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Australasia Supplementary Material

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SM11.1 Adaptation Strategies, Plans and Initiatives for Australia and New Zealand

Table SM11.1a | Examples of Australian adaptation strategies, plans and initiatives at national, sub-national, and regional or local levels.

Jurisdiction	Strategies/plans/actions (complementary or supporting strategies/plans)	Vision/aim highlights	Examples of key foci
National Level			
Australia	National Climate Resilience and Adaptation Strategy 2015 (CoA, 2015)	'We act together to support prosperity and wellbeing in Australia and beyond by building the resilience of communities, the economy and the environment to a variable and changing climate'	Strategy highlights past activities; provides a set of principles and priority areas for future consultation and action
	National Disaster Risk Reduction Framework (COA, 2018); Home Affairs (2020)	A national, comprehensive approach to proactively reducing disaster risk, now and into the future	Guides national, whole-of-society efforts to proactively reduce disaster risk to minimise the loss and suffering caused by disasters
Sub-national			
Australian Capital Territory (ACT)	ACT Climate Change Strategy 2019–2025 (ACT Government, 2019) Canberra's Living Infrastructure Plan: Cooling the City (ACT Government, 2020b); ACT Wellbeing Framework (ACT Government, 2020a)	Net zero emissions by 2045, impacts well managed, reduced urban heat, sustainable and resilient farmlands, forests and biodiversity	Six key priority areas and associated set of actions reflect region's risk profile: community leadership and just transition; ACT government leadership; transport; waste avoidance and management; energy, buildings and urban development; land use and biodiversity. Canberra's Living Infrastructure Plan seeks to reduce urban heat and slow storm runoff through increased green cover and permeable surfaces and to promote climate-wise urban design.
New South Wales (NSW)	NSW Climate Change Policy Framework (NSW Government, 2016)	Achieve net-zero emissions by 2050 NSW is more resilient to a changing climate	High-level policy directions. Commitments include: – Development of an adaptation action plan and investigating how to embed climate change mitigation and adaptation across government operations; – Committed $30 million to NSW Climate Change Fund including research and on-ground actions; – Previous policy initiative invested in regional adaptation plans. Ongoing investment in down-scaled projections.
	Coastal Management Framework (OEH, 2018b) including: Coastal Management Act 2016; State Environmental Planning Policy (Coastal Management) 2018; NSW Coastal Management Manual (OEH, 2018c, 2018a)	The Act requires local governments to prepare coastal management programmes. These will set the long-term strategy for coordinated coastal management; programmes will be prepared using a staged risk management process	Specific planning measures prevent development of land within the coastal zone unless the relevant authority is satisfied the development is not likely to cause increased risk of coastal hazards on that land or other land. Local governments must review coastal hazards and identify and select management actions for the coastal zone.
Northern Territory	Northern Territory Climate Change Response: Towards 2050 (DENR, 2020b); three-year action plan (DENR, 2020a)	Taking action on climate change to maximise the economic, social and environmental well-being of Territorians	Activities for 2020–2023 against four objectives: net zero emissions by 2050; a resilient Territory with adaptation actions for multiple sectors; unlocking opportunities including investment in new technologies and low-carbon industries; inform and involve science, risk awareness and education.
Queensland	Pathways to climate-resilient Queensland: Queensland Climate Adaptation Strategy 2017–2030 (DEHP, 2013)	An innovative and resilient Queensland that manages the risks and harnesses the opportunities of a changing climate	Sets out four pathways People and knowledge (climate science and communication); state government (embed adaptation across whole of government); local governments and regions (funding for on-ground action); sectors and systems (industry-led, sector-specific adaptation plans)
	Queensland's QCoast2100 programme		A significant state programme that funds local governments to prepare Coastal Hazard Adaptation Strategies for 32 councils

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Jurisdiction	Strategies/plans/actions (complementary or supporting strategies/plans)	Vision/aim highlights	Examples of key foci
	Sector adaptation plans: https://www.qld.gov.au/environment/climate/climate-change/adapting/sectors-systems	Sector leaders in collaboration with government agencies, local governments and other stakeholders identify adaptation needs and prioritize adaptation activities	Seven sector-led adaptation plans in place (one more to be completed), each identifying principles or strategic actions to inform adaptation in relevant sector
	State heatwave risk assessment 2019 (QFES, 2019)	A comprehensive overview of current and future heatwave risk in Queensland	Developed using Queensland's Emergency Management framework https://www.disaster.qld.gov.au/dmg/Prevention/Pages/3-5.aspx Considers future exposure of infrastructure, industry, community and environment to extreme heat events; assesses risks and evaluates risk treatments
	Planning Act 2016 (Queensland Government, 2020) and the Coastal Protection and Management Act 1995 (Queensland Government, 1995) plus supporting initiatives: Coastal Management Plan (DEHP, 2013); Shoreline Erosion Management Plans (DES, 2018)	Planning arrangements to protect the coastal environment and management of coastal hazards	Policy and regulation to guide development and management on both private and public lands. Guidance from the Coastal Management Plan is primarily targeted at local governments; objectives aimed at coastal management including consideration of climate variability and sea-level rise. Proactive management of erosion encouraged in development of Shoreline Erosion Management Plans
South Australia	Directions for a Climate Smart South Australia (SA Government, 2019a)	Policy direction to drive low-emissions jobs and growth, protect the environment and support community resilience and well-being	Five policy directions: support development of low-emissions, climate-smart industries/services; transition to a low-emission economy; manage risk, harness opportunities, adapt and build resilience; provide accessible information; embed climate risk and opportunity into government decision-making and investment; next step is action plans and performance targets and measures
Tasmania	Climate Action 21: Tasmania's Climate Change Action Plan 2017–2021 (State of Tasmania, 2017)	Building climate resilience enhances our capacity to withstand and recover from extreme weather events and better understand and manage the risks of a changing climate	Whole-of-government climate change action plan covering mitigation and adaptation, including actions to build climate resilience to enhance Tasmania's capacity to withstand and recover from extreme weather events and better understand and manage the risks of a changing climate. The Tasmanian government will develop Tasmania's next climate change action plan for post 2021. The plan sets out 37 actions around 6 priority areas: understand future climate; advance renewable energy capability; decrease transport emissions; grow climate-ready economy; build climate resilience; support community action
	Tasmanian Disaster Resilience Strategy 2020–2025 and Tasmanian State Natural Disaster Risk Assessment 2016 (White et al., 2016)	Understanding and awareness of natural hazard risks affecting Tasmania	The assessment adopts Australia's National Emergency Risk Assessment Guidelines (AIDR 2016) and considers all natural hazards. The assessment includes consideration of climate change implications on hazards
	Tasmanian Planning Scheme—State Planning Provisions 2017, Coastal Inundation Hazard Code and a Coastal Erosion Hazard Code (Government of Tasmania, 2017)	Ensure that use or development subject to risk from coastal erosion is appropriately located and managed	Requires local governments to prepare Local Provision Schedules that consider coastal erosion and inundation hazard maps and incorporate an allowance for sea level rise (SLR)
Victoria	In accordance with the Climate Change Act 2017, Victoria has a Climate Change Adaptation Plan 2017–2020 (Victoria State Government DELWP, 2016) including a Monitoring, Evaluation, Reporting and Improvement (MERI) framework for Climate Change Adaptation in Victoria (DELWP, 2018), Victorian Climate Projections (2019) and multiple resources for regions and local government. In 2021 will release adaptation plans for 11 sectors/systems and 6 regions	More effectively manage risks to the government's own assets and services from climate change; help the community to understand and manage the risks and impacts of climate change; encourage adaptation action across all policy areas and sectors of the economy	Sets out the government's strategic priorities, measures and responses for adaptation in Victoria over 4 years, as required by the Climate Change Act 2010 (revised in 2017). A monitoring and evaluation framework supports the plan with reporting at 6-month, 18-month and 3-year intervals to track activities and progress. New climate change adaptation plans for regions and sectors in Victoria are currently being developed
	Heatwaves in Victoria. A Vulnerability Assessment 2018 (Natural Capital Economics, 2018)	Vulnerability assessment for heatwave hazards to better understand the nature and extent of heatwave vulnerability for key sectors, distribution of heatwave vulnerability across regional areas and implications for the economy	A Vulnerability assessment of the state to heatwaves using a Damage and Loss Assessment methodology; the approach puts particular focus on the vulnerability of the state's economy

Jurisdiction	Strategies/plans/actions (complementary or supporting strategies/plans)	Vision/aim highlights	Examples of key foci
Western Australia	Western Australian Government Adapting to our changing climate 2012 (WA Government, 2016)	Western Australians will need to adapt to ensure well-being of the community, the environment and the economy and to minimise costs of climate change impacts on society	Support infrastructure risk assessment and adaptation planning; integrate climate change considerations into development assessment, land use and infrastructure planning, infrastructure procurement, management and maintenance programmes; ensure that urban design reduces sprawl and encourages the use of public and other alternative forms of transport and considers transit-oriented and passive solar design
	State Planning Policy 2.6 – Coastal Planning (SPP2.6)	Provides guidance for decision-making within the coastal zone including managing development and land use change; establishment of foreshore reserves; and to protect, conserve and enhance coastal values	Local councils are required to undertake minimum requirements of a Coastal Hazard Risk Management and Adaptation Plan in order to consider their coastal hazard risk and build adaptation plans. Adaptation measures are provided in a hierarchy to be considered on a sequential and preferential basis: avoid, planned and managed retreat, accommodation, protection
Regional and local (examples only)			
Climate emergencies have been declared by 101 regional and local governments to leverage climate action as of May 2021 covering 34.5% of the Australian population (Climate Emergency Declaration, 2020)			
Tasmania	Tasmanian Coastal Adaptation Pathways Project (Tasmanian Climate Change Office, 2012)	To help Tasmanian communities and decision makers adapt to climate change impacts	The project worked directly with councils on addressing coastal areas vulnerable to climate change. The project supported these councils to assess their risk and work with communities to identify adaptation options
South Australia	Regional integrated vulnerability assessments (IVAs) and adaptation plans (SA Government, 2019a)	To support communities, business and individuals adapt to and mitigate the economic, social and environmental impacts of climate change	Vulnerability assessments and adaptation plans were led locally by partnerships of regional leaders with support from the South Australian government. Eleven regional adaptation plans were developed, covering the entire state
NSW	Enabling Regional Adaptation (Jacobs et al., 2016)	Using local knowledge to identify potential threats and response options can help communities prepare for climate change	The NSW government developed a process to support regional adaptation. Guidelines step users through collating information and a participatory workshop. Eight regions in NSW have completed the process
Victoria	Every region and catchment management authority in Victoria has an adaptation plan, as does virtually every local government. In addition, three alliances of multiple local governments are working on climate change and new initiatives such as the Climate Change Exchange. The 2019 Inquiry into Tackling Climate Change in Victorian Communities attracted 162 submissions: https://www.parliament.vic.gov.au/967-epc-la/inquiry-into-tackling-climate-change-in-victorian-communities	The Western, Northern and Eastern Alliances for Greenhouse Action together account for approximately 30 local councils that are sharing ideas and resources to adapt to climate change. This includes commissioning research on topics such as 'How well are we adapting?' and providing resources for other councils	Policy briefs on regional adaptation plans provide snapshots of the core climate risks, vulnerabilities and adaptation needs in each region. Catchment Management Authorities and local government adaptation plans are more bottom-up and varied, though local government alliances are improving consistency
NSW	Coastal Zone Management Plan for Bilgola Beach (Bilgola) and Basin Beach (Mona Vale) (Haskoning Australia, 2016)	Describes proposed actions to be implemented by council, other public authorities and potentially by the private sector to address priority management issues in the coastal zone over a defined period	Includes risk assessment and management options for a section of the coast
Queensland	Torres Strait Climate Change Strategy (TSRA, 2014); Torres Strait Regional Adaptation and Resilience Plan 2016–2021 (TSRA, 2016)	'Torres Strait is the ancestral homeland of our people and is inseparable from our culture…[W]e strive to remain here, to retain the achievements of the present and regain the good ways of the past for a future that is resilient to change, in particular to the effects of climate change. The ability to be responsive and adaptable is important in attaining the goals of individual and community happiness and wellbeing' (TSRA, 2016)	Assessment of climate change risks and identification of actions to reduce climate risks. The plan focuses on both climate impacts as well as reducing vulnerability through building resilience

Jurisdiction	Strategies/plans/actions (complementary or supporting strategies/plans)	Vision/aim highlights	Examples of key foci
	Climate Risk Management Framework for Queensland Local Government (Erhart et al., 2020)	The increasing frequency, severity and diversity of disasters are impacting local communities and Queensland's economic productivity. Queensland local governments need to prepare for climate risks and their consequences	The Climate Risk Management Framework for Local Government in Queensland provides an overarching approach for progressing a holistic response to all current and future climate risks within a local government area (LGA).
Northern Territory	Climate Change Action Plan (2011–2020) (Darwin City Council, 2011)	Council is committed to finding practical and effective ways to address climate change concerns within the municipality.	The Plan sets out actions for both the council itself (corporate actions) and the community. Actions address water, land, air quality, biodiversity, recycling and waste, and energy; actions include mitigation and adaptation actions

Table SM11.1b | Examples of New Zealand national and sub-national government adaptation strategies and plans

Jurisdiction	Strategies/plans/actions	Summary of key points
New Zealand Central Government	The New Zealand Government's adaptation policy framework is based on the following legislation: Resource Management Act 1991, Local Government Act 2002, National Disaster Resilience Strategy 2019 (CDEM, 2019), and the Climate Change Response (Zero Carbon Amendment) Act 2002.	Mandated under the Climate Change Response Act 2002: A national framework is in place for climate change risk assessment (MfE, 2019) National Climate Change Risk Assessment completed (MfE, 2020a) and every 6 years. A National Adaptation Plan (in preparation) prepared no later than 2 years after each successive risk assessment The Climate Change Commission to monitor and review progress on implementation of adaptation plans
	Department of Conservation Climate Change Adaptation Action Plan	Establishes a long-term strategy for climate change research, monitoring and action across all DOC functions, which will guide internal strategic planning, prioritisation and operations to meet their goals in the face of climate change.
Local Government	In July 2017, a group of 39 local government mayors and council chairs (of 78 in total) endorsed a 2015 local government declaration calling for urgent responsive leadership and a holistic approach on climate change, with the government needing to play a vital enabling leadership role (LGNZ, 2017; Schneider et al., 2017)	Seventeen councils have declared climate emergencies to leverage climate action plans as of May 2021 covering 75.3% of the New Zealand population.
Regional councils (examples only)		
Bay of Plenty Regional Council	Climate Action Plan July 2019 (non-statutory)	Covers climate change mitigation and adaptation; requires inclusion of climate change implications in council papers, statutory planning, non-statutory strategies, plans and processes, also focuses on the council's role in protecting biodiversity from the impacts of climate change
Waikato Regional Council	Long Term Plan 2018–2028 (LTP)	Climate change impacts are factored into council's planning and design activities, including impacts on the management of flood protection scheme assets. Climate change is a significant financial forecasting assumption for infrastructure over the next 50 years. LTP for 2018–2028 decisions include assessment of climate change implications and guidance for business cases, on risks and opportunities for adaptation and opportunities to reduce the impact on the climate system through greenhouse gas reduction and sequestration action.
	Regional Policy Statement	Climate change integrates policy responses particularly in the allocation of freshwater and natural resources
Greater Wellington Regional Council	GWRC's Climate Change Strategy (October 2015) Climate change strategy implementation Hutt River Flood Risk Management Plan	Climate change is an integral part of planning and decision-making to increase long-term adaptive capacity using adaptive planning tools and techniques (e.g. adaptation pathways map with flood management options) and dynamic adaptive policy planning (DAPP) to understand and evaluate long-term consequences of different policy actions. Climate change mitigation and adaptation is integrated into regional spatial planning and modelling to assess impacts of SLR on freshwater abstraction Hutt River Flood Risk Management Plan; first NZ use of DAP; Room for the River for a 1:440 year ARI (Average Recurrence Interval) to accommodate increased flood frequency from climate change; purchase of up to 75 properties; removal of flow checkpoint (bridge/road changes); new community amenities and cycle ways) (Infometrics and PSConsulting, 2015; Lawrence et al., 2019)
Northland Regional Council	Proposed Regional Plan (section C.8.6)	Contains a provision to restrict rebuilding in hazard zones following material damage from a hazard event. The decision whether to rebuild must take into account climate change effects over a 100-year timeframe.

Jurisdiction	Strategies/plans/actions	Summary of key points
Unitary authorities (examples only)		
Auckland Council	Auckland Unitary Plan AUP RPS B10 Table B11.9 (bottom of doc) E36. Natural hazards and flooding	Ensures potential effects of climate change are accounted for when undertaking natural hazard risk assessments, particularly for structure planning and plan changes. Any new buildings or substantial additions to existing buildings in vulnerable coastal areas are required to be above the 1% AEP coastal storm inundation event, including an additional SLR of 1 m
Marlborough District Council	Marlborough Environment Plan, first to integrate DAPP into plan policies and rules.	Based on IPCC AR4 (IPCC, 2007) and 1.5 Degrees Report (IPCC, 2018). Covers regional climate projections, sources of climate variability (ENSO and the IPO), and impacts—drought, SLR, ocean acidification, flooding, human disease vectors, biosecurity, water quality and quantity (instream and out-of-stream uses and values), fire, mental health effects and disruption to businesses and individuals, consideration of uncertainty (flexibility and adaptability to change) and using DAPP. Until DAPP is undertaken, several SLR thresholds are set to manage potential coastal hazard risk (e.g. land use changes and redevelopment beyond existing footprint; min 1.52 m SLR); existing development and assets within existing footprint (min 1 m SLR); non-habitable short-lived assets necessary at coast with low consequences or adaptable (min 0.65 m SLR), as defined in the 'Coastal Hazards and Climate Change: Guidance for Local Government' (MfE, 2017).
Gisborne District Council	Tairāwhiti Resource Management Plan (District Plan) March 2020	Requirements for consents in Natural Hazards Policy within a hazard area to consider minimum floor levels for residential buildings to reduce exposure to flooding risk and relocatable buildings to avoid damage. The implications of climate change must be considered in hazard assessments and for consents, e.g. likelihood of SLR, altering of coastal processes, higher temperatures, changes in rainfall patterns and any increase in storms
District council (example only)		
Waimakariri District Council	Infrastructure Strategy in LTP 2017 Long-Term-Plan-Further-Information-Document-WEB.pdf	Factors in climate change impacts on water supply, wastewater and stormwater (e.g. through sizing of new stormwater pipes to account for intense rainfall events); flood modelling includes 1 m of SLR; future modelling includes the impacts of increasing groundwater levels due to SLR, which helps guide the location of new development and floor levels for buildings; the implications of slow SLR and changing weather patterns for infrastructure asset management; adoption of community resilience measures

SM11.2 Key Risk Trace-back Tables

The following tables provide traceable evidence supporting key risks in Table 11.14 and 'burning embers' in Figure 11.6. The evidence comes from published literature and/or expert judgement.

There are four risk levels: undetectable, moderate, high and very high. The transition between each level can be defined by a global warming range, relative to 1850–1900. This can be derived from the literature describing risks for different levels of global warming. However, the literature usually describes risks based on years/RCPs (e.g. 2050 RCP8.5) rather than global warming, so it is necessary to convert from years/RCPs to global warming using data from the IPCC Working Group (WG) I report (IPCC, 2021) (Figure SM11.1 and Table SM11.1). For example, the global warming relative to 1850–1900 is about 0.3°C in 1980, 0.5°C in 1990, 0.7°C in 2000, 1.0°C in 2010, 1.2°C in 2020, 1.5°C in 2030 (RCP2.6), 1.6°C in 2030 (RCP8.5), 1.7°C in 2050 (RCP2.6), 2.4°C in 2050 (RCP8.5), 1.8°C in 2090 (RCP2.6) and 4.4°C in 2090 (RCP8.5).

While global warming is used as the common metric for defining risk transitions, associated changes in climate vary regionally. For example, over Australia and New Zealand land areas, the warming will be slightly higher than the global average and precipitation may increase or decrease (Figure SM11.2).

The risk transition can be related to events that have been observed after particular years. For example, widespread bleaching of coral reefs was first recorded in the 1980s, with mass bleaching events in 1998, 2002, 2006 and 2008–2011, followed by major loss of coral in three bleaching events during 2016–2020. Therefore, the risk was undetectable prior to 1980 (less than 0.3°C global warming), increasing to moderate risk between 1980 and 1990 (0.3°C–0.5°C), then increasing to high risk between 1990 and 2010 (0.5°C–1.0°C), and very high risk from 2010 onward (over 1.0°C).

The following trace-back tables also consider the difference between low and moderate adaptation. Published literature on the benefits of adaptation rarely express the change in risk as a function of global warming, so expert judgement has been used. Broad regional risks may underestimate local risks. Moderate adaptation 'buys time'—it can increase the global warming level associated with some risk categories. Moderate adaptation includes both incremental and transformational options.

Global-average surface warming relative to 1850–1990 under the five illustrative scenarios

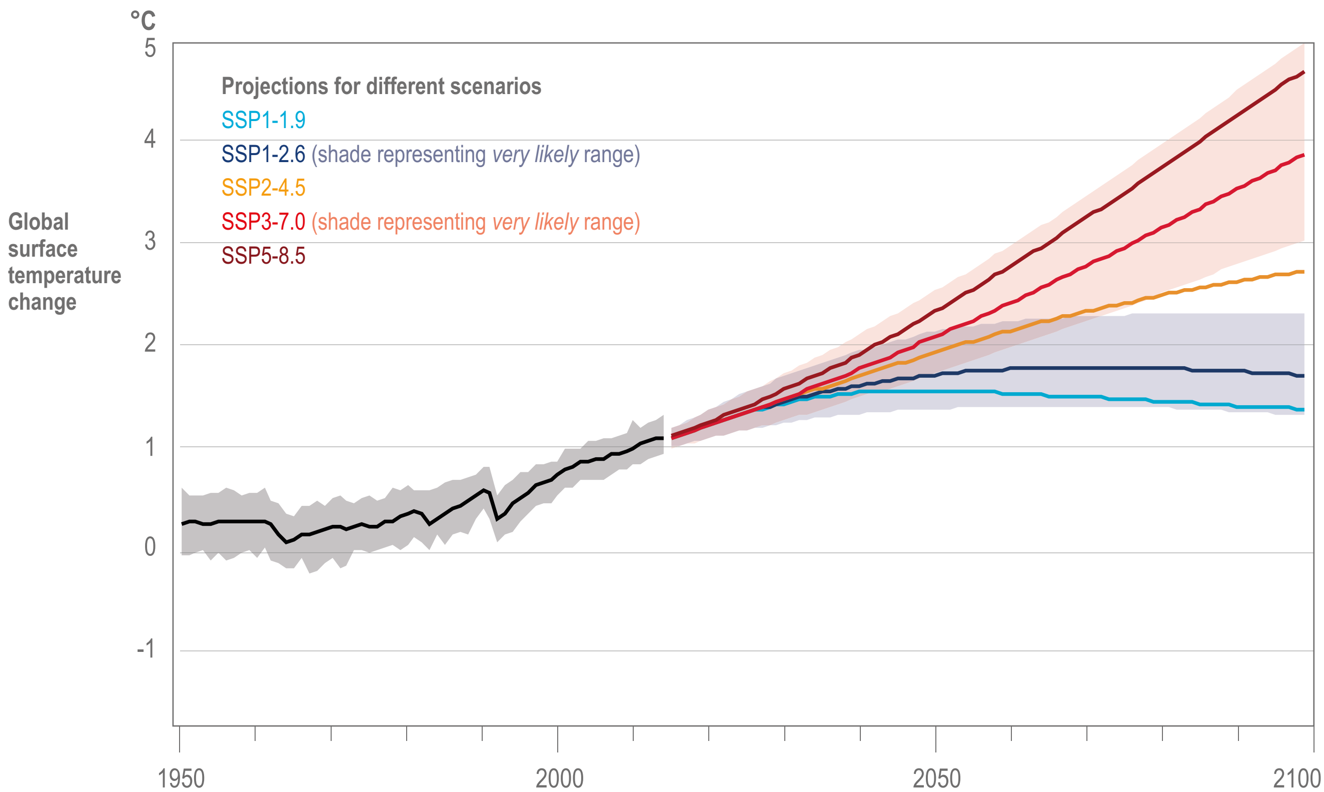

Figure SM11.2a | Global average surface warming relative to 1850–1990 under the five illustrative scenarios. Source: IPCC (2021) WGI Figure SPM.8.

Projected regional changes in annual average maximum and minimum temperature, precipitation and daily maximum precipitation for 1.5, 2.0 and 4.0°C Global Warming relative to 1850–1900

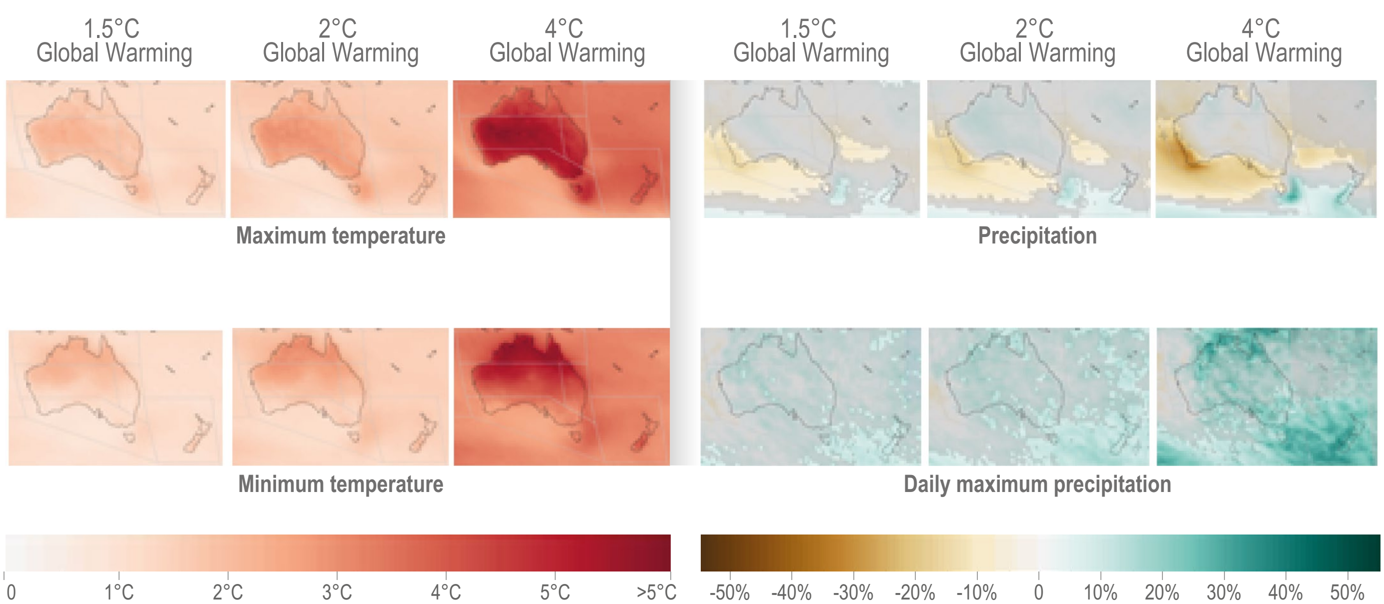

Figure SM11.2b | Projected regional changes in annual average maximum and minimum temperature, precipitation and daily maximum precipitation for 1.5°C, 2.0°C and 4.0°C global warming relative to 1850–1900. Source: IPCC WGI Australasia factsheet (IPCC, 2021).

Table SM11.2a | Changes in global surface temperature, which are assessed based on multiple lines of evidence, for selected 20-year time periods and five illustrative emissions scenarios. Temperature differences are relative to the average global surface temperature for the period 1850–1900. Source: IPCC (2021) WGI Table SPM.1.

	Near term, 2021–2040		Mid-term, 2041–2060		Long term, 2081–2100	
Scenario	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)
SSP1-1.9	1.5	1.2 to 1.7	1.6	1.2 to 2.0	1.4	1.0 to 1.8
SSPI-2.6	1.5	1.2 to 1.8	1.7	1.3 to 2.2	1.8	1.3 to 2.4
SSP2-4.5	1.5	1.2 to 1.8	2.0	1.6 to 2.5	2.7	2.1 to 3.5
SSP3-7.0	1.5	1.2 to 1.8	2.1	1.7 to 2.6	3.6	2.8 to 4.6
SSP5-8.5	1.6	1.3 to 1.9	2.4	1.9 to 3.0	4.4	3.3 to 5.7

Table SM11.2b | Loss and degradation of coral reefs and associated biodiversity and ecosystem service values in Australia due to ocean warming and marine heatwaves.

Transition in risk (colour change in Figure 11.6)	Description/rationale/references, no/low adaptation scenario	Description/rationale/references, moderate adaptation scenario
Undetectable to moderate risk	The transition occurred around 0.3°C because – Wide-scale bleaching of the Great Barrier Reef (GBR) was first recorded in the 1980s (AIMS, 2021), and global warming reached 0.3°C in 1980 (IPCC, 2021); – Globally, the median return time between pairs of severe bleaching events since 1980 is 5.9 years (Hughes et al., 2018a).	The transition occurred around 0.3°C because moderate adaptation options were limited.
Moderate to high risk	The transition occurred around 0.5°C because – Mass bleaching events were evident in 1998, 2002, 2006 and 2008–2011 (AIMS, 2021), and global warming reached 0.5°C in 1990 (IPCC, 2021); – The cumulative impacts of tropical cyclones, marine heatwaves and regular outbreaks of coral-eating crown-of-thorns starfish (CoTS) have severely depleted coral cover (Condie et al., 2021).	The transition occurred around 0.5°C because moderate adaptation options were limited.
High to very high risk	The transition occurred around 1.0°C because – Multiple thermal stress events between 2011 and 2020 caused significant bleaching and loss of corals, and global warming reached 1.0°C in 2010 (IPCC, 2021); – Bleaching of Ningaloo Reef in Western Australia in 2011 occurred due to a marine heatwave (Moore et al., 2012); – Three marine heatwaves occurred on the GBR from 2016 to 2020 (BoM, 2020); – 29% of GBR coral reef cover was catastrophically impacted by the 2016 marine heatwave between March and November (Hughes et al., 2018b); – In 2017, the central third of the GBR was severely affected, with a cumulative loss over the 2016 and 2017 events of close to half of the corals in shallow-water habitats across the northern two-thirds of the reef (Hughes et al., 2019b); – The 2016–2017 mass bleaching events led to an unprecedented shift in the composition of GBR coral assemblages, transforming the northern and middle sections of the reef system to a highly degraded state (Hughes et al., 2019b); – Coral recruitment to the GBR in 2018 was reduced to only 11% of the long-term average (Hughes et al., 2019a); – Bleaching is projected to occur annually after 2044 under RCP 8.5 and 2051 under RCP4.5 (Heron et al., 2017); – A 3°C global warming would result in over six times the 2016 level of thermal stress on the GBR (Lough et al., 2018).	The transition may occur around 1.2°C because moderate adaptation includes – Natural recovery of coral reefs after repeated disturbance events is slow (IPCC, 2019), and it takes at least a decade after each bleaching event for the very fastest growing corals to recover (Osborne et al., 2017); – The Australian government investment of $1.9 billion to support the GBR through science and practical environmental outcomes includes reducing other anthropogenic pressures (CoA, 2019); – Achieving the 1.5°C Paris Agreement target would be insufficient to prevent more frequent mass bleaching events (Lough et al., 2018), but it may reduce their occurrence (Heron et al., 2017), and the occurrence of warming events similar to the 2016 bleaching could be reduced by 25% (King et al., 2017); – Interventions could include reducing flood plume impacts, expanding control of Crown of Thorns Starfish (CoTS) populations, stabilizing coral rubble, managing solar radiation and introducing heat-tolerant coral strains. Without intervention, all climate scenarios result in precipitous declines in GBR coral cover over the next 50 years. The most effective strategies for delaying decline were combinations that protected coral from both predation (CoTS control) and thermal stress (solar radiation management) deployed on a large scale. Successful implementation could expand opportunities for climate action, natural adaptation and socioeconomic adjustment by at least one to two decades (Condie et al., 2021).

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Table SM11.2c | Loss of kelp forests in southern Australia and southeast New Zealand due to ocean warming, marine heatwaves and overgrazing by climate-driven range extensions of herbivore fish and urchins.

Transition in risk (colour change in Figure 11.6)	Description/rationale/references, no/low adaptation scenario	Description/rationale/references, moderate adaptation scenario
Undetectable to moderate risk	The transition occurred around 0.5°C because – The decline in giant kelp in Tasmania, Australia, was first documented in 1990 (Wahl et al., 2015) and global warming reached 0.5°C in 1990 (IPCC, 2021).	The transition occurred around 0.5°C because moderate adaptation options were limited.
Moderate to high risk	The transition occurred around 1.0°C because – impacts became more widespread after 2010, and global warming reached 1.0°C in 2010 (IPCC, 2021); – Extreme climatic events in Australia from 2011 to 2017 led to abrupt and extensive mortality of key habitat-forming organisms—corals, kelps, seagrasses and mangroves—along more than 45% of the continental coastline of Australia (Babcock et al., 2019); – Less than 10% of giant kelp in Tasmania, Australia, remained by 2011 due to ocean warming and change in the East Australian Current (Wahl et al., 2015; Butler et al., 2020), with giant kelp being listed as endangered in 2012; – On the east coast of Australia, extreme marine heatwaves and an increase in tropical herbivores during 2002–2011 (associated with the heatwave) led to a loss of kelp forests in a study area spanning 25-km in latitude (Vergés et al., 2016) and a 100-km range contraction of extensive kelp forests from 2001 to 2015 (Wernberg et al., 2016); – Loss of bull kelp (*Durvillaea)* populations in southern New Zealand were subsequently replaced by the introduced kelp *Undaria* following the 2017–2018 heatwave when sea and air temperatures exceeded 23°C and 30°C respectively (Salinger et al., 2019; Thomsen et al., 2019; Salinger et al., 2020).	The transition occurred around 1.0°C because moderate adaptation options were limited.
High to very high risk	The transition occurs around 1.5°C because – Kelp forests are expected to face growing risks at 1.5°C global warming because of loss of habitat (IPCC, 2018); – In the transition to 1.5°C of global warming, changes to water temperatures are expected to drive some species (e.g. plankton, fish) to relocate to higher latitudes, but other ecosystems (e.g. kelp forests) are relatively less able to move and are projected to experience high rates of mortality and loss (IPCC, 2018); – Native kelp is projected to further decline in southern New Zealand with warming seas (Section 11.3.2); – Kelp range contracts and shifts poleward (Chapter 3) as temperatures become too warm and herbivory increases (Vergés et al., 2016; Wernberg et al., 2016).	The transition occurs around 1.7°C because moderate adaptation options include – Reducing local stressors, local restoration and transplantation of heat-tolerant phenotypes (Chapter 3).

Table SM11.2d | Loss of alpine biodiversity in Australia due to less snow

Transition in risk (colour change in Figure 11.6)	Description/rationale/references, no/low adaptation scenario	Description/rationale/references, moderate adaptation scenario
Undetectable to moderate risk	The transition occurred around 0.3ºC because – The decline in snow metrics became evident from the 1980s, and global warming was 0.3°C in 1980 (IPCC, 2021); – At Mt Hotham, Mt Buller and Falls Creek (1638–1760 m elevation), annual maximum snow depth decreased 37% from 1988 to 2013 (Fiddes et al., 2015); – At Spencers Creek (1830 m elevation) in NSW, annual maximum snow depth decreased 10% and length of snow season decreased 5% during 2000–2013 relative to 1954–1999 (Pepler et al., 2015); – Snow depths were 15% lower during 2001–2010 compared to 1961–1990 (Davis, 2013); – At Rocky Valley Dam (1650 m elevation) in Victoria, annual maximum snow depth decreased 5.7 cm/decade from 1954 to 2011 (Bhend et al., 2012); – Annual maximum snow depth declined 10% from 1962 to 2002 (Nicholls, 2005).	The transition occurred around 0.3°C because moderate adaptation options were limited.
Moderate to high risk	The transition occurred around 1°C because – Shifts in alpine species became evident after 2010, and global warming reached 1.0°C in 2010 (IPCC, 2021); – Loss of snow-related habitat occurs for alpine zone endemic and obligate species (Thompson, 2016); – Dominant vegetation shifts with a decline in grasses and other graminoids and an increase in forb and shrub cover in Bogong High Plains, Victoria, Australia (Hoffmann et al., 2019); – Interactions change within and among three key alpine taxa related to food supply and vegetation habitat resources: The mountain pygmy-possum (*Burramys parvus*), the mountain plum pine (*Podocarpus lawrencei*) and the bogong moth (*Agrostis infusia*) (Hoffmann et al., 2019).	The transition occurred around 1.2°C because – Reducing non-climatic stressors can offset some of the loss of habitat (Ballantyne et al., 2014; Driscoll et al., 2019); – There is nowhere for species to migrate to beyond mountain tops as temperatures increase and colder high-elevation climate envelopes contract. This presents unique challenges to the conservation of alpine biodiversity (Love et al., 2019); – Where species are isolated or without the ability to propagate and colonise emerging areas of suitable habitat, assisted relocation may be necessary (Love et al., 2019).

Transition in risk (colour change in Figure 11.6)	Description/rationale/references, no/low adaptation scenario	Description/rationale/references, moderate adaptation scenario
High to very high risk	The transition occurs around 2°C because – Risks become very high by the year 2050, when global warming is projected to reach about 2°C (IPCC, 2021); – By 2050, maximum snow depth may decline 30–70% relative to 1990 (SRES B1) and 45–90% (SRES A1FI) at Falls Creek and Mt Hotham (Bhend et al., 2012); – By 2050, maximum snow depth may decline 40–80% relative to 1990 (SRES B1) and 50–100% (SRES A1FI) at Mt Buller and Mt Buffalo (Bhend et al., 2012); – Loss of alpine vegetation communities (snow patch feldmark and short alpine herbfields) and increased stress on snow-dependent plant and animal species which changes suitability for invasive species (Slatyer, 2010; Morrison and Pickering, 2013; Williams et al., 2015; Harris et al., 2017); – Alpine vegetation communities are projected to experience 21–70% change in species composition in the distant future (2060 to 2079). Alpine herbfields, montane bogs and fens, grassy woodlands and wet sclerophyll forests are projected to decrease in area and compositional suitability as climatic conditions transition to those better suiting species of woodland and dry sclerophyll forests, which are predicted to expand accordingly (Love et al., 2019); – Key flora species are predicted to be impacted by future changes in climate, including plants listed as critically endangered: the black-hooded sun orchid (*Thelymitra atronitida*), Kelton's leek orchid (*Prasophyllum keltonii*) and *Prasophyllum bagoense* (Love et al., 2019); – Other threatened flora species predicted to be impacted are pale pomaderris, suggan buggan mallee, feldmark grass, anemone buttercup, austral pillwort, mauve burr-daisy, slender greenhood, Max Mueller's burr-daisy, shining cudweed, leafy anchor plant, Monaro golden daisy, slender greenhood, Kiandra leek orchid (Love et al., 2019); – Mammals from habitats predicted to be most impacted by future climate change include southern myotis (*Myotis macropus*), eastern pygmy possum (*Cercartetus nanus*), mountain pygmy possum (*Burramys parvus*), broad-toothed rat (*Mastacomys fuscus*), smoky mouse (*Pseudomys fumeus*), spotted-tailed quoll (*Dasyurus maculatus*) and brush-tailed rock-wallaby (*Petrogale penicillate*) (Love et al., 2019); – The Australian painted snipe (*Rostratula australis*) is an endangered bird species that occupies montane lakes and bogs and fens. These areas are likely to contract under the projected future climate, potentially placing the snipe at greater risk of habitat loss. Other bird species listed as vulnerable are projected to be impacted by climate change (Love et al., 2019); – Sub-alpine woodlands, alpine heaths and herb fields and alpine bogs and fens are habitat for several species of frogs listed as critically endangered. These vegetation classes also provide habitat for the endangered alpine she-oak skink (*Cyclodomorphus praealtus*) and the Guthega skink (*Liopholis guthega*). These habitats are predicted to experience large change by 2060–2079. It is predicted that the southern corroboree frog (*Pseudophryne corroboree*) and alpine tree frog (*Litoria verreauxii alpina*) will also be severely impacted (Love et al., 2019); – For 2060 to 2079, it is projected that some areas of NSW will be 30–60% less bioclimatically suitable for the alpine species they currently support (Love et al., 2019).	The transition occurs at 2.2°C because – Reducing non-climatic stressors can offset some habitat loss (Ballantyne et al., 2014; Driscoll et al., 2019); – There is nowhere for species to migrate to beyond mountain tops as temperatures increase and colder high-elevation climate envelopes contract; this presents unique challenges to the conservation of alpine biodiversity (Love et al., 2019); – Where species are isolated or without the ability to propagate and colonise emerging areas of suitable habitat, assisted relocation may be necessary (Love et al., 2019).

Table SM11.2e | Transition or collapse of alpine ash, snowgum woodland, pencil pine and northern jarrah forests in southern Australia due to hotter and drier conditions with more fires

Transition in risk (colour change in Figure 11.6)	Description/rationale/references, no/low adaptation scenario	Description/rationale/references, moderate adaptation scenario
Undetectable to moderate risk	The transition occurred at 0.3°C because – Hotter and drier conditions since the 1980s have affected some forests in southern Australia, and global warming was 0.3°C in 1980 (IPCC, 2021); – An increase in the number of extreme fire weather days from July 1950 to June 1985 compared to July 1985 to June 2020, especially in the south and east, was partly attributed to climate change (BoM and CSIRO, 2020); – Declining rainfall in southern Australia over the past 30 years has led to drought-induced canopy dieback across a range of forest and woodland types (Hoffmann et al., 2019); – Australia's mega fires of 2019–2020 burnt between 5.8 and 8.1 million hectares of mainly temperate broadleaf forest and woodland, with substantial areas of rainforest also impacted, and were unprecedented in their geographic location, spatial extent and forest types burnt (Boer et al., 2020; Nolan et al., 2020; Collins et al., 2021), showing an imprint of anthropogenic climate change (Abram et al., 2021; van Oldenborgh et al., 2021) with significant consequences for wildlife (Hyman et al., 2020; Nolan et al., 2020; Ward et al., 2020) and flow-on impacts for aquatic fauna (Silva et al., 2020); – Jarrah forests of southwestern Australia have experienced tree mortality and dieback from long-term precipitation decline and acute heatwave-compounded drought (Wardell-Johnson et al., 2015; Matusick et al., 2018); – Local extinctions and replacement of dominant canopy tree species and replacement by woody shrubs occurred because seeders had insufficient time to reach reproductive age (alpine ash) or vegetative regeneration capacity was exhausted (snow gum woodlands) (Slatyer, 2010; Bowman et al., 2014; Fairman et al., 2016; Harris et al., 2018; Zylstra, 2018); – Death of fire-sensitive tree species from unprecedented fire events (palaeo-endemic pencil pine forest growing in sphagnum, Tasmania, killed by lightning-ignited fires in 2016) (Hoffmann et al., 2019).	The transition occurred at 0.3°C because moderate adaptation options include – Increased resources and capacity to extinguish wildfires during extreme fire weather conditions (CoA, 2020b); – Avoiding and reducing forest degradation from inappropriate forest management practices and land use (Lindenmayer and Taylor, 2020a); – Targeted fuel-reduction burns (Gibbons et al., 2012; Lindenmayer and Taylor, 2020a).
Moderate to high risk	The transition occurs around 1.7°C because – Risks become high by the year 2050 for low emissions (RCP2.6), and global warming by 2050 is projected to be 1.7°C for RCP2.6 (IPCC, 2021); – By 2050 for RCP2.6, warming in southern and eastern Australia is projected to be 0.7°C–1.5°C (median ~1.1 C) from the 1986–2005 baseline, rainfall change is projected to be –15 to +2% (median approx. –7%) in southern Australia and –13 to +7% (median approx. –3%) in eastern Australia, and the number of severe fire weather days is projected to increase by 5 to 35% (median approx. +20%); – An increase in fire frequency prevents recruitment of obligate seeder resulting in changing dominant species and vegetation structure including long-lasting or irreversible shift in formation from tall wet temperate eucalypt forests dominated by obligate seeder trees (e.g. alpine ash) to open forest or, in the worst case, to shrubland (Doherty et al., 2017; Zylstra, 2018; Bowman et al., 2019; Naccarella et al., 2020); – Tree line stasis or regression for snow gum forests (Doherty et al., 2017; Bowman et al., 2019; Naccarella et al., 2020).	The transition occurs around 2.0°C because moderate adaptation options include – Increased resources and capacity to extinguish wildfires during extreme fire weather conditions (CoA, 2020b); – Avoiding and reducing forest degradation from inappropriate forest management practices and land use (Lindenmayer and Taylor, 2020b); – Targeted fuel-reduction burns (Gibbons et al., 2012; Lindenmayer and Taylor, 2020b).
High to very high risk	The transition occurs around 2.4°C because – Risks become very high by the year 2050 for high emissions (RCP8.5), and global warming by 2050 is projected to be 2.4°C for RCP8.5 (IPCC, 2021); – By 2050 for RCP8.5, warming in southern and eastern Australia is projected to be 1.3°C–2.3°C (median around 1.8°C) from 1986–2005 baseline, rainfall change is projected to be –14 to +3% (median around -6%) in southern Australia and –17 to +8% (median around -5%) in eastern Australia, and the number of severe fire weather days is projected to increase by 10 to 70% (median around +40%) (Table 11.3a); – If the high end of fire weather conditions for 2060–2080 eventuate for south east Australia (Clarke and Evans, 2019), stand-killing wildfires could occur at a severity and frequency greater than the regenerative capacity of seeders (Enright et al., 2015; Clarke and Evans, 2019); – Altered climatic regimes may reduce the extent of mountain ash forest by up to 80% by 2080 (Lindenmayer and Sato, 2018).	The transition occurs around 3.0°C because moderate adaptation options include – Increased capacity to extinguish wildfires during extreme fire weather conditions (CoA, 2020b); – Avoiding and reducing forest degradation from inappropriate forest management practices and land use (Lindenmayer and Taylor, 2020b); – Targeted fuel-reduction burns (Gibbons et al., 2012; Lindenmayer and Taylor, 2020b).

Table SM11.2f | Loss of natural and human systems in low-lying coastal areas due to sea level rise (SLR)

Transition in risk (colour change in Figure 11.6)	Description/rationale/references, no/low adaptation scenario	Description/rationale/references, moderate adaptation scenario
Undetectable to moderate risk	The transition occurs around 0.7°C because – Moderate risks have been detected in recent decades, and global warming reached 0.7°C in 2000 (IPCC, 2021); – SLR averaged 2.4 mm yr^{-1} in 1961–2018 around New Zealand, including vertical land motion (Bell and Hannah, 2019), and averaged 3.4 mm yr^{-1} in 1992–2019 around Australia based on satellite altimetry (Watson, 2020); – In Australia, the current value of existing residential buildings at risk from inundation is AUD$41–63 billion. Many facilities supporting the delivery of community services are within 200 m of the coastline, including 258 police, fire and ambulance stations, 5 power stations/sub-stations, 75 hospitals and health services, 41 landfill sites, 3 water treatment plants and 11 emergency service facilities (DCCEE, 2011); – In New Zealand, 72,000 people and 50,000 buildings (with a NZD$12.4 billion replacement value) are currently exposed to a 1-in-100-year extreme sea level event (Paulik et al., 2020); – In New Zealand, in 2003–2011, subsidence of about 5 mm yr^{-1} occurred along the northeast coast of the North Island and 2–3 mm yr^{-1} near the top of the South Island, exacerbating the impacts of SLR (Levy et al., 2020); – Nuisance and extreme coastal flooding have increased in New Zealand in recent decades off a 0.2 m SLR increase since 1900 (PCE, 2015; Stephens et al., 2017; Stephens, 2015); – Climate-related impacts on Aboriginal and Torres Strait Islander Peoples, traditional estates and cultures have been observed. For example, loss of biocultural diversity, nutritional changes through the availability of traditional foods and forced diet change, water security and loss of land through erosion and SLR (Table 11.10) (TSRA, 2018); – Remote Indigenous communities in northern Australia and communities living on the low-lying Torres Strait Islands are particularly vulnerable to SLR. Some Torres Strait communities are affected under current king tide conditions (DCCEE, 2011); – In Australia, the coastal systems most at risk are estuaries and associated wetlands, coral reefs, constrained tidal flat communities and saltmarshes, and beaches where there is a lack of sediment for replenishment (DCCEE, 2011).	The transition occurs around 0.7°C because moderate adaptation includes – Reactive and incremental actions (e.g., clean-up responses after coastal flooding events) (Rouse et al., 2017); – New or upgraded buildings with minimum floor levels in design, development and planning standards (MfE, 2017); – Protection and improved management of coastal habitats (Lundquist et al., 2011).

Transition in risk (colour change in Figure 11.6)	Description/rationale/references, no/low adaptation scenario	Description/rationale/references, moderate adaptation scenario

Moderate to high risk	The transition occurs around 1.5°C–2.5°C because
	
	– High risks start at around a 0.2 to 0.3 m local SLR relative to 1986–2005;
	– A 0.20 to 0.23 m local SLR is associated with 2050 RCP2.6, while a 0.25 to 0.28m local SLR is associated with 2050 RCP8.5 (MfE, 2017);
	– Global warming is 1.7°C by 2050 for RCP2.6 and 2.4°C by 2050 for RCP8.5 (IPCC, 2021), which has been rounded to 1.5°C–2.5°C for this risk transition;
	– In New Zealand, local SLR will be faster than regional averages due to land subsidence along the Waikato Coast, Hauraki Plains, mid-lower eastern North Island, Marlborough, Nelson, Wellington and Dunedin (Levy et al., 2020);
	– For a rise in relative sea level of 0.3 m in New Zealand, the 'present-day' 1-in-100-year storm tide levels (PCE, 2015) may occur about
	– every 4 years at the port of Auckland,
	– every 2 years at the port of Dunedin,
	– every year at the port of Wellington,
	– every year at the port of Christchurch;
	– An increase in the SLR allowance for a storm tide event to maintain security for a 1-in-100-year event by 2050 is about 0.2 m (RCP2.6) to 0.25 m (RCP8.5) in Australia (McInnes et al., 2015);
	– Coastal flooding is projected to become more frequent by mid-century with mid-range sea-level rise (Table 11.3b) (Hunter, 2012; Steffen et al., 2014; McInnes et al., 2016; Stephens et al., 2018, 2020; Hague et al., 2019; Paulik et al., 2020);
	– Property and infrastructure damage will increase (Steffen et al., 2014; PCE, 2015; Harvey, 2019; LGNZ, 2019), for example in New Zealand, the value of buildings exposed to coastal inundation (1% annual exceedance probability) could increase by NZ$5.10 billion for a 0.2 m SLR and NZ$7.65 billion for a 0.3 m SLR (Paulik et al., 2020);
	– Cultural and archaeological sites are disturbed and projected to compound with several hazards over this century in New Zealand and Australia (Bickler et al., 2013; Birkett-Rees et al., 2020);
	– Tropical mangroves cannot keep pace with a rate of SLR > 6 mm yr^{-1} (Saintilan et al., 2020);
	– Increasing flood risk and water insecurity, with health and well-being impacts on Australia's small northern islands, especially Torres Strait Islands (Steffen et al., 2014; McInnes et al., 2016; McNamara et al., 2017).
		The transition occurs around 2.0°C–3.0°C because moderate adaptation includes
		
		– Temporary ecosystem-based adaptation (McInnes et al., 2015);
		– A shift from gravity to pumped stormwater and groundwater systems (Kool et al., 2020);
		– Land ownership models that incorporate risk and facilitate ongoing SLR (Storey et al., 2017);
		– Insurance premium incentives that reduce risk and insurance withdrawal for high-risk areas (11.3.8) (Storey and Noy, 2017);
		– Habitats undergoing coastal squeeze (Tait and Pearce, 2019; Swales et al., 2020);
		– Protection measures such as beach nourishment and dune rehabilitation (Rouse et al., 2017);
		– Planning legislation and long-term spatial housing and infrastructure plans, implemented to avoid further developments in hazard-prone areas and adjustments to existing developments, including accommodation and managed retreat (MfE, 2017);
		– Protection measures such as large-scale engineering options (Haasnoot et al., 2021) (including protection for low-lying CBD areas of major cities);
		– Managed retreat from very high-risk locations (Kool et al., 2020; Lawrence et al., 2020c);
		– Effectiveness thresholds as illustrated in dynamic adaptation pathways diagrams (Figure 11.7);
		– Measures that can be evaluated within an options framework, which could include (MfE, 2017)
		  – soft measures, such as dune restoration, wetland enhancement or creation, and beach nourishment and areas for biodiversity change to occur (e.g. migration of species);
		  – land use change, including transfer of development potential and land acquisition that enables reassignment of land uses through zoning for example;
		  – planning policies and rules through the Resource Management Act at regional and district levels, based on aspects such as types and densities of land uses, building restrictions and coastal setbacks;
		  – staged retreat, which could initially include moving buildings back on the property, an alternative lot to relocate to when a trigger is reached (e.g. Whakatāne District Plan) or rerouting a coastal road;
		  – structural options, such as seawalls, groynes, raised roads and building platforms and storm surge barriers.

High to very high risk	The transition occurs around 2.5°C–3.5°C because – Very high risks start at around 0.5 m of local SLR relative to 1986–2005; – A 0.5 m local SLR is associated with 2090 RCP4.5; – Global warming is 2.1–3.5°C by 2090 for RCP4.5 (IPCC, 2021), which has been narrowed to 2.5°C–3.5°C for this risk transition; – In New Zealand, the value of buildings exposed to coastal inundation (present-day 1-in-100-year storm tides) could increase by NZD$12.75 billion for a 0.5 m SLR and NZD$25.5 billion for a 1.0 m SLR (Paulik et al., 2020); – In Australia, for a 0.5 m SLR, events that now happen every 10 years would happen about every 10 days, and the current 1-in-100-year event could occur several times a year (DCCEE, 2011); – In Australia, 157,000–247,600 residential buildings are at risk for a 1.1 m SLR. The asset value of exposed residential, commercial and light industrial buildings and transport infrastructure is AUD$164–226 billion (DCCEE, 2011); – In Australia, damage from coastal inundation is projected to increase 111% between 2020 and 2100, especially in Queensland and NSW (Mallon et al., 2019); – The internationally important river–floodplains of the Kakadu Region in northern Australia are at risk from invasive species and future SLR–saltwater inundation. Coastal landscapes and socioecological systems in the region will be very different by 2100 as a result of SLR; freshwater ecosystems will transform into marine-dominated ecosystems (Bayliss et al., 2018).	The transition occurs around 3.0°C–4.0°C because moderate adaptation includes – Tidal barrages to protect some city or high-value locations (Haasnoot et al., 2021); – Planning legislation and long-term spatial housing and infrastructure plans to avoid further developments in hazard-prone areas and adjustments to existing developments, including accommodation and managed retreat (MfE, 2017); – Managed retreat, undertaken from very high-risk locations (Lawrence et al., 2020c; Haasnoot et al., 2021).

Table SM11.2g | Disruption and decline in agricultural production and increased stress in rural communities in southwestern, southern and eastern mainland Australia.

Transition in risk (colour change in Figure 11.6)	Description/rationale/references, no/low adaptation scenario	Description/rationale/references, moderate adaptation scenario
Undetectable to moderate risk	The transition occurs around 0.3°C because – There is evidence of moderate risk from 1980 onward, and global warming was 0.3°C in 1980 (IPCC, 2021); – Australia has become warmer with more extreme high temperatures and more extreme fire weather days (1985–2020 relative to 1950–1985) and more extreme rainfall since 1980 (BoM and CSIRO, 2020); – April–October rainfall has decreased 16% in southwest Australia since 1970 and has decreased 12% in southeast Australia since the late 1990s (BoM and CSIRO, 2020); – Streamflow has generally decreased in southern Australia since the mid-1970s (Zhang et al., 2016), largely due to a decline in cool-season rainfall (which has been partly attributed to climate change) (Timbal and Hendon, 2011; Post et al., 2014; Hope et al., 2017; DELWP, 2020); – The large decline in river flows during the 1997–2009 'Millennium' drought in southeast Australia resulted in low irrigation water allocations, severe water restrictions and major environmental impacts (Potter et al., 2010; Chiew and Prosser, 2011; Leblanc et al., 2012; van Dijk et al., 2013); – Climate conditions between 2000–2001 and 2014–2015 reduced national wheat yields by around 12% relative to the long-term average (16% in Western Australia and 15% in Victoria) (ABARES, 2017); – Drier winters have decreased wine grape yield and delayed budburst in Australia (Bonada et al., 2020); – Smoke from the 2019–2020 fires caused significant taint damage, especially because the fires occurred early in the grape growing season and reoccurred (Jiang et al., 2021); – Drought and its physical and social flow-on effects have caused financial and emotional stress in farm households and communities (Austin et al., 2018; Bryant and Garnham, 2018; Yazd et al., 2019); – In many regions warming is increasing winter growth, whereas warmer and drier conditions lead to reduction in spring growth (Perera et al., 2020); – Heat load in cattle leads to reduced growth rates and reproduction, and extreme heat waves can lead to death (Lees et al., 2019); – Temperatures over 32°C reduce ewe and ram fertility, along with lamb birth weight (van Wettere et al., 2021); – Extreme heat is increasingly threatening liveability in some rural areas in Australia (Turton, 2017); – Long supply chains, poorly maintained infrastructure, social disadvantage and poor health and lack of skilled workers (Eldridge and Beecham, 2018; Mathew et al., 2018b; Rolfe et al., 2020) are contributing to serious stress and disruption (Smith and Lawrence, 2014; Kiem et al., 2016); – In many rural settlements, population ageing and reliance on an overstretched volunteer base for recovery from extreme events are increasing vulnerability to climate change (Astill and Miller, 2018; Davies et al., 2018); – Recovery from long, intense, more frequent and compounding climatic events in rural areas has been disrupted by the erosion of natural, financial, built, human and social capital (De et al., 2016; Sheng and Xu, 2019); – Delayed recovery from extreme climatic events has been compounded by long-term displacement, which in turn prolongs the impacts (Matthews et al., 2019); – Severe droughts have contributed to poor health outcomes for rural communities, including extreme stress and suicide (Beautrais, 2018; Perceval et al., 2019); – In Australia, competition between water users has left some rural communities suffering from extreme water shortage and insecurity with associated health impacts (Wheeler et al., 2018; Judd, 2019) (Box 11.3).	The transition occurs around 0.3°C because moderate adaptation includes – New smart technologies that reduce resource inefficiencies, professional knowledge and skills development, new farmer and community networks and diversification of business and household income (Ghahramani et al., 2015; De et al., 2016); – Adaptation by farmers to drier and warmer conditions through more effective capture of non-growing-season rainfall (e.g. stubble retention to store soil water), improved water use efficiency and matching sowing times and cultivars to the environment (Kirkegaard and Hunt, 2011; Fitzer et al., 2019); – Later pruning in the grape industry to spread harvest period and partially restore wine balance, with neutral effects on yield and cost (Moran et al., 2019); – The cotton sector shifts sowing dates to avoid financial impacts (Luo et al., 2017); – During years of low water availability, rice growers trade water and/or shift to dry land farming (Mushtaq, 2016).

Transition in risk (colour change in Figure 11.6)	Description/rationale/references, no/low adaptation scenario	Description/rationale/references, moderate adaptation scenario
Moderate to high risk	The transition occurs around 2.0°C because – There is evidence for high risk around 2050 when global warming is 2.0°C for RCP4.5 (IPCC, 2021); – Australian wheat yields may decrease 7% by 2050 for RCP4.5 (Wang et al., 2018); – Median changes in wheat yield by 2050 for RCP4.5 under a most likely climate scenario are projected to be –13 to –23% in the southwest, 0 to –7% in South Australia, with increases and decreases in the east (Taylor et al., 2018); – In temperate fruit, winter chill is projected to further decline (Darbyshire et al., 2016); – Increased heat stress in livestock by 31–42 d yr^{-1} by 2050 (Nidumolu et al., 2014); – The distribution of existing and new pests and diseases is projected to increase (e.g. new tick- and mosquito-borne diseases such as Bovine ephemeral fever (Kean et al., 2015).	The transition occurs around 2.5°C because moderate adaptation includes – Earlier sowing of wheat and a longer season cultivar, which may increase yield by 2–4% by 2050, with a range of –7 to +2% by 2090 (Wang et al., 2018); – Later pruning in the grape industry to spread harvest period and partially restore wine balance, with neutral effects on yield and cost (Moran et al., 2019); – The cotton sector shifts sowing dates to avoid financial impacts (Luo et al., 2017); – During years of low water availability, rice growers trade water and/or shift to dry land farming (Mushtaq, 2016); – Pasture management adaptations for livestock production include deeper rooted pasture species in higher-rainfall regions (Cullen et al., 2014) and drought-tolerant species (Mathew et al., 2018a); – Soil and land management practices, play an important role in ensuring soils can maintain their supporting and regulating services (Orwin et al., 2015); – Managing heat stress in livestock, include altering the breeding calendar, providing shade, altering nutrition and feeding times and switching to more heat-tolerant animal breeds (Chang-Fung-Martel et al., 2017; Lees et al., 2019; van Wettere et al., 2021); – By 2030, warmer and drier conditions decreased national wheat yields by 1% using current technology and practices but yields increased by 18% with optimised adaptation. However, there was substantial regional variation with median yields and gross margins decreasing in 55% of sites (Ghahramani et al., 2015).
High to very high risk	The transition occurs around 2.5°C because – Australian wheat yields may decrease 9% by 2050 for RCP8.5 (Wang et al., 2018) when global warming is 2.4°C (IPCC, 2021); – Median changes in wheat yield by 2050 for RCP8.5 under a most likely climate scenario are projected to be –29 to –33% in the southwest, –2 to –15% in South Australia, with increases and decreases in the east (Taylor et al., 2018); – Median wheat yield changes for the *most likely* scenario by 2090 for RCP4.5 are projected to be –24 to –40% in the southwest, +4 to +4% in South Australia, with increases and decreases in the east (Taylor et al., 2018); global warming by 2090 for RCP4.5 will be 2.7°C (IPCC, 2021); – Median time in drought in southern and eastern Australia increases from about 40% for 20 years centred on 1995 to about 50% for 20 years centred on 2050 for RCP8.5 (Kirono et al., 2020), which corresponds to 2.4°C global warming; – Median wheat yield changes for the *most likely* scenario by 2090 for RCP8.5 are projected to be –33 to –50% in the southwest, –18 to –41% in South Australia, with increases and decreases in the east (Taylor et al., 2018); global warming by 2090 for RCP8.5 is 4.4°C (IPCC, 2021); – The change in runoff by 2060 for RCP8.5 is –40 to +10% in the southeast, –20 to –70% in the southwest, –40 to +25% in the mid-east (most of the Murray Darling Basin) and –40 to +20% in the northeast (Chiew et al., 2017); – Reduced Pasture growth rates of 3–23% by 2070 from late spring to autumn and elevated growth in winter and early spring (Cullen et al., 2014; Chang-Fung-Martel et al., 2017); – A narrowing of grain growing regions is projected with a shift of the inner margin towards the coast under drier and warmer projections (Nidumolu et al., 2012; Fletcher et al., 2020).	The transition occurs around 3.0°C because – While there is potential for agriculture to be located in northern Australia, significant and complex agronomic, environmental, institutional, financial and social challenges need to be overcome for successful transformation (Mathew et al., 2018a).

Table SM11.2h | Increase in heat-related mortality in Australia due to heatwaves.

Transition in risk (colour change in Figure 11.6)	Description/rationale/references, no/low adaptation scenario	Description/rationale/references, moderate adaptation scenario

Undetectable to moderate risk	The transition occurs around 0.5°C because
	
	– Moderate risks became evident around 1990 and global warming reached 0.5°C by 1990 (IPCC, 2021);
	– During 1987–2016, natural disasters caused 971 deaths and 4370 injuries, with more than 50% due to heatwaves (Deloitte, 2017);
	– For Australia's five largest cities combined, the annual mean excess of deaths attributable to temperature over the period 1979–1990 was 175 for the 28°C threshold; people aged 65 years and older were the most vulnerable (Guest et al., 1999);
	– Heatwaves are exacerbated by urban heat islands (UHIs) (Rogers et al., 2018);
	– Other factors likely to exacerbate health impacts in cities and linked to UHIs, such as indoor temperatures of dwellings, use of ventilation, passive and active cooling systems and the location of inhabitants within the hottest parts of buildings, such as upper floors (Heaviside et al., 2016);
	– Increases in heat-related human mortality from 1991 to 2018 in Melbourne, Sydney and Brisbane have been 35% attributed to human-induced warming (Vicedo-Cabrera et al., 2021);
	– For heatwaves defined as the 95th percentile of mean temperature for two or more consecutive days in summer, the relative risk for total mortality at lag 1 day in Brisbane, Melbourne and Sydney was 1.13, 1.10 and 1.06 respectively; elderly, particularly females, were more vulnerable (Tong et al., 2014).
	– Heat-related morbidity and mortality outcomes are influenced by individual vulnerability factors (old age, Indigenous communities, comorbidity, first or later heatwave of season, UHIs (Rocklov et al., 2011; Hall and Crosby, 2020);
	– Temperature thresholds should also be location-specific and may depend on cultural, social and economic adaptation (Liss et al., 2017);
	– Exposure to high temperatures at work is common in Australia, and the health consequences include more accidents, acute heat stroke and chronic disease (Kjellstrom et al., 2016);
	– Extreme heat is associated with decreased mental well-being (Ding et al., 2016);
	– Recent heatwaves have caused high mortality in groups of species such as birds, flying foxes and tree-dwelling mammals (AAS, 2021);
	– Mass mortality of wildlife species above 42°C (e.g. 45,000 flying foxes in southeast Queensland and 50% of one species) (Ratnayake et al., 2019);
	– An analysis of atlas data for zebra finches suggests that population declines associated with very hot conditions are already occurring in the hottest areas (Conradie et al., 2020);
	– Homeless people lack access to temperature-controlled or structurally safe housing and often are excluded from disaster preparation and responses (Every, 2016);
	– Extreme heat is increasingly threatening liveability in some rural areas in Australia (Turton, 2017).
		The transition occurs around 0.5°C because
		
		– Moderate adaptation options include public education, behaviour change, early warning systems (Nitschke et al., 2016), heatwave mitigation plans, building interventions, air conditioning and heat-reducing urban landscapes (Wong et al., 2020; Ebi et al., 2021; Tapper 2021);
		– Air-conditioning was installed in most of Australia's estimated 8 million homes and in most of nearly 18 million registered road vehicles (Expert Group, 2018);
		– Air conditioning in Australian homes reduced mortality in heat waves by up to 80% (Broome and Smith, 2012);
		– Improvements in infrastructures and health care services, together with the implementation of heat-adaptation measures and heat health watch warning systems, likely contributed to improve population adaptation, reducing the impact of heat on mortality and morbidity (Kendrovski et al., 2017);
		– Preventive measures such as heatwave early-warning forecasts have been implemented to prevent temperature-related mortality in developed countries worldwide. Several studies have reported the effectiveness of early heat health warning forecasts or surveillance systems for reducing heat-related mortality by comparing the risks between time periods with and without these preventive measures (Heo et al., 2016);
		– To minimise the health impacts of extreme heat, the Heatwave Plan for Victoria outlines processes to
		  – ensure heat health information and support is readily available to the community, at-risk groups and their carers,
		  – develop partnerships and collaborative arrangements to better respond to heatwaves,
		  – increase understanding of the health impacts of heatwaves on communities and their capacity to respond during heatwaves,
		  – manage public health emergencies during heatwaves more effectively,
		  – develop long-term and sustainable behavioural change to minimise the impacts of heatwaves on health and well-being (DOH, 2011).

Moderate to high risk	The transition occurs around 1.7°C because – High risks are projected by 2050 for RCP2.6, and global warming by 2050 is 1.7°C for RCP2.6 (IPCC, 2021); – Heatwave-related excess deaths in Melbourne, Sydney and Brisbane are projected to increase by about 300 yr^{-1} (RCP2.6) for 50 years centred on 2055 (2031–2080) relative to 142 yr^{-1} during 1971–2020, assuming no adaptation and high population growth (Guo et al., 2018); – By 2030 for RCP4.5 (1.5°C global warming), the average number of days over 40°C is projected to increase by about 50% in capital cities such as Sydney, Melbourne, Brisbane, Adelaide and Perth (CSIRO and BOM, 2015); – Assuming no planned adaptation, the number of heat-related deaths is likely to rise from 1,115 yr^{-1} at present in Adelaide, Melbourne, Perth, Sydney and Brisbane to 2,300 to 2,500 yr^{-1} by 2020, and 4,300 to 6,300 yr^{-1} by 2050, for all SRES emission scenarios, including demographic change (Australia Department of Health and Ageing, 2003).	The transition occurs around 1.9ºC because – Multiple interventions at the landscape, building and individual scales are available to reduce the negative health effects of extreme heat (Jay et al., 2021); – Heatwave-related excess deaths in Melbourne, Sydney and Brisbane are projected to increase by about 200 yr^{-1} (RCP2.6 and RCP8.5) for 50 years centred on 2055 (2031–2080) relative to 142 yr^{-1} during 1971–2020, assuming full adaptation and high population growth (Guo et al., 2018); – Moderate adaptation options include public education, behaviour change, early warning systems, heatwave mitigation plans, building interventions, air-conditioning and heat-reducing urban landscapes (Wong et al., 2020; Ebi et al., 2021; Tapper, In Press); – This is the level of warming at which heat-related human health impacts become severe and widespread, under moderate adaptation scenarios, which should be achievable in Australia and New Zealand, according to expert judgement (Ebi et al., 2021).

Transition in risk (colour change in Figure 11.6)	Description/rationale/references, no/low adaptation scenario	Description/rationale/references, moderate adaptation scenario
High to very high risk	The transition occurs around 2.4ºC because – Very high risks are projected by 2050 for RCP8.5, and global warming by 2050 is 2.4°C for RCP8.5 (IPCC, 2021); – Heatwave-related excess deaths in Melbourne, Sydney and Brisbane are projected to increase by about to 600 yr^{-1} (RCP8.5) for 50 years centred on 2055 (2031–2080) relative to 142 yr^{-1} during 1971–2020, assuming no adaptation and high population growth (Guo et al., 2018); – By 2090 for RCP4.5 (2.7°C global warming), the average number of days over 40°C is projected to more than double in capital cities such as Sydney, Melbourne, Brisbane, Adelaide and Perth (CSIRO and BOM, 2015); – By 2100, the proportion of all deaths attributable to heat in Australia's three largest cities may rise from about 0.5 to 3.2% under RCP 8.5 (Gasparrini et al., 2017); – By 2100, zebra finches' potential exposure to acute lethal dehydration risk will reach around 100 d yr^{-1} in the far northwest of Australia and exceed 20 d yr^{-1} for over 50% of this species' current range (Conradie et al., 2020).	The transition occurs around 2.6°C because – Moderate adaptation options include public education, behaviour change, early-warning systems, heatwave mitigation plans, building interventions, air-conditioning and heat-reducing urban landscapes (Wong et al., 2020; Ebi et al., 2021; Tapper, In Press); – This is accompanied by very high risks of severe impacts, and significant irreversibility or persistence of hazards, combined with limited ability to adapt, according to expert judgement (Ebi et al. 2021).

Table SM11.2i | Cascading, compounding and aggregate impacts on cities, settlements, infrastructure, supply chains and services due to extreme events.

Transition in risk (colour change in Figure 11.6)	Description/rationale/references, no/low adaptation scenario	Description/rationale/references, moderate adaptation scenario
Undetectable to moderate risk	The transition occurred around 0.7°C because – Moderate cascading impacts were documented during a 20-year period centred on 2000, when global warming was 0.7°C (IPCC, 2021); – Climate impacts are cascading, compounding and aggregating across sectors and systems due to their interactions between risks (Pescaroli and Alexander, 2016; Challinor et al., 2018; Zscheischler et al., 2018; Steffen et al., 2019; AghaKouchak et al., 2020; CoA, 2020b; Lawrence et al., 2020b; Simpson et al., 2021); – In recent decades, there has been widespread and pervasive damage to property and infrastructure, supply chain and service disruption and major impacts on ecosystems and their services (CSIRO, 2018; CoA, 2020a; Lawrence et al., 2020b; Simpson et al., 2021); – During 2007–2016, aggregate economic costs associated with Australian natural disasters averaged AUD$18.2 billion yr^{-1} with the largest contributions from floods (AUD$8.8 billion), followed by cyclones (AUD$3.1 billion), hail (AUD$2.9 billion), storms (AUD$2.3 billion) and fires (AUD$1.1 billion) (Deloitte, 2017); – Individual weather-related disaster costs across multiple sectors in Australia have exceeded AUD$4 billion, such as the 2009 fires in Victoria (Parliament of Victoria, 2010), the 2010–2011 floods in South East Queensland (Deloitte, 2017), interconnected across systems, contingent, emergent and uncertain; – In New Zealand, SLR has combined with extreme snow, rainfall and wind events to impact road networks, power and water supply and has impeded interdependent wastewater and storm water services and business activities (Deloitte, 2019; Cradock-Henry et al., 2020; MfE, 2020b); – In New Zealand, the 2007–2008 drought cost NZD$3.2 billion and the 2012–2013 drought cost NZD$1.6 billion, of which about 20% could be attributed to anthropogenic climate change (Frame et al., 2020); – In New Zealand, community and infrastructure services have been periodically overwhelmed during extreme weather events, triggering long-lasting impacts, including homelessness, health incidents and reduced health services (Cusack et al., 2013; Every et al., 2014; Brown et al., 2017; Brookfield and Fitzgerald, 2018; Rychetnik et al., 2019); – Significant impacts on Māori tribal investments in forestry, agriculture, horticulture, fisheries and aquaculture (King et al., 2010; Warmenhoven et al., 2014; RSNZ, 2016; Smith et al., 2017; Awatere et al., 2018; Hardy et al., 2019); – Indigenous Australian Peoples have been especially impacted by multiple and complex forms of loss (Johnson et al., 2021).	The transition occurred around 0.7°C because moderate adaptation included – High-level strategies at the national level, adaptation planning at sub-national levels and new enabling legislation (Table 11.15a, Table 11.15b) (Lawrence et al., 2015; Macintosh et al., 2015; MfE, 2020a); – Australian State and Territory climate change adaptation strategies with plans to address them (Table 11.15a) (Warnken and Mosadeghi, 2018; Harvey and Clarke, 2019; Robb et al., 2019; Elrick-Barr and Smith, 2021); – Implementation at the state level and increasingly at local government level (Table 11.15a) (Jacobs et al., 2016; Warnken and Mosadeghi, 2018); – Some businesses and industry sectors recognizing climate-related risks and adaptation planning (Sections 11.3.4, 11.3.7 and 11.3.10); – New Zealand's Climate Change Response Act in 2019 (revising the 2002 act), which creates a legal mandate for National Climate Change Risk Assessments (first one completed) (MfE, 2020a) and National Adaptation Plans (first in preparation) and a climate change commission to monitor and report on adaptation implementation; – New Zealand's national coastal guidance for adaptation planning to address changing climate risks (Table 11.15b) (MfE, 2017) and several local authorities developed integrated climate change strategies and plans and revised policies and rules to enable adaptation (Table 11.15b); – The NCCARF Coast Adapt portal (2018) provided guidance on coastal adaptation; – Disaster risk reduction being positioned as part of climate change adaptation (Forino et al., 2017, 2019; CDEM, 2019); – Significant investment in disaster response and recovery (11.5.2); – Major inquiries and reports following disasters, recommending ways to improve resilience (Parliament of Victoria, 2010; Queensland Government, 2011; Productivity Commission, 2017; CoA, 2020b); – Heatwave early-warning systems were operational for most Australian capital cities (Nitschke et al., 2016); – Following construction of a levee in Roma cost AUD$23.9 million, flood risk for more than 500 Roma properties was downgraded, and some insurance policyholders have achieved up to a 90% reduction in their premium (Actuaries Institute, 2020); – The Queensland government funding improved the resilience of homes and reduced premiums in cyclone-affected regions via the Household Resilience Programme. The government notes 1749 households from Bundaberg to Cape York Peninsula have already seen insurance premiums reduced by an average of $310 yr^{-1} under the programme (Actuaries Institute, 2020); – The 2010–2011 flooding in eastern Australia resulted in changes to reservoir operations to mitigate floods (QFCI, 2012) and insurance practice to cover flood damages (Phelan, 2011; Phelan et al., 2011; QFCI, 2012; Schuster, 2013); – Adaptation options in urban areas include improved stormwater management (Hettiarachchi et al., 2019; Matteo et al., 2019), ecosystem-based approaches such as retaining floodplains, restoring wetlands and retrofitting existing flood control systems to attenuate flows, and water-sensitive urban design (WSAA, 2016; Radcliffe et al., 2017; Radhakrishnan et al., 2017; Rogers et al., 2020).

Transition in risk (colour change in Figure 11.6)	Description/rationale/references, no/low adaptation scenario	Description/rationale/references, moderate adaptation scenario
Moderate to high risk	The transition occurred around 1.1°C because – Many cascading, compounding and aggregate impacts occurred during the period 2011–2020, when global warming was 1.1°C relative to 1850–1900 (IPCC, 2021); – Cyclone Yasi and the Queensland floods of 2011 cost AUD$6.9 billion (Deloitte, 2016); – The floods of early 2019 in north Queensland cost AUD$5.68 billion (Deloitte, 2019); – The 2019–2020 drought, heatwaves and fires in southern and eastern Australia cost over AUD$8 billion (CoA, 2020b); – Insured losses from weather-related disasters cost almost NZD$1 billion during 2015–2021 (ICNZ, 2021); – Insured losses for the 12 costliest floods in New Zealand cost NZD$471 million between 2007 and 2017, of which 30% could be attributed to climate change (Frame et al., 2018).	The transition occurs around 1.3°C because moderate adaptation includes – A stocktake of impacts and preparedness assessment (CCATWG, 2017); – Large investment in replacement and upgrade of water and wastewater infrastructure to address rising seas, heavy rainfall (Hughes et al., 2021); – Australian Sustainable Finance Initiative & Roadmap (AFSI, 2020); – New Zealand Sustainable Finance Forum Roadmap for Action (TAO, 2020); – Preparation of New Zealand Natural and Built Environment, Strategic Planning and Climate Change Adaptation Acts, including provision for funding and managed retreat (MfE, 2020b); – The New Zealand Climate Change Risk Assessment (MfE, 2020a) catalysed action at a local level; – Systems understanding, network analysis, stress testing and spatial mapping, collaboration, information sharing and interoperability across states, sectors, agencies and value chains, as well as national-scale facilitation (Espada et al., 2015; CoA, 2020b; Cradock-Henry et al., 2020; Jozaei et al., 2020); – Greater network system diversity, modularity, redundancy, adaptability and decentralised control (Sinclair et al., 2017; Sellberg et al., 2018); – Redressing existing pressures and harms to reduce susceptibility and improve the resilience of interdependent systems (11.7.3); – Reducing and managing aggregate risks through strong multi-level leadership, including national and sub-national policies, laws and finance (11.7.3); – Anticipatory governance and agile decision-making to build resilience to cascading and compounding impacts (Boston, 2016; Deloitte, 2016; Steffen et al., 2019; CoA, 2020b; CSIRO, 2020; Lawrence et al., 2020b; MfE, 2020b); – Implementation of Australia's National Disaster Risk Reduction Framework (CoA, 2018), National Recovery and Resilience Agency, and Australian Climate Service (CoA, 2021); – Implementation of the New Zealand National Adaptation Plan and Climate Change Adaptation Act (MfE, 2020a); – Adaptation pathways (Kool, 2020, Ramm 2018) start active phase, including some transformational changes.
High to very high risk	The transition occurs around 2°C because – Very high risks are documented by the year 2050, and global warming by 2050 is 1.7°C for RCP2.6 to 2.4°C for RCP8.5 (IPCC, 2021); – The aggregate impact of a 2°C global warming (relative to 1986–2005) on GDP growth is estimated at –0.6% yr^{-1} for Australia and –0.4% yr^{-1} for New Zealand (Kompas et al., 2018); – In Australia, the aggregate loss of wealth due to climate-induced reductions in agricultural and labour productivity across agriculture, manufacturing and service sectors is projected to exceed AUD$19 billion by 2030 and AUD$211 billion by 2050 for RCP8.5 (Steffen et al., 2019); – In New Zealand, under RCP8.5 and considering the increased severity of uncertain effects, GDP is projected to be 13.6% lower by mid-century (Swiss Re, 2021); – More detailed modelling indicates a loss in Australia's GDP of 3% on average from 2020 to 2070 (RCP8.5), leading to a fall of 6% of GDP by 2070 for 3°C global warming (Deloitte, 2020); – In Australia, the aggregate loss of wealth due to climate-induced reductions in agricultural and labour productivity across agriculture, manufacturing and service sectors is projected to exceed AUD$4 trillion by 2100 for RCP8.5 (Steffen et al., 2019); – In Australia, the total annual cost of damage due to floods, coastal inundation, forest fires, subsidence and wind (excluding cyclones) is estimated to increase 55% between 2020 and 2100 for RCP8.5 (Mallon et al., 2019).	The transition occurs around 2.5°C because moderate adaptation includes – Adaptation pathways (Ramm et al., 2018; Kool et al., 2020), including some transformational changes; – Retreat process continues its active phase (Lawrence et al., 2020a); – Reducing and managing aggregate risks through strong multi-level leadership, including national and sub-national policies, laws and finance (11.7.3); – Anticipatory governance and agile decision-making to build resilience to cascading and compounding impacts (Boston, 2016; Deloitte, 2016; Steffen et al., 2019; CoA, 2020b; CSIRO, 2020; Lawrence et al., 2020b; MfE, 2020b); – Public education, behaviour change, heatwave early-warning systems, heatwave mitigation plans, building interventions, air-conditioning and heat-reducing urban landscapes (Wong et al., 2020; Ebi et al., 2021; Tapper, In Press).

Table SM11.2j | Inability of institutions and governance systems to manage climate risks.

Transition in risk (colour change in Figure 11.6)	Description/rationale/references, no/low adaptation scenario	Description/rationale/references, moderate adaptation scenario
Undetectable to moderate risk	The transition occurs around 0.7°C because – Moderate climate-related failures of institutions and governance became evident around the year 2000, when global warming was around 0.7°C in 2000 (IPCC, 2021); – Failure of institutions and governance systems is documented in current exposure and vulnerability to climate variability and change (Iorns Magallanes et al., 2018; Iorns Magallanes and Watts, 2019); – Institutional and governance failures were highlighted in the Victorian Royal Commission following the 2009 fires, and the Queensland Inquiry following the 2010–2011 floods (11.5.1); – Soil erosion and flood protection institutions dominate New Zealand decision making and governance (White and Lawrence, 2020); – Lack of clarity about mandate, roles and leadership and inadequate funding for adaptation by national and state governments and sectors (Lukasiewicz et al., 2017; Waters and Barnett, 2018; LGNZ, 2019; MfE, 2020a).	The transition occurs around 0.7°C because moderate adaptation includes – Using a range of adaptation enablers (Table 11.17) including decision tools that are fit for purpose (Table 11.18).
Moderate to high risk	The transition occurs around 1.1°C because – High risk climate-related failures of institutions and governance became evident between 2010 and 2020, and global warming was 1.1°C during 2011–2020 (IPCC, 2021); – The 2019 floods in northern Queensland exposed failures in institutions and governance (Deloitte, 2019); – Australian Royal Commission following the 2019–2020 fires highlighted failure of governance and institutions (CoA, 2020b); – The intense drought conditions in 2017–2019 (BoM, 2019), the South Australian Royal Commission into the MDB water reforms (SA Government, 2019b), and major fish kills in the lower Darling River in the summer of 2018/2019 (AAS, 2019; Vertessy et al., 2019) have increased concerns about the MDB plan; – Disaster risk governance should be strengthened to manage disaster risk (CSIRO, 2020); – Hierarchy of plans, climate change effects and integrated catchment planning, integrated coastal planning, and then pathways emerge to dominate institutions and governance (White and Lawrence, 2020; Ramm, 2018), and participatory approaches emerge (Bosomworth and Gaillard, 2019); – Institutions, funding and process deficits are put in place for managed retreat (Hanna et al., 2021); – COVID-19 responses in 2020–2021 have highlighted weaknesses in the information system and the inability of governance and institutions to manage major risks (11.3.6.3; 11.5.1); – Examples of maladaptation are evident across all domains due to the application of practices, processes and tools that do not account for uncertainty and change over long time frames (MfE, 2020a); – The New Zealand Climate Change Risk Assessment (MfE, 2020a) found that climate change impacts across all domains will be exacerbated because current institutional arrangements are not suitable for climate change adaptation. Institutional arrangements include legislative and decision-making frameworks, coordination within and across levels of government and funding mechanisms – The New Zealand Climate Change Risk Assessment (MfE, 2020a) identified risks of delayed adaptation and maladaptation due to knowledge gaps resulting from underinvestment in climate adaptation research and capacity building; – Risks to governments and businesses from climate-change-related litigation due to inadequate or mistimed climate change adaptation (MfE, 2020a); – Breach of Treaty of Waitangi obligations from a failure to engage adequately with and protect current and future generations of Māori from the impacts of climate change (MfE, 2020a) – Climate-related litigation in Australia (O'Donnell et al., 2019; Bell-James and Collins, 2020; Peel et al., 2020) – Climate-related litigation in New Zealand (Tombs and France-Hudson, 2018; Hodder, 2019); – There is a lack of consistent policy direction from higher levels and frequent policy reversals (Dedekorkut-Howes et al., 2020); – There is a lack of institutional and professional capabilities and capacity (e.g. to monitor and evaluate adaptation outcomes) (Lawrence et al., 2015; Scott and Moloney, 2021); – Fear of litigation and demands for compensation drive decision-maker reluctance to take adaptation action (Tombs and France-Hudson, 2018; O'Donnell, 2019).	The transition occurs around 1.5°C because moderate adaptation includes – Using a range of adaptation enablers (Table 11.17), including decision tools that are fit for purpose (Table 11.18).
High to very high risk	The transition occurs around 2.0°C because – There are very significant and uneven consequences for vulnerable groups (Boston and Lawrence, 2018).	The transition occurs around 2.5°C because moderate adaptation includes – A shift from reactive/incremental adaptation to anticipatory/transformative adaptation (11.3.5.3; 11.8.1); – Clear mandates in legislation (MfE, 2019).

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