and property-scale adaptation planning has improved in some key parts of the Wet Tropics Cluster, but overall strategic capacity at that scale remains low. • While there is much greater integration of effort and connectivity in disaster recovery arrangements, proactive support-based approaches are weak. • Information systems associated with support for business and property scale resilience planning are improving, particularly through regional development programs, RRRC efforts, spatial information hubs and the Wet Tropics science engagement cluster.	2.5

Recommendations

The following core recommendations are based on some of the opportunities and challenges raised previously and the structural/ functional health analysis outlined above. These recommendations are focused on what regional NRM bodies (given their current fractured mandates and limited resources) can do to progress the system of climate adaptation planning within the Wet Tropics.

- Encourage state and federal bilateralism for new approaches to regional land use planning and regional NRM planning focused on climate adaptation (e.g. via combined NRM body responses to the current Green Paper process on the development of northern Australia)
- Encourage the state to reinvigorate regional land use planning In the Wet Tropics and Mackay Whitsunday regions to focus on climate change responses/disaster preparedness
- Build alliances with northern Queensland RDAs in working towards a strong "whole of north Queensland" and an FNQ&TS approach to progressing climate adaptation
- Seek to sure up the best possible regional spatial priorities for adaptation over the current phase of next generation development of regional NRM plans
- Build alliances with the FNQ and Whitsunday Regional Organisation of Councils (ROCs) to build council capacity to integrate climate adaptation into corporate and community plans and planning schemes
- Continue to build upon current strengths in the current system of adaptation planning related to catchment management, but better integrate water resource, river improvement and water quality improvement planning
- Continue to trial and evaluate Local Area Planning Approaches to managing biodiversity hotspots facing significant climate change risks
- Take a combined and strategic lead regionally in building a range of long term, targeted and measurable delivery programs aimed at increasing business and property scale resilience in the face of climate change in the Wet Tropics Cluster
- Secure programmatic investment in business resilience planning for climate adaptation; and
- Trial the development of an agreement with the state government aimed at working together towards more integrated property planning.

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9. Evolving methodology for identifying climate adaptation pathways and options

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IN A NUTSHELL
• A 'co-research' approach involving multiple scientific disciplines and genuine collaboration between researchers and NRMs is critical. • Participatory planning approaches are essential to the development of useful adaptation plans. • Social network analysis is a useful means of identifying key actors, networks and institutions for collaboration.

Precis

This chapter provides an update on progress from the 'Participatory Scenarios and Knowledge Integration Node' of the Wet Tropics Cluster (WTC) region. Since the first workshop, led by the 'Participatory Scenarios and Knowledge Integration Node' in April 2013, members of this research node, in collaboration with the natural resource management (NRM) organisations, have initiated a wide range of research activities, based on the findings from this workshop and discussions with the four NRM organisations of the Wet Tropics Cluster. Appendix B summarises these transdisciplinary research activities, some of which are completed, while others are in progress. Our transdisciplinary research is showing that, based on the differences identified in the initial workshop with members of the Brokering Hub and discussions with staff of the four NRM organisations, the research needed to support these four NRM organisations in their planning for climate change differs considerably. This is not only a reflection of the differences between the four NRM regions in their biogeography, demography, and governance but also a reflection of past and current research activities carried out in these four NRM regions such as through the National Environmental Research Program (NERP) and the Rural Industries Research and Development Corporation (RIRDC). The key messages associated with each of the topics addressed in this chapter are:

TOPIC	KEY MESSAGES
Evolving methodology	143. The co-research approach, i.e. the Brokering Hub and the co-research cycle, is critical to the success of the Wet Tropics Cluster project. 144. Research (synthesis) needs to be driven by the NRM organisations of the Wet Tropics Cluster, and needs broad stakeholder support to facilitate development of 'no regrets' adaptation strategies. 145. Transparent and open communication is critical for improving understanding about issues and supporting learning among Brokering Hub members (and among staff of the four NRM organisations). 146. The research approaches and methods taken by the 'Participatory Scenarios and Knowledge Integration Node' need to be flexible, adaptable and tailored to the needs of each of the four NRM organisations.

TOPIC	KEY MESSAGES
	147. Research syntheses need to involve careful processes of translation across the 'boundaries' between the "knowledges" of research and practice. 148. Close collaboration among researchers of different scientific disciplines, NRM staff and stakeholders within the NRM regions is critical to identification of adaptation pathways and options.
Adaptation pathways and options	149. Identification of climate adaptation pathways and options requires participatory approaches and collaboration with stakeholders representing the broad interests and sectors across the NRM region. 150. Social network analysis (SNA) can assist in the identification of key actors, networks, and institutions that are important to collaborate with. 151. Participatory scenario planning is a powerful tool to engage multiple stakeholders in identifying adaptation pathways and options to address climate change and other key drivers of change in the region.

Introduction

In April 2013 the 'Participatory Scenarios and Knowledge Integration Node' led a half-day workshop with members of the Brokering Hub to identify the key issues and drivers of change in the four NRM regions based on the knowledge and experiences of the members of the Brokering Hub (Stream 1 and Stream 2). The outcomes of this workshop were delivered to the Australian Government in a Milestone report in May 2013 and informed the research of our node (Bohnet *et al*. 2013). In Appendix B we provide an overview of all the activities undertaken by members of our Node. In subsequent sections we describe the activities in more detail and provide the rationale for each of the activities.

The aim of this chapter is to illustrate how the various activities carried out by our research node support NRM planning for climate change. In particular, we aim to show how participatory scenario planning can support transdisciplinary research activities and enables identification of different types of knowledges, knowledge integration, and building of adaptive capacity.

Adapting to the impacts of climate change – how science informs NRM planning for climate change

Scientists and NRM practitioners working together in a Brokering Hub

The co-research approach, i.e. the Brokering Hub and the co-research cycle, is critical to the success of the Wet Tropics Cluster project.

A prerequisite and critical to the success of the Wet Tropics Cluster (WTC) project is this innovative co-research approach that has been taken by the project team, and the establishment of the Brokering Hub at the beginning of the project (see Chapter 1, Figure 1.2). The co-research cycle adopted includes stages that provide for: system analysis; processes and tools to support knowledge translation and integration; and updating through social learning (see Chapter 1, Figure 1.3).

Participation in regular meetings of the Brokering Hub is critical to the research carried out by the 'Participatory scenarios and knowledge integration node' since its research is largely driven by the needs of the NRM organisations (Bohnet *et al*. 2013). However, participation in Brokering Hub meetings is also critical as a means to reach an improved understanding of the science, approaches and methods, e.g. landscape approach, social network analysis, participatory scenario development, that may be useful in assisting the NRM organisations in their planning for climate change. In addition, participation in the Brokering Hub also enables the 'Participatory Scenarios and Knowledge Integration Node' to gain a better understanding of the research carried out in the other research nodes and to support and capitalise on their research activities (connection between the 'Participatory Scenarios Node' and other research nodes via Brokering Hub shown in Figure 1.2). For example, members of the 'Participatory Scenarios and Knowledge Integration Node' contributed substantially to, and thereby supported, the research carried out by the 'Science Synthesis Node' (Hilbert *et al*. 2014). At the same time, the 'Participatory Scenario and Knowledge Integration Node' used extracts from the suite of key messages from the science synthesis report (Hilbert *et al*. 2014) in a participatory scenario planning workshop (Bohnet and Bell 2014) to inform workshop participants.

The co-research cycle (Chapter 1, Figure 1.3) is based on recognition that 'knowledges' generated under different disciplinary matrices, and under research or practice settings, are of different kinds and that any joint use will require careful processes of translation across the 'boundaries' between knowledge systems (Vatn and Vedeld 2012). Processes of conscious boundary management that include knowledge co-production, mediation, translation, and negotiation have been identified as necessary to build integrated knowledge for generation of adaptation pathways and sustainability solutions (Cash *et al*. 2006). A growing body of research has emerged that analyses boundaries and boundary work to link different knowledge domains in sustainability science (Robinson and Wallington 2012). Our cycle is based on the six stages identified by Hill *et al*. (2010) which emphasises the need to pay attention to tools for developing knowledge integration and shared understanding. In addition to the participatory scenarios, cultural mapping and social network analysis (SNA), the ongoing discussions at the Brokering Hub are critical to identifying issues of knowledge translation and boundary management.

Workshop to identify key issues and drivers of change in the Wet Tropics Cluster NRM regions

Research (synthesis) needs to be driven by the NRM organisations of the Wet Tropics Cluster, and needs broad stakeholder support to facilitate development of 'no regrets' adaptation strategies.

Transparent and open communication is critical for improving understanding about issues and supporting learning among Brokering Hub members (and among staff of the four NRM organisations).

One of the initial steps that need to be taken in the process of identifying climate adaptation pathways and options is identification of key issues and drivers of change. A workshop, led by the 'Participatory Scenarios and Knowledge Integration Node' was organised with the members of the Brokering Hub to identify key issues and drivers of change in the four NRM regions of the WTC region. This workshop provided the opportunity for scientists and managers to work together and to get a better understanding of the key issues and drivers of change in the four NRM regions of the Wet Tropics Cluster. The output from this workshop was a milestone report delivered to the Australian Government. The outcomes of this workshop (Bohnet *et al*. 2013) informed the research synthesis that has been and is currently carried out by the 'Participatory Scenarios and Knowledge Integration Node'.

Synthesis of climate change knowledge and planning practices of the Wet Tropics Cluster NRM organisations

The research approaches and methods taken by the 'Participatory scenarios and Knowledge Integration Node' need to be flexible, adaptable and tailored to the needs of each of the four NRM organisations.

To establish a baseline about current climate change knowledge in the four NRM organisations and their planning practices, our science node carried out a review of relevant documents, which the NRM organisations provided. To supplement the review and clarify questions that arose from the review, we conducted interviews with NRM staff members. The output from this research, a milestone report, was delivered to the Australian Government (Lyons *et al*. 2013). The outcomes, five key messages, were presented to the NRM organisations in a Brokering Hub meeting and the report (Lyons *et al*. 2013) was made available. These five key messages further informed the research in our science node.

Contribution to research led by other research nodes

Research syntheses need to involve careful processes of translation across the 'boundaries' between the "knowledges" of research and practice.

Close collaboration among researchers of different scientific disciplines, NRM staff and stakeholders within the NRM regions is critical to support identification of adaptation pathways and options.

The first science synthesis report (Hilbert *et al*. 2014) responded to a list of 'Priority science deliverables' initially prepared by the NRM organisations during the development of the project proposal, and subsequently updated through the Brokering Hub (Appendix A, Volume 1). The structure of the report was framed by this needs analysis, and lead authors were asked to direct their synthesis to these topics. Nevertheless, the evaluation conducted at the Brokering Hub meeting identified that authors did not include key information that was requested, and that insufficient review and interaction occurred around the document. Key authors on the other hand identified that meeting the exact requirements of the NRM groups would require a multi-year research program rather than a synthesis from a body of science largely driven by other needs. This again highlights the requirements for careful translation and management across the knowledge boundaries between research and practice.

Researchers from our science node contributed substantially to the science synthesis report (Hilbert *et al*. 2014) as outlined in Appendix B. This report was a major project deliverable to the Australian Government and our four NRM collaborators. While the preparation, coordination and writing of these chapters was a time-consuming exercise it provided opportunities for collaboration amongst WTC researchers from the different science nodes and additional researchers from outside the project with specific expertise relevant to the research of the WTC project. Special attention was paid to the specific issues associated with knowledge integration across Indigenous and western world-views. The outputs, i.e. extracts from the key messages from each of the chapters, have already been displayed during scenario planning workshops in the Reef Catchments NRM region and will further inform the research in our node. Overall, the science synthesis report improves our understanding of the science that can support NRM adaptation planning for climate change.

To improve communication and co-ownership of key messages from the science synthesis report within the NRM groups, a brochure was developed in collaboration with the NRM groups, led by Ro Hill and Cath Moran from the science team (Hilbert *et al*. 2014b), also outlined in Appendix B. Science teams provided the key messages and the NRM groups provided most of the images, and influenced layout and design.

Cultural Heritage Mapping and participatory scenario planning with Traditional Owners in the Reef Catchments NRM region

Identification of climate adaptation pathways and options requires participatory approaches and collaboration with stakeholders representing the broad interests and sectors across the NRM region.

Engagement with a broad range of stakeholders, sectors and community groups is essential for developing effective 'no regrets' adaptation pathways. For some groups who may be disadvantaged and have a reduced capacity to engage in collaborative adaptation planning opportunities (e.g. some Traditional Owner groups), additional effort may be required to ensure their needs and perspectives are incorporated into adaptation planning processes. This case study, initiated by Reef Catchments and our research node, consists of two components: a land use and occupancy mapping exercise (cultural heritage mapping) and an adapted scenario planning activity. The aim of this case study is to explore and critically assess the appropriateness of planning and community engagement tools to integrate knowledge, and include Indigenous cultural values, into regional planning. An Indigenous-driven process has been adopted as Indigenous driven processes have demonstrated greater capability for including Indigenous perspectives and protection of Indigenous intellectual property (Christensen and Grant 2007; Hill *et al*. 2012; Sillitoe and Marzano 2009).

Participatory Cultural Heritage and Land Use and Occupancy Mapping

Participatory mapping is a general term for gathering and mapping spatial information to help communities learn, discuss, build consensus, and make decisions about their communities and associated resources. The participatory cultural heritage mapping exercise will involve researchers who support the Traditional Owners to collect, depict, and interpret new information to assist them and Reef Catchments NRM to make resource management decisions.

Participatory mapping is a powerful tool that increases Traditional Owner involvement and provides a means for participants to express their ideas in an easily understandable visual format. Participatory mapping has previously been used in the following ways:

- to create maps that represent cultural resources, community values, perceptions of alternative scenarios and usage
- to gather traditional knowledge and practices for assessment or monitoring
- to identify data gaps
- to inform other data collection methods (e.g. formal surveys, interviews, planning workshops)
- to facilitate the decision making process
- to empower stakeholders in resource negotiation processes
- to conduct trend analyses.

Participatory mapping can simultaneously provide:

- a way to engage Traditional Owner groups near and far
- objective local information on resources
- a means to strengthen traditional knowledge and practise from their Traditional Owner group(s)
- information on how Traditional Owners perceive, value and use these resources
- a focal point for discussion on climate change impacts and other issues/impacts on cultural heritage
- a valuable tool to support decision making
- graphical and easily understandable communication tools.

In the land-use use occupancy mapping Traditional Owners define what they want to map and the information they make public. The aim of the mapping exercise is to show the different ways that people are connected to particular features of their country and to draw the boundaries of that country. The types of information that can be mapped include use of and access to country, such as fishing, camping, art and story sites and historical use of land. Mapping can enhance engagement with other stakeholders, to visualise issues and resources and stimulate discussion.

Participatory Scenario Planning On-Country

Participatory scenario planning follows the cultural heritage mapping exercise. The maps will be the basis for discussion with the Traditional Owners to discuss their values of their country and develop scenarios and adaptation options for their country.

One of the key attributes of participatory scenario planning is the involvement of multiple stakeholders in the scenario development process (Albert *et al*. 2012; Bohnet 2010; Bohnet *et al*. 2011; Johnson *et al*. 2012). While this is critical for robust participatory scenario outcomes, the inclusion of Indigenous knowledge may require its own process for several reasons. These include adaptation of tools to support: Indigenous ways of communication and representation especially cultural values and connection to country; Indigenous interpretation and meaning that is based on Indigenous ways of knowing; negotiation of consensus which may require different types of agreement based on governance arrangements; alternative perspectives of time and scale; and recognition of Indigenous interests in the engagement process. This case study will use an Indigenous driven process to explore the capability of participatory scenario planning to address the Indigenous perspective.

Outputs from this case study will include a combination of the following: Traditional Owner approved maps of country, cultural heritage maps for the Traditional Owners, Traditional Owner vision or plan for country that include adaptation options, narratives and stories. A journal article and summary results sheets, for the Brokering Hub members and the Traditional Owner group, will be published from this work.

This case study will offer a unique approach to incorporating an Indigenous driven process and perspective into regional NRM planning. Through this research we will identify conditions, approaches and processes that support or limit the integration of Indigenous knowledge into a regional NRM governance setting.

Social Network Analysis

Social network analysis (SNA) can assist in the identification of key actors, networks, and institutions that are important to collaborate with.

This social network analysis (Ahammad *et al*. 2013) case study, initiated by Terrain NRM and our research node, takes a broad structural view of knowledge integration in biodiversity management. This research investigates how knowledge and information is negotiated and brokered among conservation actors, at the broader structural network level. The SNA will be based on the institutional arrangements and contributions of different types of knowledge to biodiversity connectivity in the Terrain NRM region.

The aims of the SNA are to investigate and document:

- the relational structural arrangements that support on-ground works for biodiversity
- the types of relationships that support particular types of knowledge that contribute to biodiversity connectivity
- the sharing of knowledge and the use of different types of knowledge that support decision-making
- gaps and opportunities to improve collaboration in the knowledge networks to support effective biodiversity outcomes.

This project will investigate how different types of knowledge are shared and used to support decision-making for biodiversity management in the Wet Tropics Cluster region.

SNA is becoming a recognised and accepted tool to examine relationship ties and types of interactions that occur among actors in NRM (Bodin *et al*. 2011; Janssen *et al*. 2006). SNA can identify exchange and connections among stakeholders that occur through institutional arrangements, information paths and resource relationships (Bodin *et al*. 2011; Hahn *et al*. 2006). An understanding of the interactions between organisations can improve our knowledge of how governance arrangements influence NRM in each region, the types of bonds and bridging relationships between agencies, and improve the ability of agencies to identify opportunities to invest resources effectively for biodiversity outcomes. An understanding of the structural relations in a network can provide clarity about the knowledge and power interactions that shape those relations and elucidate areas where action can be taken to reduce vulnerability (Weiss *et al*. 2012).

This work will focus on the knowledge relationships, as well as the quality of knowledge engagement, between agencies contributing to biodiversity in the Wet Tropics Cluster region. Increased biodiversity is a strategic NRM outcome for Terrain NRM. The SNA will be conducted in the Terrain NRM region and will explore how different actors in conservation work contribute to governance of biodiversity connectivity. This case study will complement the completed spatial strategic offset corridor maps developed by Terrain NRM. At least three strategic corridors will be targeted for this work, a coastal, peri-urban and hinterland area, based on Terrain NRM's off-set corridor maps.

Identification of an initial set of key actors involved in on-ground biodiversity corridor work will be completed with Terrain NRM staff. This will be followed by a snowball selection method. The case study will engage actors operating at different NRM scales, including industry, Traditional Owner groups and property owners.

The SNA will occur at the institutional level and will involve several stages:

1. scoping of the social network analysis with Terrain NRM based on their NRM program and their strategic offset corridor spatial maps
2. exploratory qualitative exercise, focus groups sessions with some of the stakeholder groups on information sharing and their decision networks to guide development of the quantitative survey (spatial map will be used to determine which groups to meet)
3. discussion of the findings and the development of the survey with Terrain NRM
4. development of a survey that will form the basis of mapping the social network of biodiversity corridors
5. pilot test and adjust questionnaire as required
6. conduct the SNA survey, through meetings and phone conversations
7. development of the social network using exponential random graph modelling
8. review of the initial findings with Terrain NRM and supervisor to design the second stage of the study, a qualitative survey
9. pilot test then conduct focused qualitative survey on particular relationships in the network to identify how knowledge is negotiated, exchanged, translated, and/or transformed and any interactions between scales
10. review of findings with Terrain NRM and supervisor and discuss implications for NRM planning for climate mitigation
11. write up results – report and paper.

The outputs from this case study will include:

- a journal article
- summary report for Terrain NRM and participants, where requested
- recommendations for actions that will strengthen decision-making and knowledge sharing for biodiversity management.

Outcomes include:

- improved understanding of the key variables that influence, and can acted on to, to build on the benefits from existing biodiversity offset corridors
- improved planning and engagement strategies in the NRM community for effective biodiversity management.

Scenario planning workshops in the Reef Catchments NRM region

Participatory scenario planning is a powerful tool to engage multiple stakeholders in identifying adaptation pathways and options to address climate change and other key drivers of change in the region.

A series of regional stakeholder workshops were held in collaboration with Reef Catchments NRM to assist with their incorporation of climate change adaptation measures into their updated NRM plan. Earlier Brokering Hub meetings with NRM representatives had identified a range of issues relevant to the NRM region that would affect stakeholder engagement and adaptation planning processes, including mining industry growth, port developments within and adjacent to the NRM region, and a degree of climate change scepticism among some community stakeholders. A participatory scenario workshop process was applied to address these and other regionally relevant issues and elicit broad stakeholder participation into the identification of:

1. community and stakeholder values associated with the NRM region
2. key drivers of change in the NRM region
3. the risks and opportunities associated with those drivers of change

4. strategies and actions to reduce/mitigate risks and capitalise on opportunities
5. key players and potential working groups to implement the identified strategies and actions.

Stakeholder workshops were held in two stages:

1. initial workshops to address (i) to (iii) above, held in Mackay (12/2/14) and Proserpine (13/2/14)
2. a follow-up workshop to address (iv) and (v) above, held in Mackay (17/6/14).

The initial workshops were held in two centres within the Reef Catchments NRM region as organisers considered the likelihood of intra-regional differences in key issues and drivers of future change identified by participants from different parts of the NRM region. The follow-up (Stage 2) workshop was help in Mackay, synthesising key outcomes of both initial workshops for regional stakeholders to review, prioritise and develop collaborative strategies and actions. Key details and outcomes of the workshops are summarised below in Table 9.1. Full details of the workshop structure, participants and outcomes are reported in Bell *et al*. (in prep). Workshops were held at a hired venue, with independent, professional facilitators appointed to mitigate any potential perception of bias in the process.

Table 9.1 Summary of Reef Catchments participatory scenario workshop in F.Y. 2013/14.

WORKSHOP	PARTICIPANTS AND SECTORS	KEY OBJECTIVES	KEY OUTCOMES
<u>Stage 1:</u> **Mackay (12/2/14)**	**34 total; including:** • Local government • State government • Emergency management • Traditional Owners • Conservation NGOs • Landcare • Great Barrier Reef Marine Park Authority • Regional Development • Agriculture industry • Tourism Promotion Rep. • Research (CSIRO & JCU) • Reef Catchments NRM	1. Identify participant values associated with the MWI region. 2. Review and identify drivers of change, key issues and associated impacts in region. 3. Identify opportunities and risks associated with drivers of change. 4. Preliminary scoping of actions, strategies and collaborations to address opportunities and risks.	**Values included:** • Small population • Natural areas • Favourable climate • Lifestyle • Recreation opportunities **Drivers included:** • Population growth • Economic development from mining & ports development • Climate change • Community capacity, skills and education **Opportunities included:**

WORKSHOP	PARTICIPANTS AND SECTORS	KEY OBJECTIVES	KEY OUTCOMES
Proserpine (13/2/14)	**14 total; including:** • Local government • Emergency management • Landcare • Regional Development Corp. • Agriculture industry • Tourism industry • Research (CSIRO & JCU) • Reef Catchments NRM		• Regional infrastructure investment • New agricultural crops & diversification • Carbon market opportunities • Business & retail growth **Risks included:** • Natural resource degradation • Cultural shift and loss of values • Water use competition and scarcity • Economic inequality • Loss of agricultural land • Erosion of Traditional cultural heritage • Reduces lifestyle quality • Coastal flooding and storm impacts
Stage 2: Mackay (17/6/14)	**31 total; including:** • Local government • State government • Education sector • Traditional Owners • Conservation NGOs • Landcare • Great Barrier Reef Marine Park Authority • Insurance industry • Agriculture industry • Mining industry • Research (CSIRO & JCU) • Reef Catchments NRM	1. Review and prioritise key drivers, opportunities and risks. 2. Develop collaborative strategies and actions to address opportunities and risks 3. Identify key players and potential collaborations to implement strategies and actions.	**Strategies and actions included:** • Professional development for teachers • Development of a multicultural centre and creation of a contact list to facilitate improved engagement with local Traditional Owners. • Development of regional renewable energy strategy • Planning mechanisms to preserve and prevent development over prime agricultural land • Establishment of a community development consultation forum. • Build climate change adaptation framework into NRM and council planning.

As reported in Bell *et al*. (in prep), the diversity of stakeholder participants at the Reef Catchments workshops was an aspect that was greatly appreciated by the workshop participants. The broad representation of a wide range of community sectors and industries in the region provided an opportunity for identifying shared values of the region, and for the acknowledgement of opportunities and threats associated with different groups and sectors.

Regional values and issues

Common values identified across the Stage 1 workshops included an appreciation of the 'sense of community', small town size, access to good services (e.g. health, schooling, infrastructure), agreeable climatic and weather conditions and the diversity of the natural landscape, including proximity to both the Great Barrier Reef and hinterland ranges. Regional economic diversification arose as a key issue at both the Mackay and Proserpine workshops. Current dominant industry sectors include agriculture (primarily sugar cane and grazing), mining and tourism (principally in the Whitsundays region). Concerns about the reliance on mining for economic viability, and the impacts of this industry on both social and environmental issues were raised in both Mackay and Proserpine, reflecting the strong influence of this sector on the region. A key distinction between the two locations, was that the Mackay area had experienced a 'boom' but is now seeing a downturn in investment, whereas an impending 'boom' for the Whitsundays region was expected following the federal government's recent approval of expansions to the Abbott Point coal export facility. The strength of the mining sector was identified as a key driver of both opportunities and risks to the future of the region's landscape, other industries and the social well-being of communities within the region. While invitations were sent, unfortunately no mining industry representatives were able to attend the Stage 1 workshops; however, mining representation was achieved at the Stage 2 workshop.

Key drivers in the region

At both Stage 1 workshops, Reef Catchments staff provided a summary snapshot of the socio-economic and climactic drivers that are currently and likely to impact on the future of the region. These included:

- population growth (47% by 2031)
- capacity – resources, people (e.g. low per capita higher education attainment, high per capita trade skills associated with mining and construction)
- climate change (high variability accepted as regional norm, extreme events projected to increase in intensity, warming trend already evident, sea level rise expected to impact low lying areas).
- economic sectoral growth/ decline (e.g. growth in mining and related industries, decline in relative economic importance of agriculture)

Risks and opportunities

At the Stage 1 workshops, the main impacts identified that were associated with the mining 'boom' included increased urban and industrial development and an increasingly transient population. Impacts identified from such growth included reduced social connectivity and community capacity, degradation of the natural environment, and impacts to other sectors including tourism and agriculture. In Proserpine, concerns around mining included impacts on future tourism, the health of the Great Barrier Reef (in particular water quality from port dredging), biodiversity loss, industrial and urban encroachment on good quality agricultural land, and risks to the viability of the local sugar mill.

The risks associated with climate change were acknowledged by participants in all workshops, despite the earlier identification of climate change scepticism within the community. Contributions by emergency services representatives, who shared details of response plans and activities associated with extreme weather events in recent years contributed significantly to the identification of risks, opportunities and strategies. Similarly, a presentation by an insurance industry representative at the Stage 2 workshop on insurance industry statistics, policy and issues in the north Queensland region provided excellent additional contextual information to inform the development of risk reduction and mitigation strategies by the workshop participants (full details reported in Bell *et al*. in prep).

Actions, strategies and collaborations

A range of actions, strategies and collaborations were identified in both the Stage 1 and Stage 2 workshops, to address the identified opportunities and risks relevant to the NRM region (see summary in Table 9.1 above, and outcomes reported in Bell *et al*. in prep for details). A prioritisation process was applied in the Stage 2 workshop to categorise actions/strategies according to (a) their breadth of benefits to community sectors, industries and the natural environment, and (b) their affordability in terms of economic investment required, and the likely political will to achieve implementation. Considerations were also given to potential negative side-effects and trade-offs that would affect other sectors, community groups and/or the environment. Strategies and actions that scored the highest in both categories were flagged as a high priority for actioning and key players associated with implementation were identified for some examples (see Bell *et al*. in prep for further details and an outline of the Stage 2 workshop processes).

Future directions

Following reporting of workshop outcomes to participants (Bell *et al*. in prep), further work is planned, involving the Participatory Scenarios and Knowledge Integration Node and Reef Catchments NRM staff, to develop spatially explicit scenarios and to provide support for community working groups to implement the identified adaptation strategies and actions. Participatory scenario methods, supported by spatial tools, and an ongoing participatory action research approach to advancing NRM adaptation planning will form a key component of the 'evolving methodology,' that is responsive to locally-specific contexts, issues, opportunities and problems that characterise natural resource management and planning.

Summary and conclusions

The research and communication activities carried out by the 'Participatory Scenario and Knowledge Integration Node' have been driven by the needs of the four NRM organisations that are part of the Wet Tropics Cluster. As a result, a wide range of transdisciplinary research activities have been completed and are underway to address the diverse needs of the four NRM organisations (Appendix B). These activities comprise a wide range of research approaches and methods, including desktop based reviews, interviews and participatory research approaches such as scenario and cultural heritage planning, to support identification of climate adaptation pathways and options.

While the NRM adaptation checklist: Supporting climate adaptation planning and decision-making for regional NRM (Rissik *et al*. 2014) provides an excellent resource for NRM practitioners, the research carried out by our science node explicitly addresses the four challenges outlined in the NRM adaptation checklist:

1. making decisions for multiple possible futures
2. employing flexible and adaptive planning processes
3. explicitly identifying and preparing for likely future decisions
4. strengthening the adaptive capacity of people and organisations.

We acknowledge that our research is limited, in particular by the resources (time and funding) that we have available. However, the co-research and collaborative approach taken in the Wet Tropics Cluster provides a framework and opportunity to strengthen the adaptive capacity of the people and organisations involved in the project. Strengthened adaptive capacity seems to be critical to address all other challenges and the participatory approaches employed in our research activities are a pathway to achieve this. In particular, the participatory scenario planning workshops provided opportunities to address the four challenges simultaneously and to enhance collaboration among people and organisations.

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10. Climate adaptation planning in practice: NRM approaches in the Wet Tropics Cluster

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IN A NUTSHELL
• NRM approaches to developing climate adaptation action plans are more than technical exercises. They are strongly participatory, involving iterative and adaptive phases of engagement with a diverse range of stakeholders, focusing on community core values. • NRM processes are aimed at integrating climate change adaptation action across all sectors rather than framing it as a separate issue. • Many climate adaptation actions will require supportive policy and funding environments at multiple levels of government.

Precis

This chapter synthesises NRM approaches to developing adaptation pathways in the WTC region. These processes are works-in-progress and are at different stages among the four NRM groups. All processes are strongly participatory and based on iterative phases of engagement with regional stakeholders. Based on responses by NRM groups in the WTC region to a questionnaire about their approaches to developing adaptation pathways, this chapter summarises aims and rationale, methodology, key stakeholders, stakeholder engagement processes and key information, tools and support. The key messages associated with this chapter are:

TOPIC	KEY MESSAGES
Aims and rationale	152. NRM approaches aim to promote and support informed action by regional communities as a component of risk management and building resilience to climate change impacts. 153. The development of adaptation pathways is central to NRM planning approaches. 154. Adaptation pathways must be co-generated by regional communities and NRM groups, based on local knowledge and values as well as sound science. 155. Adaptation to climate change is framed in terms of risk-management. 156. Conceptual planning frameworks that emphasise systems function focus on the resilience of natural systems as well as social, economic and cultural systems, in the face of changing climatic conditions. This is a shift away from former conceptual frameworks that emphasised the protection of fixed natural assets.
Methodology	157. There is a trend towards integrating climate change across all NRM sectors rather than framing it as a separate issue. 158. Primary planning units are place-based rather than asset-based. 159. Groups structure their processes around the identification of stakeholder values, key drivers of

TOPIC	KEY MESSAGES
	change, risks and options for adaptation action. Identifying likely or preferred future scenarios can help to focus these conversations. 160. Adaptation planning methods are largely based on previous NRM experience of informing regional stakeholders and incorporating their knowledge into planning.
Key stakeholders	161. All NRM groups have a high diversity of stakeholders, including a range of industry groups, Indigenous people, community groups, Indigenous Ranger groups, other NRM organisations and all three levels of government.
Stakeholder engagement processes	162. NRM approaches are strongly participatory and founded on iterative and adaptive phases of community engagement. 163. NRM groups' engagement has generally started with individual sectoral groups before attempting to integrate multiple sectors. 164. Engagement is resource-intensive. Large regional areas, sparse populations and logistical difficulties of travel, especially in remote regions such as Cape York and Torres Strait, mean that substantial resourcing is required for effective engagement. 165. Scientific information is fed into engagement processes at all stages and in different formats. 166. Communicating with different stakeholder groups requires different processes and tools.
Key information, tools and support	167. Reports and other information from the Stream 2 project provide useful information. 168. Involvement of key experts in stakeholder and internal NRM workshops has been useful. 169. NRMs are collecting their own data on climate change impacts to feed into processes of developing adaptation pathways.

Introduction

This chapter documents key elements of the processes that are being used by NRM groups in the WTC region to develop adaptation pathways. This provides practical context for the information on potential adaptation pathways presented in the previous chapters of this report, as well as the opportunity for groups to articulate and reflect on their processes.

The emphasis of this chapter is on the *processes* of developing climate change adaptation pathways in regional NRM bodies in the WTC region rather than on outcomes. These processes are ongoing and, for the most part, adaptation pathways are still in development.

The content of this chapter is based on NRM groups' responses to a questionnaire (Appendix C) that was strongly informed by previous work in the Stream 2 WTC project (Lyons *et al*. 2013), refined for the current purpose by Stream 2 researchers and NRM representatives. NRM project partners compiled responses for their respective regional group and these were subsequently collated. Original NRM responses to the questionnaire may be available on request. The three NRM groups in the WTC region (Cape York NRM, Reef Catchments and Terrain NRM) contributed information about their processes for developing adaptation pathways. The Torres Strait Regional Authority (TSRA) is a statutory authority, and the TSRA Land and Sea Management Unit is the NRM body for the region. TSRA did not apply for funding under Stream 1 of the Commonwealth *NRM Fund*. However, TSRA is a member of the WTC Brokering Hub (detail provided in Hilbert *et al.*, 2014) and is also developing adaptation pathways; we include insights from the TSRA where possible.

This chapter documents the aims and rationale, methodology, key stakeholder groups, stakeholder engagement processes, key supporting tools and information, as well as preliminary adaptation options developed through early stages of stakeholder engagement.

Aims and rationale of NRM approaches to developing adaptation pathways

NRM approaches aim to promote and support informed action by regional communities as a component of risk management and building resilience to climate change impacts.

The development of adaptation pathways is central to NRM planning approaches.

Adaptation pathways must be co-generated by regional communities and NRM groups, based on local knowledge and values as well as sound science.

Adaptation to climate change is framed in terms of risk-management.

Conceptual planning frameworks that emphasise systems function focus on the resilience of natural systems as well as social, economic and cultural systems, in the face of changing climatic conditions. This is a shift away from former conceptual frameworks that emphasised the protection of fixed natural assets.

The development of adaptation pathways is happening in the context of a broader process of NRM plan revision to provide strategic direction with respect to adaptation to climate change. The development of adaptation pathways is central to this process.

NRM approaches to developing adaptation pathways in the WTC region share the following aims:

- Provide regional stakeholders with regionally-relevant scientific information;
- Help stakeholders to identify desirable futures and priority adaptation actions;
- Integrate stakeholder knowledge into adaptation pathways and NRM plans; and
- Build the community resilience by increasing their capacity to adapt to change.

Accordingly, NRM approaches are strongly participatory and founded on engagement with community stakeholders. These participatory processes are intended to enable articulation of the values and visions of NRM communities and to collaboratively identify action pathways to achieving desired outcomes. The co-generation of adaptation pathways is critical to building community adaptive capacity, which is achieved through the provision of accurate, regionally-relevant scientific information, the formation and facilitation of networks and identification of responsibility and time-frames for adaptation action. These approaches are centred on the premise that unless adaptation actions are owned by stakeholder communities, efforts of NRM groups to foster planned adaptation will likely fail, irrespective of the underlying scientific support.

The conceptual frameworks of all four WTC NRM groups have shifted from a natural assets–based framework to systems-based frameworks. This reflects a shift in focus from the protection of fixed natural assets to an emphasis on protecting the resilience of natural systems as well as social, economic and cultural systems, in the face of changing climatic.

Planning and engagement methods

There is a trend towards integrating climate change across all NRM sectors rather than framing it as a separate issue.

Primary planning units are place-based rather than natural asset-based.

Groups structure their processes around the identification of stakeholder values, key drivers of

change, risks and options for adaptation action. Identifying likely or preferred future scenarios can help to focus these conversations.

Adaptation planning methods are largely based on previous NRM experience of informing regional stakeholders and incorporating their knowledge into planning. Scenario-planning approaches have been useful to focus stakeholders on valued outcomes and the processes by which these can be achieved.

There is a trend towards integrating climate change across all sectors rather than framing it as a separate issue. A general framework for embedding climate adaptation into planning is that climate change is a major determinant (e.g., driver or risk) of how important systems function or the character of future landscapes. However, climate change is not the sole - or even primary – topic for engaging stakeholders in adaptation planning processes. For example, in Reef Catchments NRM, climate change is embedded within a framework of S*ustainable development* (ecological, economic, social and cultural) in the region. Climate change was identified by stakeholders as one of the four main drivers of change, along with population, skills and education and economic growth. TSRA has also framed climate adaptation planning broadly in terms of relationships to all sectors, for example including health and the economy.

Primary planning units for NRM processes are being formed using a 'place-and-value' approach. For example, the primary planning units for Reef Catchments are landscapes defined by combinations of geography, vegetation and land use, in Terrain NRM it will be 'Local Landscapes' (approx.12-17) identified through stakeholder consultation, and Cape York NRM is using 'socio-ecological clusters'.

Cape York, Reef Catchments and Terrain NRM groups are developing overarching strategic planning documents, with adaptation pathways incorporated into subsidiary components of their plans. Both Cape York and Terrain NRMs are developing substantial interactive digital platforms which will contain most of the planning material. These digital formats are relatively easily able to be updated, consistent with adaptive planning principles. For these two groups, higher-level strategic documents are intended to be relatively minimal, providing context for the more substantial interactive digital platforms. For example, Cape York's digital *Atlas* will be central base for stakeholders in the Cape York region to find and communicate information related to natural resource management, including tools to assist them with their planning. It is planned that the *Atlas* portal will contain the following components:

- Carbon tool
- Land Manager
- Who Plans Here
- Climate Stories
- Corporate site
- Fire Knowledge
- Living Knowledge Place
- Maps and data
- NRM Plan
- Water Quality Improvement Plan

Reef Catchments NRM's *Climate Sustainability Plan* is one of several supporting operational action plans (e.g., *Climate Sustainability Plan*, *Biodiversity Plan*, *Water Quality Improvement Plan*) within the substantial, overarching NRM Strategic Plan. Climate change adaptation is intended to be incorporated into all of these documents, but information on adaptation pathways will mostly be contained in the *Climate Sustainability Plan*. TSRA has developed a Draft *Torres Strait Regional Adaptation and Resilience Plan* that presents preliminary information on adaptation action in the region.

NRM planning and engagement methodologies have largely been informed by previous experience of participatory planning processes but have been influenced by the broader conceptual framework of systems thinking, including the focus on developing plans that account for changing climate conditions and the social, economic and cultural context of adaptation. Scenario-planning approaches incorporating identification of values and desired futures, key drivers of change, barriers and enablers have been useful to focus stakeholders on valued outcomes and the processes by which these can be achieved. Reef

Catchments NRM have used elements of scenario-planning in their processes (e.g., key drivers of change), but not developed explicit alternative scenarios. TSRA have used a scenario planning approach based on two alternative future scenarios (business-as-usual and desired future), in parallel with a process that focuses on system function in five ‘core capitals’ (i.e., natural, human, social, financial, physical).

All groups are broadly approaching the development of adaptation pathways with stakeholder groups by facilitating the:

- Articulation of values;
- Examination of vulnerability under changing conditions of places/services/systems that are of high value;
- Identification of potential action to reduce vulnerability and increase resilience.

NRM methodology for adaptation planning has been informed by the history of stakeholder engagement. For example, previous consultation has revealed that Cape York residents have expressed:

- planning fatigue;
- a desire to be able to access knowledge and information about Cape York through a single digital portal;
- the importance of giving voice to existing local plans;
- the desire to be able to access and use their data; and
- that they wish to have the tools available to them to plan while continuing to do what they do.

In response, Cape York NRM is developing an interactive web portal, synthesising the >120 existing local plans, and taking a *Planning by doing* approach consistent with adaptive planning principles and which incorporates feedback loops from processes already in place to enable adaptive planning processes, rather than attempting to start a separate planning process.

NRM approaches are characterised by staged, iterative and adaptive processes of engagement with regional stakeholder groups. NRM groups in the WTC had pre-existing networks and relationships with stakeholder groups and have built on these during the Stream 1 program through targeted engagement. NRM groups have also sought to engage new stakeholder groups through less targeted approaches, for example by having stalls at regional agricultural shows (Cape York NRM).

Key stakeholders

All NRM groups have a high diversity of stakeholders, including a range of industry groups, Indigenous people, community groups, Indigenous Ranger groups, other NRM organisations and all three levels of government.

There is substantial similarity between the NRM regions in terms of their stakeholder communities (Table 10.1), although key differences include the dominance of Indigenous peoples in the Cape York NRM region, and the presence of mining industry as a key NRM stakeholder in both Cape York and Reef Catchments NRM regions. In both cases, there are strong barriers to engagement which clearly influence the capacity of the adaptation pathway planning and implementation process. In the Cape York NRM region some key stakeholders are politically aligned with other agencies, which can limit their capacity for engagement with the Cape York NRM group’s process. Local Government is a key stakeholder in all four NRM regions in relation to a range of issues, including local land-use planning, environmental management, economic development and emergency services. Several State Government agencies (e.g.,Dept. State Development, Infrastructure & Planning, Dept. Transport & Main Roads, Dept. Environmental Heritage & Protection, Dept. National Parks, Recreation, Sport & Racing, Dept.

Natural Resources & Mines, Dept. Education and, Dept. Health) are also considered to be key to the development of adaptation pathways, but political and structural (e.g., communication between Departments or sections) barriers to effective engagement limit this ability. Interaction with other NRMs is facilitated at the cluster scale through the Brokering Hub in the WTC Stream 2 project, and state-wide through Operations meetings, the NRM regional planners’ network, and the Regional Groups collective.

__Table 10.1 Key stakeholder groups for NRM groups in the WTC region.__ 'CY' is Cape York NRM, 'RC' is Reef Catchments NRM, 'Tr' is Terrain NRM.

KEY STAKEHOLDER GROUP	NRM REGION(S)	POTENITAL BARRIERS OR LIMITS TO ENGAGEMENT	POTENTIAL SOLUTIONS IDENTIFIED
Traditional Owners and Indigenous groups	all	Historical and ongoing economic and social disadvantage (climate change may not be an immediate concern); Resource-intensive to engage in remote areas; Difficult to engage at regional scale in Tr.	Build capacity; strong links between climate change and on-ground action. One-on-one engagement
Indigenous Rangers	CY	Historical and ongoing economic and social disadvantage.	Build capacity
Community groups (e.g., conservation, landcare)	all	Availability for multiple meetings (mostly volunteers).	Engage through their meetings
Primary Industry (e.g., sugar cane, cattle grazing, agriculture; AgForce)	all	Availability for multiple meetings (run own businesses); Can have strong political or social alignment .	On-property visits; Involvement in industry worksing groups.
Tourism industry	all	Have not historically been engaged in NRM planning processes.	Target industrty membership groups.
Fishing industry	all		Engage through Water Quality Improvement planning process
Mining industry	CY, RC	Profit-oriented; Substantial political issues (e.g., divestment campaign).	Engage one-on-one.
Port operators (e.g., NQ Bulk Ports)	RC	Substantial political issues (e.g., divestment campaign).	Engage one-on-one.
General community	all	Limited power to influence land management decisions	
Local Government	all	Don't see value of participating in NRM process in some areas.	
State Government	all	Policy environment; Not perceived as relevant to some State Agencies(e.g., community health)	
Federal	RC		

Government (e.g., GBRMPA)	
Other NRMs	all
Regional Development Australia	RC, Tr

Stakeholder engagement

NRM approaches are strongly participatory and founded on iterative and adaptive phases of community engagement.

NRM groups' engagement has generally started with individual sectoral groups before attempting to integrate multiple sectors.

Engagement is resource-intensive. Large regional areas, sparse populations and logistical difficulties of travel, especially in remote regions such as Cape York and Torres Strait, mean that substantial resourcing is required for effective engagement.

Scientific information is fed into engagement processes at all stages and in different formats.

Communicating with different stakeholder groups requires different processes and tools.

NRM groups have initially engaged with stakeholders one-on-one or within sectoral groups before moving to integrated, cross-sectoral approaches. This phase of engagement is intended to:

- establish awareness of and interest in the NRM planning process;
- encourage stakeholder participation in engagement opportunities;
- provide climate change and other relevant information; and/or
- collect information on stakeholders' values and visions.

Reef Catchments NRM and TSRA used phone calls and face-to-face meetings (in combination with a questionnaire in TSRA) with 'already-engaged' stakeholders and Indigenous leaders, respectively, to:

- discuss proposed projects and workshop plans;
- present relevant climate change information;
- document potential valid adaptation pathways options for a given sector; and
- collect preliminary information to help prepare for workshops.

In Cape York, initial in-depth conversations were mediated by a 'Your Climate' questionnaire used by all CYNRM staff and three NRM partners in conversations with general community, other stakeholders, and in schools. This process enabled exchange of information about climate change impacts and also collected preliminary information about stakeholders' values, perceptions of change (climate and other), the functioning of systems (environment and industry) and adaptive capacity. Over 100 questionnaires had been completed at the time of writing. Terrain NRM have contacted >650 stakeholders, also using a survey and by attending various meetings of sectoral and community groups. Substantial engagement with Terrain stakeholders has been initiated through their Industry Innovation program, which involves intensive one-on-one engagement with primary industry stakeholders to promote innovation and resilience in agricultural production systems.

Based on preliminary engagement, Reef Catchments NRM held three invited, multi-sectoral regional workshops during February and June 2014 which provided opportunities to present targeted information about projected regional climate change impacts and to facilitate collaborative envisioning of desirable futures for the region. A community forum involving expert speakers on current and future climate risk in the region was also organised. The first two workshops were held in different locations to facilitate participation from different parts of the NRM region. The second workshop progressed from the outcomes of the first workshop series towards identifying potential strategies (see Table 9.1 in this report). Traditional Owners were represented at the workshops and their engagement with the planning process was facilitated by a parallel project implemented with the Stream 2 project (see Chapter 9). In Reef Catchments, the second phase workshops included identification of groups who could potentially have responsibility for or be involved with particular adaptation actions. These will form the basis of sectoral- or issue-based working groups to be facilitated by Reef Catchments in the next phase of stakeholder engagement.

TSRA held regional workshops during June 2014 and plans to follow up with local workshops.

The proposed next phases of stakeholder consultation in Terrain NRM will involve invited sectoral- or topic-based, Region-Wide Technical Workshops in late January – early February 2015 with stakeholders and key experts. At this stage, the workshop is proposed to:

- develop understanding of the current state of knowledge of participants;
- identify current or past action on the issue;
- develop indicators for monitoring and evaluating success of action; and
- identify potential strategies for moving forward, including explicit consideration of projected climate change impacts.

Regional workshops will be followed by Local Landscape Workshops in various locations (e.g., 12-17) across the Terrain NRM region. These will bring together the many stakeholders who identify with a particular area of the landscape. These workshops will address the multiple issues or topics relating to the local landscape and identify potential action strategies.

On-country, Indigenous-led engagement is central to the Cape York NRM approach. Workshops have been held around various sectoral and regional issues during 2014.

In summary, engagement in the WTC region has been broadly targeted by i) spatial extent (i.e., regional and local) and ii) the number of sectors (i.e., single or multiple). All NRM groups used combinations of these techniques, although the order in which they engaged at the different scale varies. For example, Cape York NRM engage on local scales (e.g., central Cape York cluster) as well as regionally (e.g., South Cape York Catchments, Cape York Sustainable Futures, Cook Shire Council). The first stage of targeted engagement in the current process was through sub-regional workshops across multiple sectors. Workshops have also included the Wenlock Catchment Group meetings (multiple sector, local), Cattle Industry Roundtable (regional, single sector), Indigenous fire workshop (Australia-wide, multiple sector), RIS workshop (Regional, multiple sector), WCTTAA meetings (single sector, sub-regional) and board meetings (regional, multiple sector). In Reef Catchments NRM, initial engagement was conducted with either individuals of single-sector groups, before moving to sub-regional or regional, multi-sector processes. The next phase of Reef Catchments NRM's engagement process will involve a return to smaller-scale focus or working groups formed around key sectors or issues identified in the previous workshops.

The effectiveness of communicating information through particular media varies among stakeholder groups. NRMs typically use combinations of direct conversation and different hard copy formats (e.g., brochures, fact sheets, letters, posters, reports) and increasingly make use of digital forms. Cape York NRM in particular routinely makes use of a variety of other media, including visual and audio-visual products to communicate information.

Information, tools and support used by NRMs

Reports and other information from the Stream 2 project provide useful information.

Involvement of key experts in stakeholder and internal NRM workshops has been useful.

NRMs are collecting their own data on climate change impacts to feed into processes of developing adaptation pathways.

Table 10.2 shows the key sources of information, tools and forms of support that NRMs use in processes for developing adaptation pathways, along with strengths, weaknesses and potential improvements. NRM workers are linked in to a multitude of sources of information on climate change impacts (Lyons *et al*., 2013), ranging from scientific papers (which can be difficult for NRM groups to access) to web-based discussion groups. Together with information from the Stream 2 projects, these form the complex information store they use to communicate with stakeholders. In this chapter we focus on the information coming from Stream 2 projects.

Stream 2 outputs

Scientific outputs of the Stream 2 WTC project (e.g., Hilbert *et al*. (2014)) have been used in the process of understanding impacts and developing adaptation pathways, mostly in terms of increasing information to NRM communities. Information contained within these reports has informed conversations with stakeholder groups as well as internally within NRM groups. Information has also been transformed into specific communication tools for stakeholders who may not relate to the language or complexity of the messages. For example, key messages from the reports have been selected for certain stakeholder groups and presented in fact sheets, posters or other forms by Reef Catchments, Cape York NRM and TSRA.

The process of internally preparing stakeholder communications is generally preferred to its delivery by scientific groups because NRM groups have a well-developed undertanding of their various stakeholder groups and often (but not always) employ dedicated staff for this purpose. In some cases, NRMs consult with representatives of target stakeholder groups, for example to increase the likelihood that appropriate language and examples are used. However, NRM groups have suggested that it will be beneficial for Stream 2 scientists to review communications material developed by NRM groups from Stream 2 outputs, to ensure that important information is not lost or altered.

It has also been suggetsed that Stream 2 scientists could usefully undertake scientific review of NRM planning documents, including adaptation pathways, as they are developed. This has been done for a draft of the Strategic NRM plan prepared for Reef Catchments.

The provision by scientists of summaries of key messages has made it easier for NRM groups to distill the most important points for their different sectoral or stakeholder groups. In the case of this current report, NRM feedback on an earlier draft suggested that summary tables showing specific adaptation actions identified in the body of the report would facilitate the process of developing stakeholder communication material. These have been developed and included in each relevant chapter of this report.

The national AdaptNRM project have delivered reports on Adaptation Planning and Weeds and Climate Change (http://adaptnrm.csiro.au/) and these have also been useful to NRM groups in the WTC. It has been suggested that members of the WTC Stream 2 project may be able to mediate this process, for example by providing summaries of subequent outputs, to reduce the pressure felt by NRMs due to the volume of information.

It is anticipated that the cluster-scale climate projections reports and brochures will provide useful information when they are delivered (imminent) by the National Projections Team (Stream 2, Element 1; detail in Hilbert *et al*. (2014)). The associated web-based Climate Futures portal is also anticipated by NRM groups to be a key tool for enabling groups to project and analyse different future climate scenarios for their regions. Previously, NRM groups would typically have had to engage contractors to do this.

Participation by scientists from the Stream 2 project in stakeholder workshops has been beneficial in Cape York NRM, Reef Catchments NRM and TSRA. Stream 2 scientists also co-organised an internal Reef Catchments NRM workshop aimed at making it easier to incorporate climate change impact and adaptation information into plans and processes.

Table 10.2 Key sources of information and tools used by NRM groups in the WTC region, with associated strengths, weaknesses and suggestions for potential improvements.

INFORMATION/TOOL	STRENGTHS	WEAKNESSES	POTENTIAL IMPROVEMENTS
Stream 2 WTC project outputs (e.g., reports, key message summary)	Rigorous, accurate, multi-sectoral, regionally-relevant; Useful for to inform internal NRM staff, plans and processes; Summary material clear & concise.	Uncertainty around specific local-scale impacts; First report lacked opportunity for NRM review; Scope of some components too broad or conceptual to be relevant to the region or linked to NRM practice.	NRM review of draft Stream 2 outputs (incorporated into subsequent protocols); Facilitate accompanying info-graphics and audio-visual material; Process for revision/update of reports over time.
Stream 2 AdaptNRM outputs	Planning module provides a useful framework; Rigorous.	Weeds module lacks practical solutions to issues; Long.	Develop Adaptation planning 'checklist' into tool for NRMs, community or local Government; Stream 2 WTC project synthesise information so that NRMs are not expected to trawl through everything.
Stream 2 Scenario planning	Appealing to stakeholders; Spatially-explicit prioritisation of future scenarios.	Needs expert involvement and resourcing; Focus on process rather than outputs.	Provide more guidance to NRMs on how to use scenario planning processes; Develop spatially-explicit scenarios.
Stream 2 Traditional Owner planning processes	Adaptive; Well-suited to engaging Traditional Owners in Reef Catchments planning processes.		
NRM field data collection using Fulcrum and Cybertracker with data portals.	Enables monitoring by users; Improves information on little-known region (Cape York); Provides immediate feedback on change.	Requires on-ground training; Lack of requirement for platform is good but trade-off in function.	Combine with traditional forms of data collection in a monitoring and evaluation system.
Stakeholder knowledge	On-ground; Long-term; Relevant.	Not quantifiable; Localised.	Document this knowledge and communicate more broadly.

Potential adaptation actions

Much of the current thinking in NRM groups about action options for adaptation to climate change in the WTC is that many options are consistent with notions of 'best practice', intended to increase the ecological sustainability of land management practices. Even though many potential adaptation actions are not perceived as being "new" (although see Chapter 2 (Biodiversity) of this report), their discussion in the context of adaptation to climate change provides an opportunity to prioritise these actions. Table 10.3 shows some of the potential opportunities for climate adaptation action that have already been identified in different NRM regions.

The actions identified in Table 10.3 are the result of early stages of stakeholder engagement and internal processes in NRM groups in the WTC. Engagement with stakeholders based on the current report is expected to develop substantially more detailed lists of adaptation actions and pathways. Most are medium-term actions, with several short- but no long-term actions identified at this stage. Most actions are considered to be incremental, although transformational actions are also identified.

Table 10.3 Potential opportunities for regional climate adaptation action that have been identified in early NRM processes.
Abbreviations: 'S' is short, "M" is medium, and 'L' is long; 'I' is incremental, 'T' is transformational. . 'CY' is Cape York NRM, 'RC' is Reef Catchments NRM, 'Tr' is Terrain NRM and 'TSRA' is Torres Strait Regional Authority.

POTENTIAL ADAPATION ACTIONS	TIME SCALE (S, M, L)	SECTOR(S) INVOLVED	I/T	LIMITS/ BARRIERS	OPPORTUNITIES
Reef Catchments NRM					
Professional development for teachers	M	Industry Education	I		
Contact list of Traditional Owners	S	RC Traditional Owners	I		
Regional renewable energy strategic plan	M	RC Industry (e.g., sugar mills) Local Government State Government Research institutions	T	Government support critical	Diversify existing industries; Develop new industries.
Protection of good-quality agricultural land	M	RC Local Government State Government	I	Government support critical	Regional coalition between conservation and agriculture.
Community consultation-development forum	M	RC Regional organisation of Councils	I		Build community capacity to maintain State accountability
Indigenous/multicultural festival or centre	M	Indigenous people Universities	I		Tie in with East Point

POTENTIAL ADAPATION ACTIONS	TIME SCALE (S, M, L)	SECTOR(S) INVOLVED	I/T	LIMITS/ BARRIERS	OPPORTUNITIES
		Local Government General community			development
Cape York NRM Provide new residents with property-scale decision-making toolkit	S	CY	I		
Appropriate fire management	M	CY Indigenous Ranger groups Grazing industry Research institutions	T	Knowledge Skills Capacity	Social and cultural benefits
Ecosystem services valuation framework	M	Research institutions State Government Federal Government	T		Alternative livelihoods
Prioritise carbon plantings	S	Research institutions State Government Federal Government	I	Accounting methods; Cross-tenure negotiations	Alternative livelihoods
Protection and sharing of traditional ecological knowledge	S	Indigenous peoples	T	Ownerships permissions; Cultural barriers; Loss of knowledge.	Protection of knowledge
Terrain NRM Innovative agriculture	M	Agriculture industry Research institutions State Government	T	Legislation; Knowledge; Financial capacity.	New industries; Less reliance on costly agricultural inputs;

Summary and conclusions

Planning for climate adaptation action has begun but is still in early stages in WTC NRM groups. While details may vary, the main characteristics of approaches to developing adaptation pathways are similar across regional NRM groups. The following is a list of the broad characteristics of WTC NRM approaches (not necessarily ordered consecutively):

- Develop a framework for embedding discussions of climate change impacts and adaptation options.
- Initial stakeholder engagement, typically with already-engaged stakeholders. Include outreach to the general community or new target groups.
- Identify key issues, usually through process of initial engagement, also internal analysis of scientific information.

- Implement a series of workshops that are a combination of i) being either regional or local in scope and ii) involving either one or multiple sectoral groups. Identify values associated with places or systems, threats or risks, opportunities and actions.
- Prioritise potential climate adaptation action. Identify responsibility for action.
- Integrate climate adaptation action into other NRM plans and processes.
- Monitor, evaluate and revise actions in relation to desired adaptation pathways, in light of new information etc.

Communication of climate change information is integrated into all stages of these processes and is delivered in a range of formats, tailored by NRMs to specific stakeholder groups.

Ongoing process will benefit from the specific adaptation opportunities and pathways identified in the present report.

Literature cited

Hilbert D.W. *et al.* (2014). *Climate change issues and impacts in the Wet Tropics NRM cluster region.* James Cook University, Cairns, Australia.

Lyons, P., Bohnet, I.C, Hill, R.(2014). *Synthesis of Climate Change Knowledge held and Planning Practices carried out by the Wet Tropics Cluster Natural Resource Management (NRM) Organisations.* CSIRO Climate Adaptation Flagship, Cairns.

Appendix B. Summary of research activities carried out by the Participatory Scenarios and Knowledge Integration Node of the Wet Tropics Cluster.

WHAT ACTIVITY?	WHY THIS ACTIVITY?	PARTICIPANTS (WHO?)	OUTPUTS	OUTCOMES
Participation in Brokering Hub meetings	Good governance and regular communication	Ro Hill (CSIRO overall project leader/ manager) Iris Bohnet (Leader of Participatory Scenarios and Knowledge Integration Node) Team members on request (e.g. Peci Lyons to present her case studies)	Minutes and actions arising from these meetings	Regular updates on research activities and feedback from NRM groups
Preparation of NRM groups' priority science deliverables	To gain a common understanding about the knowledge needed for NRM climate change adaptation	First undertaken by the Wet Tropics Cluster NRM groups and incorporated by Steve Turton and Ro Hill into project proposal; subsequently updated through leadership by Cath Moran	NRM groups' priority science deliverables for the Science Synthesis of Impacts and Issues and Adaptation Pathways and Opportunities	Provided advice for scientists on how to target their synthesis of science to meet the knowledge identified by the NRM groups as required for adaptation planning
Half-day workshop to identify key issues and drivers of change in the four Wet Tropics Cluster NRM regions	To gain a common understanding among participants about key issues and drivers of change in each of the regions	Led by Iris Bohnet with members of the Brokering Hub (Stream 1 and 2)	Milestone report delivered to the Australian Government (May 2013)	Improved understanding among participants about key issues and drivers of change in each of the NRM regions
Presentations of research in our Science Node	To showcase and discuss our work beyond the Wet Tropics Cluster	Iris Bohnet presented at: • JCU Cairns • TESS science meeting • MODSIM conference	MODSIM conference paper (Bohnet *et al*. 2013) published in conference proceedings with co-authors from Stream 1 and 2	Discussions with regional, national and international colleagues about our work. Follow-up phone-links ups and email discussions with national and international colleagues to discuss learnings and challenges this type of collaborative research presents

WHAT ACTIVITY?	WHY THIS ACTIVITY?	PARTICIPANTS (WHO?)	OUTPUTS	OUTCOMES
Synthesis of Climate Change Knowledge and Planning Practices carried out by the Wet Tropics Cluster NRM Organisations	To establish a baseline about Climate Change Knowledge and Planning Practices carried out by the Wet Tropics Cluster NRM Organisations	Led by Iris Bohnet and Peci Lyons with contributions from Ro Hill and Cath Moran	Report (Lyons *et al*. 2013) delivered to the Australian Government in November 2013 including 5 key messages	Better understanding of current climate change knowledge and planning practices
Cultural heritage mapping and participatory scenario planning with Traditional Owners in the Reef Catchments NRM region	To support Reef Catchments NRM in their planning to include Indigenous knowledge and information in their Climate Action plan as well as in their updated NRM plan	Led by Peci Lyons with support from Iris Bohnet, Ro Hill, Matt Curnock, Cath Moran and Reef Catchments NRM (Robyn Bell, Alice Spencer, John Franklin)	Maps, a report and/or journal article, presentation to Brokering Hub	Identification of conditions, approaches and processes that support or limit the integration of Indigenous knowledge into a regional NRM governance setting.
Social network analysis for Terrain NRM region	To support Terrain NRM in their corridor planning	Led by Peci Lyons with support from Ro Hill, Iris Bohnet and Terrain NRM (David Hinchley, Gavin Kay)	Map of social network, a report and/or journal article, presentation to Brokering Hub	Improved understanding of the key variables (knowledge networks) that influence biodiversity offset corridors
Contribution to the Science Synthesis report (research node led by Dave Hilbert) • Social science workshop	To contribute chapters requested by the four NRM organisations that relate to the social sciences	Led by Ro Hill and Cath Moran (organised social science workshop in collaboration with Dave Hilbert) Iris Bohnet, Ro Hill, Matt Curnock, Peci Lyons, Petina Pert from our science node participated in the workshop	Co-edited science synthesis report (Ro Hill) Chapters led by: Ro Hill, Petina Pert, Iris Bohnet Contributions to chapters: Matt Curnock, Peci Lyons, Iris Bohnet Major contribution to deliverable to the Australian Government (February 2014) (Hilbert *et al*. 2014)	Improved understanding of the science to support NRM adaptation planning for climate change

WHAT ACTIVITY?	WHY THIS ACTIVITY?	PARTICIPANTS (WHO?)	OUTPUTS	OUTCOMES
Contributions to the evaluation of the 1st Science Synthesis Report	To identify knowledge translation and boundary management issues	Led by Cath Moran through a focus on what worked and what didn't work, facilitating primary input from the NRM Groups	Summary of findings included in Minutes of Meeting of 11 March 2014	Highlighted the need for greater interaction between the NRM groups and the scientists to arrive at a Synthesis that meets the needs of the NRM groups
Co-development and distribution of a "key messages" brochure, synthesising findings presented in 1st Science Synthesis Report	Improved communication, co-ownership and uptake of 1st Science Synthesis Report key messages among NRM groups	Key messages provided by science teams; layout, design and imagery selection by NRM groups, in close collaboration with Ro Hill and Cath Moran through design stages	Succinct, high-impact 12 page brochure with targeted messages, summarising key messages from Science Synthesis Report (Hilbert *et al*. 2014b)	Improved understanding of specific impacts of climate change in the NRM cluster. Improved communication and understanding of key messages from 1st Science Synthesis Report
Regional scenario planning workshops supported in the Reef Catchments NRM region	To support Reef Catchments NRM in their climate adaptation planning and identification of strategies and actions	Led by Robyn Bell Reef Catchments NRM with support from Alice Spencer, John Franklin, Jaylan Smith, Jaime Newborn in collaboration with Iris Bohnet, Matt Curnock and Cath Moran	Fact sheet (Bohnet and Bell, 2014) Workshop report (Bell *et al*. 2014 in prep)	Improved understanding of strategies and actions required to address potential impacts of climate change. Improved stakeholder relations
Regular meetings (via phone/email) with four NRM organisations	To provide research updates, receive feedback and ensure the NRM organisations receive the support from our science node that they need	Iris Bohnet	Actions arsing from these meetings	Improved understanding of what is expected from our science node
Regular meetings with Cath Moran (knowledge broker)	To provide research updates, receive feedback and ensure the NRM organisations receive the support from our science node that they need	Iris Bohnet	Actions arsing from these meetings	Improved understanding of what is expected from our science node

WHAT ACTIVITY?	WHY THIS ACTIVITY?	PARTICIPANTS (WHO?)	OUTPUTS	OUTCOMES
Participation in activities organised by NRM groups relevant to our science node: • Science-driven cross-cluster meeting • NRM-driven cross-cluster meeting • NRM state-wide GIS workshop • Spatial Working Group	To respond to requests by our collaborators (meant to improve our understanding of their science needs)	All Matt Curnock, Petina Pert, Iris Bohnet Iris Bohnet Petina Pert Iris Bohnet, Petina Pert	-	Potential for improved collaboration
Participation in activities organised by the national science teams relevant to our science node: -Roadshow of Wet Tropics Cluster downscaled climate change information - Webinar of how to use Climate tool		Iris Bohnet, Peci Lyons	-	Improved understanding of downscales climate projections and how information can be used
Participation in “Novel research that could be transferable and useful to other clusters” group at the Stream 2 Annual Workshop 2014	To develop a national inventory of new adaptation technologies	Brendan Edgar led the group; Ro Hill from the Wet Tropics Cluster participated	Stream 2 NRM Fund Annual Workshop Report 2014	Several novel tools were discussed and Brendan undertook to develop the concept of a national audit

Appendix C. Proforma used by NRM partners to document their approaches to developing climate change adaptation pathways.

1. What are the **approaches** you have used **to** develop regional adaptation pathways? Break this up if different approaches were used for different sectors or local landscapes. List the **stages** in these processes and include a brief description of what's involved, as well as an indicative time frame.
2. What **tools or support** have you used or are planning to use? What are their strengths and weaknesses for developing adaptation pathways? How could these be improved?
3. Which **key stakeholders**/ stakeholder groups have you involved or do you intend to involve in developing adaptation pathways? Are there barriers or limits to engaging with some groups?
4. What **climate change information is incorporated** into the adaptation pathway process? How is this adapted for use with stakeholders? Did you use different approaches for different stakeholder groups? What facilitated the process of transforming scientific information and how could this be improved?
5. How have you framed/will you **frame the development of adaptation pathways** with your stakeholders? How does this vary with different stakeholder groups?
6. Have any **potential adaptation pathways already been identified** through your engagement processes? At what scale(s) are they relevant (e.g., spatial or temporal, particular sectors or groups)? Are the adaptation pathways incremental (i.e., intended to maintain current systems) or transformational (i.e., intended to develop new systems)? Are there limits or barriers? Do the adaptation pathways present opportunities for NRM communities?
7. Do you want to provide any other detail or comments?

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