Chapter 11: Australasia
Supplementary Material

Coordinating Lead Authors: Judy Lawrence (New Zealand) and Brendan Mackey (Australia)

Lead Authors: Francis Chiew (Australia), Mark J. Costello (New Zealand/Norway/Ireland), Kevin Hennessy (Australia), Nina Lansbury (Australia), Uday Bhaskar Nidumolu (Australia), Gretta Pecl (Australia), Lauren Rickards (Australia), Nigel Tapper (Australia), Alistair Woodward (New Zealand), Anita Wreford (New Zealand)

Contributing Authors: Jason Alexandra (Australia), Anne-Gaelle Ausseil (New Zealand), Shaun Awatere (New Zealand), Douglas Bardsley (Australia), Rob Bell (New Zealand), Paula Blackett (New Zealand), Sarah Boulter (Australia), Nicholas Cradock-Henry (New Zealand), Sandra Creamer (Australia), Rebecca Darbyshire (Australia), Sam Dean (New Zealand), Alejandro Di Luca (Australia/Canada), Andrew Dowdy (Australia), Joanna Fountain (New Zealand), Michael Grose (Australia), Stefan Hajkowicz (Australia), David Hall (New Zealand), Sarah Harris (Australia), Peter Hayman (Australia), Jane Hodgkinson (Australia), Karen Hussey (Australia), Rhys Jones (New Zealand), Darren King (New Zealand), Martina Linnenluecke (Australia), Erich Livengood (New Zealand), Mary Livingston (New Zealand), Cate MacInnis-Ng (New Zealand), Belinda McFadgen (New Zealand), Celia McMichael (Australia), Bradley Moggridge (Australia), Sandy Morrison (New Zealand), Vinnitta Mosby (Australia), Esther Onyango (Australia/Kenya), Sharanjit Paddam (Australia), Grant Pearce (New Zealand), Petra Pearce (New Zealand), Rosh Ranasinghe (Netherlands), David Schoeman (Australia), Rodger Tomlinson (Australia), Michael Watt (New Zealand), Seth Westra (Australia), Russell Wise (Australia).

Review Editors: Ove Hoegh-Guldberg (Australia), David Wratt (New Zealand)

Chapter Scientists: Belinda McFadgen (New Zealand), Esther Onyango (Australia/Kenya)

Date of Draft: 1 October 2021

Notes: TSU Compiled Version

Table of Contents

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

Table SM11.1a: Examples of Australian adaptation strategies, plans and initiatives at the (a) national level, (b) sub-national, and (c) regional or local level.

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 (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 in order 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 the 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 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; OEH, 2018a)	The Act requires local governments to prepare coastal management programs. These will set the long-term strategy for coordinated coastal management. Programs 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 wellbeing 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 program		A significant state program that funds local governments to prepare Coastal Hazard Adaptation Strategies for 32 councils
	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 identifies principles, or strategic actions to inform adaptation in the 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 wellbeing.	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. Includes 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: understanding 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 the 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.
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 four 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 a particular focus on the vulnerability of the state's economy.
Western Australia	Western Australian Government Adapting to our changing climate 2012 (WA Government, 2016)	Western Australians will need to adapt in order to ensure the wellbeing of the community, the environment and the economy, and to minimize the 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 programs; Ensuring 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)			
101 have declared Climate Emergencies 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 to 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 stepped 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, there are 3 alliances of multiple local governments 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. CMA 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… we 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.
	Climate Risk Management Framework for Queensland Local Government (Erhart et al., 2020)	The increasing frequency, severity and diversity of disasters is 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 risk 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) every 2 years after each successive risk assessment 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 of DOC's 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) Climate Action Plan	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 be 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. Long Term Plan for 2018-2028 decisions includes 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 GHG 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 sea-level rise on freshwater abstraction. Hutt River Flood Risk Management Plan; first NZ use of DAP; Room for the River for a 1:440year ARI 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.
Unitary Authorities (examples only)		
Auckland Council	Auckland Unitary Plan AUP RPS B10 Table B11.9- (bottom of doc) E36. Natural hazards and flooding	Ensures the 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 sea-level rise of 1m.
Marlborough District Council	Marlborough Environment Plan First to integrate DAPP into Plan policies and rules.	Based on IPCC AR4 and 1.5 Degrees Report. Covers regional climate projections, sources of climate variability (ENSO and the IPO), and impacts—drought, sea-level rise, 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 dynamic adaptive pathways planning (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 1.52m SLR); existing development and assets within existing footprint (min 1m SLR); non-habitable short-lived assets necessary at the coast with low consequences or adaptable (min 0.65m 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 required to 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 the Long Term Plan 2017. Long-Term-Plan-Further-Information-Document-WEB.pdf Page 113/31	Factors in climate change impacts on water supply, wastewater, and stormwater, e.g. through sizing of new storm water pipes to account for intense rainfall events; flood modelling includes 1m of SLR; future modelling includes the impacts of increasing groundwater levels due to sea- level rise which help 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 Risks Trace-back Tables

The tables below 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 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 1 report (2021) (Figure SM11.1 and Table SM11.1). For example, the global warming relative to 1850-1900 is about 0.3ºC in 1980, 0.5ºC in 1990, 0.7ºC in 2000, 1.0ºC in 2010, 1.2ºin 2020, 1.5ºC in 2030 (RCP2.6), 1.6ºC in 2030 (RCP8.5), 1.7ºC in 2050 (RCP2.6), 2.4ºC in 2050 (RCP8.5), 1.8ºC in 2090 (RCP2.6) and 4.4ºC in 2090 (RCP8.5).

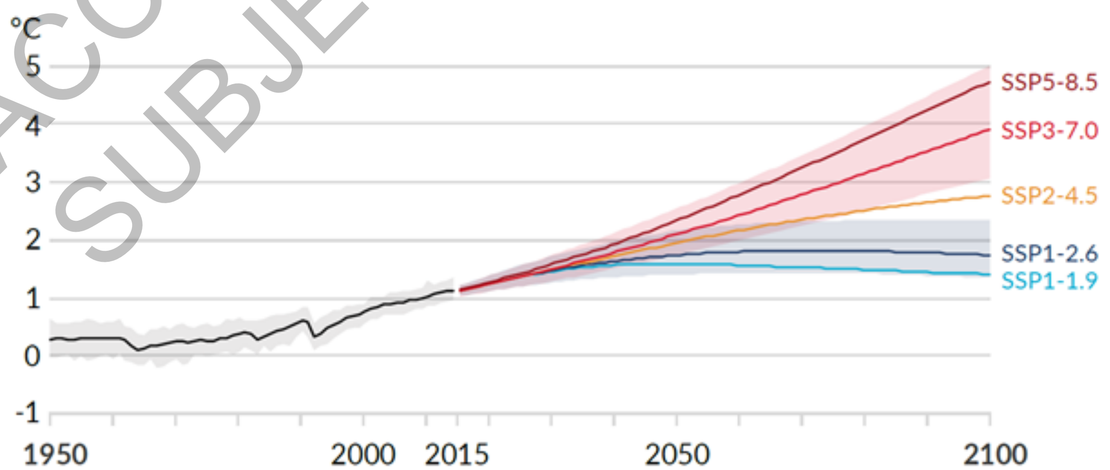

Figure SM11.2a: Global-average surface warming relative to 1850-1990 under the five illustrative scenarios. Source: IPCC (2021) Working Group 1 Figure SPM.8.

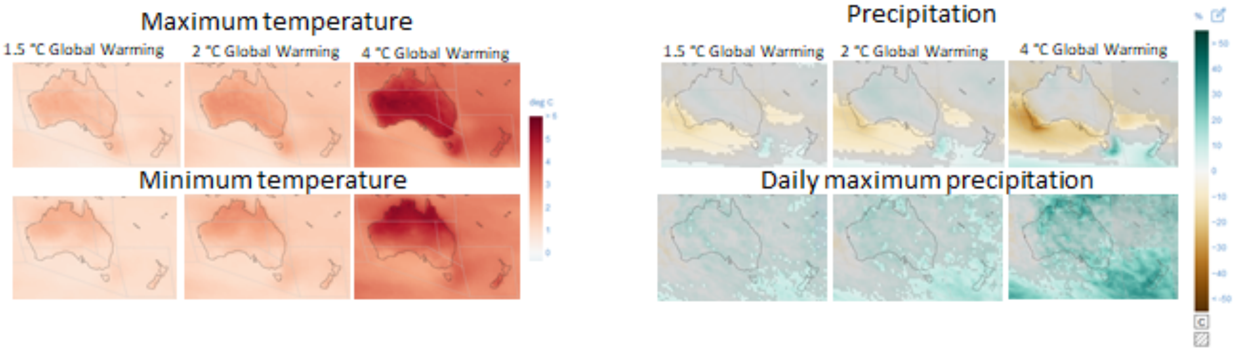

Figure SM11.2b: Projected regional changes in annual average maximum and minimum temperature, precipitation and daily maximum precipitation for 1.5, 2.0 and 4.0ºC global warming relative to 1850-1900. Source: IPCC Working Group 1 Australasia factsheet (IPCC, 2021).

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 3 bleaching events during 2016-2020. Therefore, the risk was "undetectable" prior to 1980 (less than 0.3ºC global warming), increasing to "moderate" risk between 1980-1990 (0.3-0.5ºC), then increasing to "high" risk between 1990-2010 (0.5-1.0ºC), and "very high" risk from 2010 onward (over 1.0ºC).

The trace-back tables below 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 under-estimate 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.

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) Working Group 1 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
SSP1-2.6	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 0.3ºC because: • Wide-scale bleaching of the Great Barrier Reef (GBR) was first recorded in the 1980s, (AIMS, 2021), and global warming reached 0.3ºC 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 0.3ºC because moderate adaptation options were limited.
Moderate to High Risk	The transition occurred around 0.5ºC because • Mass bleaching events were evident in 1998, 2002, 2006 and 2008-2011 (AIMS, 2021), and global warming reached 0.5º 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 0.5ºC because moderate adaptation options were limited.
High to Very High Risk	The transition occurred around 1.0ºC because • Multiple thermal stress events between 2011–2020 caused significant bleaching and loss of corals, and global warming reached 1.0º C in 2010 (IPCC, 2021). • Bleaching of Ningaloo Reef in Western Australia in 2011 due to a marine heatwave (Moore et al., 2012) • Three marine heatwaves on the GBR from 2016-2020 (BoM, 2020) • The cover of GBR corals declined by 30% between March and November 2016 (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 3ºC 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 1.2ºC 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 Great Barrier Reef 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 occurrences of warming events similar to 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 in delaying decline were combinations that protected coral from both predation (CoTS control) and thermal stress (solar radiation management) deployed at 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)

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 0.5ºC because • The decline in giant kelp in Tasmania, Australia, was first documented in 1990 (Wahl et al., 2015) and global warming reached 0.5ºC in 1990 (IPCC, 2021).	The transition occurred around 0.5ºC because moderate adaptation options were limited.
Moderate to High Risk	The transition occurred around 1.0ºC because • impacts became more widespread after 2010, and global warming reached 1.0ºC 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 >45% of the continental coastline of Australia (Babcock et al., 2019) • Less than 10% of giant kelp in Tasmania, Australia, remaining by 2011 due to ocean warming & change in East Australian Current (Wahl et al., 2015; Butler et al., 2020), giant kelp 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 loss of kelp forests in a 25 km study area (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 subsequently replaced by the introduced kelp *Undaria* following the	The transition occurred around 1.0ºC because moderate adaptation options were limited.

	2017/8 heatwave when sea and air temperatures exceeded 23 and 30 ˚C respectively (Salinger et al., 2019; Thomsen et al., 2019; Salinger et al., 2020)	
High to Very High Risk	The transition occurs around 1.5ºC because • Kelp forests are expected to face growing risks at 1.5°C of 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 contraction and poleward shift (Chapter 3) as temperatures become too warm and herbivory increases (Vergés et al., 2016; Wernberg et al., 2016)	The transition occurs around 1.7ºC 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 0.3ºC in 1980 (IPCC, 2021). • At Mt Hotham, Mt Buller and Falls Creek (1638-1760 m elevation), annual maximum snow depth decreased 37% from 1988-2013 (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 1954-2011 (Bhend et al., 2012). • Annual maximum snow depth declined 10% from 1962-2002 (Nicholls, 2005)	The transition occurred around 0.3ºC because moderate adaptation options were limited.
Moderate to High Risk	The transition occurred around 1ºC because • Shifts in alpine species became evident after 2010, and global warming reached 1.0ºC in 2010 (IPCC, 2021) • Loss of snow-related habitat for alpine zone endemic and obligate species (Thompson, 2016) • Shifts in dominant vegetation with a decline in grasses and other graminoids	The transition occurred around 1.2ºC 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 beyond mountain tops as temperatures increase and colder high elevation climate envelopes

	and an increase in forb and shrub cover in Bogong High Plains, Victoria, Australia (Hoffmann et al., 2019) • Changing interactions 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)	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)
High to Very High Risk	The transition occurs around 2ºC because • Risks become very high by the year 2050, when global warming is projected to reach about 2ºC (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 herb-fields) and increased stress on snow-dependent plant and animal species; changing 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 far future (2060 to 2079). Alpine Herbfields, Montane Bogs and Fens, Grassy Woodlands and Wet Sclerophyll Forest are projected to decrease in area and compositional suitability as climatic conditions transition to those better suiting species of Subalpine Woodland and Dry Sclerophyll Forest, 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	The transition occurs at 2.2ºC 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 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)

	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 from habitat loss. Other bird species listed as vulnerable are projected to be impacted by climate change (Love et al., 2019). • Subalpine Woodlands, Alpine Heaths and Herbfields, 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 to 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 New South Wales will be 30–60% less bioclimatically suitable for the alpine species they currently support (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 0.3ºC because • Hotter and drier conditions since the 1980s has 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 - June 1985 compared to July 1985 - June 2020, especially in the south and east, partly attributed to climate change (BoM and CSIRO, 2020).	The transition occurred at 0.3ºC because moderate adaptation options included: • 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)

	• 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 - 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 south western 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 due to seeders having insufficient time to reach reproductive age (Alpine Ash) or vegetative regeneration capacity is exhausted (Snow Gum woodlands) (Slatyer, 2010; Bowman et al., 2014; Fairman et al., 2016; Harris et al., 2018; Zylstra, 2018). • Death of fire sensitive trees 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).	• Targeted fuel-reduction burns (Gibbons et al., 2012; Lindenmayer and Taylor, 2020a)
Moderate to High Risk	The transition occurs around 1.7ºC because • Risks become high by the year 2050 for low emissions (RCP2.6), and global warming by 2050 is projected to be 1.7ºC for RCP2.6 (IPCC, 2021). • By 2050 for RCP2.6, warming in southern and eastern Aus is projected to be 0.7–1.5°C (median ~1.1 C) from 1986-2005 baseline, rainfall change is projected to be –15 to +2% (median ~ -7%) in southern Australia and –13 to +7% (median ~ -3%) in eastern Australia, and the number of severe fire weather days is projected to increase by 5 to 35% (median ~ +20%) • Increase in fire frequency prevents recruitment of obligate seeder resulting in changing dominant species and vegetation structure including long	The transition occurs around 2.0ºC because moderate adaptation options included: • Increased resources 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).

	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 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).	
High to Very High Risk	The transition occurs around 2.4ºC because • Risks become very high by the year 2050 for high emissions (RCP8.5), and global warming by 2050 is projected to be 2.4ºC for RCP8.5 (IPCC, 2021). • By 2050 for RCP8.5, warming in southern and eastern Aus is projected to be 1.3–2.3°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 3.0ºC because because moderate adaptation options included: • 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

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 0.7ºC because • Moderate risks have been detected in recent decades, and global warming reached 0.7ºC in 2000 (IPCC, 2021) • Sea level rise (SLR) was an average of 2.4 mm/year from 1961-2018 around New Zealand including vertical land motion (Bell and Hannah, 2019) and an average of 3.4 mm/year from 1992-2019 around Australia based on satellite altimetry (Watson, 2020). • In Australia, the current value of existing residential buildings at risk from inundation is A$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 / substations, 75 hospitals and health services, 41 landfill	The transition occurs around 0.7ºC because moderate adaptation included: • 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)

	sites, 3 water treatment plants, and 11 emergency services facilities (DCCEE, 2011). • In New Zealand, 72,000 people and 50,000 buildings (with NZ$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, from 2003-2011, subsidence was about 5 mm/year along the northeast coast of the North Island and 2-3 mm/year near the top of the South Island, exacerbating the impacts of sea level rise (Levy et al., 2020). • Nuisance and extreme coastal flooding have increased in New Zealand in recent decades off a 0.2m 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 bio-cultural diversity, nutritional changes through availability of traditional foods and forced diet change, water security, and loss of land through erosion and sea-level rise (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 sea-level rise. 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).	
Moderate to High Risk	The transition occurs around 1.5-2.5ºC because • High risks start at around 0.2-0.3 m local SLR relative to 1986-2005 • 0.20-0.23 m local SLR is associated with 2050 RCP2.6 while 0.25-0.28 m local SLR is associated with 2050 RCP8.5 (MfE, 2017). • Global warming is 1.7ºC by 2050 for RCP2.6 and 2.4ºC by 2050 for RCP8.5 (IPCC, 2021), which has been rounded to 1.5-2.5ºC for this risk transition. • In New Zealand, local sea level rise 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:	• The transition occurs around 2.0-3.0ºC because moderate adaptation includes: • Temporary ecosystem-based adaptation is limited (McInnes et al., 2015) • 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 for reducing risk and insurance withdrawal for high risk areas (11.3.8) (Storey and Noy, 2017) • Reduce coastal squeeze of habitats (Tait and Pearce, 2019; Swales et al., 2020)

	• 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.
	• 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; Hague et al., 2019; Paulik et al., 2020; Stephens et al., 2020)
	• Property and infrastructure damage will increase (Steffen et al., 2014; PCE, 2015; Harvey, 2019; LGNZ, 2019), e.g. in New Zealand, the value of buildings exposed to coastal inundation (1% annual exceedance probability) could increase by NZ$5.10 billion for 0.2 m SLR and NZ$7.65 billion for 0.3 m SLR (Paulik et al., 2020)
	• Cultural and archaeological sites 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 sea level rise > 6 mm/yr (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)
		• Protection: beach nourishment and dune rehabilitation (Rouse et al., 2017).
		• Planning legislation and long-term spatial housing & infrastructure plans to avoid further developments in hazard-prone areas and adjustments to existing developments including accommodation and managed retreat (MfE, 2017)
		• Protection: 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 are illustrated in the dynamic adaptation pathways diagram (Figure 11.7)
		• Measures that can be evaluated within an options framework could include (MfE, 2017):
		  ◦ soft measures, such as dune restoration, wetland enhancement or creation, and beach nourishment and areas for biodiversity change to occur (eg, 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 RMA at regional and district level, 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 (eg, 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 2.5-3.5ºC because • Very high risks start at around 0.5 m of local SLR relative to 1986-2005. • 0.5 m local SLR is associated with 2090 RCP4.5 • Global warming is 2.7ºC by 2090 for RCP4.5(IPCC, 2021), which has been broadened to 2.5-3.5ºC 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 NZ$12.75 billion for 0.5 m SLR and NZ$25.5 billion for 1.0 m SLR (Paulik et al., 2020) • In Australia, for 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 A$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 sea-level rise–saltwater inundation. Coastal landscapes and socio-ecological systems in the region will be very different by 2100 as a result of SLR; freshwater ecosystems will transform to marine-dominated ecosystems (Bayliss et al., 2018)	The transition occurs around 3.0-4.0ºC 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 & infrastructure plans to avoid further developments in hazard-prone areas and adjustments to existing developments including accommodation and managed retreat (MfE, 2017) • Managed retreat 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 south-western, 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 0.3ºC because • There is evidence for moderate risk from 1980 onward, and global warming was 0.3 C in 1980 (IPCC, 2021). • Australia has become warmer with more extremely high temperatures and more extreme fire-weather days (1985-2020 relative to 1950-	The transition occurs around 0.3ºC because moderate adaptation includes: • new smart technologies that reduce resource inefficiencies, professional knowledge and skills development, new farmer and

	1985), and more extreme rainfall since 1980 (BoM and CSIRO, 2020) • Apr-Oct rainfall decreased 16% in southwest Australia since 1970 and decreased 12% in southeast Australia since 1990 (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 2000–01 and 2014–15 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 2019/20 fires caused significant taint damage especially because the fires occurred early in the grape growing season and recurred (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 32ºC reduce ewe and ram fertility along with the birth weight of lambs (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 over-stretched 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,	community networks, and diversification of business and household income (Ghahramani et al., 2015; De et al., 2016) • Farmers are adapting 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 increasingly requires shifts in sowing dates to avoid financial impacts (Luo et al., 2017). • During years of low water availability, rice growers have been trading water and/or shifting to dry land farming (Mushtaq, 2016).

	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).	
Moderate to High Risk	The transition occurs around 2.0ºC because • There is evidence for high risk around 2050 when global warming is 2.0ºC for RCP4.5 (IPCC, 2021) • Australian wheat yields may decrease 7% by 2050 RCP4.5 (Wang et al., 2018) • Median changes in wheat yield by 2050 RCP4.5 under a most likely climate scenario are projected to be -13 to -23% in the south-west, 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 days per year by 2050 (Nidumolu et al., 2014) • The distribution of existing and new pests and diseases are projected to increase e.g. new tick and mosquito-borne diseases such as Bovine ephemeral fever (Kean et al., 2015).	The transition occurs around 2.5ºC 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 increasingly requires shifts in sowing dates to avoid financial impacts (Luo et al., 2017). • During years of low water availability, rice growers have been trading water and/or shifting 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).

		• Adaptations to manage heat stress in livestock include altering the breeding calendar, providing shade, altering nutrition and feeding times, 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% when using current technology and practices but increased yields 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 2.5ºC because • Australian wheat yields may decrease 9% by 2050 RCP8.5 (Wang et al., 2018) when global warming is 2.4ºC (IPCC, 2021). • Median changes in wheat yield by 2050 RCP8.5 under a most likely climate scenario are projected to be -29 to -33% in the south-west, -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 RCP4.5 are projected to be -24 to -40% in the south-west, +4 to +4% in South Australia, with increases and decreases in the east (Taylor et al., 2018). Global warming by 2090 RCP4.5 is 2.7ºC (IPCC, 2021) • Median time in drought in southern and eastern Australia increases from about 40% for 20 years centered on 1995 to about 50% for 20 years centred on 2050 RCP8.5 (Kirono et al., 2020), which corresponds to 2.4ºC global warming • Median wheat yield changes for the 'most likely' scenario by 2090 RCP8.5 are projected to be -33 to -50% in the south-west, -18 to -41% in South Australia, with increases and decreases in the east (Taylor et al., 2018). Global warming by 2090 RCP8.5 is 4.4ºC (IPCC, 2021) • Change in runoff by 2060 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 MDB) 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	The transition occurs around 3.0ºC because: • While there is potential for agriculture to be located to northern Australia, significant and complex agronomic, environmental, institutional, financial and social challenges need to be overcome to successful transformation (Mathew et al., 2018a)

	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)	

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 0.5ºC 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 4,370 injuries, with more than 50% due to heatwaves (Deloitte, 2017). • For Australia's 5 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 (UHI) (Rogers et al., 2018) • Other factors which are likely to exacerbate health impacts in cities and which are linked to the UHI, 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 1991-2018 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 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 the season, urban heat islands (Rocklov et al., 2011; Hall and Crosby, 2020) • Temperature thresholds should be also 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	The transition occurs around 0.5ºC 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, In Press) • 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

	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 42ºC (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)	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 wellbeing (DOH, 2011)
Moderate to High Risk	The transition occurs around 1.7ºC because • High risks are projected by 2050 for RCP2.6, and global warming by 2050 is 1.7ºC for RCP2.6 (IPCC, 2021) • Heatwave related excess deaths in Melbourne, Sydney and Brisbane are projected to increase by about 300/year (RCP2.6) for 50 years centred on 2055 (2031-2080) relative to 142/year during 1971-2020, assuming no adaptation and high population growth (Guo et al., 2018). • By 2030 (RCP4.5), 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 at present in Adelaide, Melbourne, Perth, Sydney and Brisbane to 2,300 to 2,500/yr by 2020, and 4,300 to 6,300/yr 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 scale 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/year (RCP2.6 and RCP8.5) for 50 years centred on 2055 (2031-2080) relative to 142/year 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)
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 2.4ºC for RCP8.5 (IPCC, 2021). • Heatwave related excess deaths in Melbourne, Sydney and Brisbane are projected to increase by about to 600/year (RCP8.5) for 50 years centred on 2055 (2031-2080) relative to 142/year during 1971-2020, assuming no adaptation and high population growth (Guo et al., 2018). • By 2090 for RCP4.5 (2.7ºC 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 ~ 100 days/year in the far northwest of Australia and will exceed 20 days/year for over > 50% of this species' current range (Conradie et al., 2020).	The transition occurs around 2.6ºC 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 0.7ºC because: • Moderate cascading impacts were documented during a 20-year period centred on 2000, when global warming was 0.7ºC (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 A$18.2 billion per year with largest	The transition occurred around 0.7ºC because moderate adaptation included: • High level strategies at 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 state level and increasingly at local government

	contributions from floods (A$8.8 billion), followed by cyclones (A$3.1 billion), hail (A$2.9 billion), storms (A$2.3 billion) and fires (A$1.1 billion) (Deloitte, 2017). • Individual weather-related disaster costs across multiple sectors in Australia have exceeded A$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, sea-level rise 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 2007/08 drought cost NZ$3.2 billion and the 2012/13 drought cost NZ$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 especially been impacted by multiple and complex forms of loss (Johnson et al., 2021)	level (Jacobs et al., 2016; Warnken and Mosadeghi, 2018) (Table 11.15a). • Some businesses and industry sectors recognizing climate-related risks and adaptation planning (Sections 11.3.4; 11.3.7; 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. • NZ's National coastal guidance for adaptation planning to address changing climate risks(MfE, 2017) (Table 11.15b) 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; CDEM, 2019; Forino et al., 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) • The construction of a levee in Roma cost $23.9 million, flood risk for more than 500 Roma properties was downgraded, and some insurance policyholders have achieved up to a 90 per cent reduction in their premium (Actuaries Institute, 2020). • Queensland Government funding improved the resilience of homes

		and reduced premiums in cyclone-affected regions via the 'Household Resilience Program'. The Government notes 1,749 households from Bundaberg to Cape York Peninsula have already seen insurance premiums reduced by an average of $310 p.a. under the program (Actuaries Institute, 2020). • 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).
Moderate to High Risk	The transition occurred around 1.1ºC 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 A$6.9 billion (Deloitte, 2016). • The floods of early 2019 in north Queensland cost A$5.68 billion (Deloitte, 2019), • 2019-2020 drought, heatwaves and fires in southern and eastern Australia cost over A$8 billion (CoA, 2020b). • Insured losses from weather-related disasters cost almost NZ$1 billion during 2015-2021 (ICNZ, 2021). • Insured losses for the 12 costliest floods in New Zealand cost NZ$471 million between 2007 and 2017, of which 30% could be attributed to climate change (Frame et al., 2018).	The transition occurs around 1.3ºC because moderate adaptation includes: • (CCATWG, 2017) Stocktake of impacts and preparedness assessment • 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) • NZ Sustainable Finance Forum Roadmap for Action (TAO, 2020) • Preparation of NZ Natural and Built Environment, Strategic Planning and Climate Change Adaptation Acts, including provision for funding and managed retreat (MfE, 2020b). • The NZ CCRA (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) starts its active phase including some transformational changes.
High to Very High Risk	The transition occurs around 2ºC 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%/year for Australia and -0.4%/year 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 A$19 billion by 2030 and A$211 billion by 2050 for RCP8.5 (Steffen et al., 2019).	The transition occurs around 2.5ºC 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).

	• In New Zealand, under RCP8.5 and considering 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 growth of 3%/year on average from 2020–2070 (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 A$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)	• 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) • Moderate adaptation options include 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 0.7ºC because: • Moderate climate-related failures of institutions and governance became evident around the year 2000, and 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, the Queensland Inquiry following the 2010-2011 floods (11.5.1) • Soil erosion and flood protection institutions dominate 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 occurred around 0.7ºC because moderate adaptation included: • 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 1ºC because:	The transition occurs around 1.5ºC because moderate adaptation includes:

	• High climate-related failures of institutions and governance became evident between 2010-2020, and global warming was 1.1°C during 2010-2020 (IPCC, 2021). • 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. • There is a need to strengthen disaster risk governance to manage disaster risk (CSIRO, 2020) • Hierarchy of plans, climate change effects and integrated catchment planning, integrated coastal planning then pathways emerge dominate institutions and governance (White and Lawrence, 2020) Ramm, 2018, and participatory approaches emerge (Bosomworth and Gaillard, 2019) • Institutions, funding and process deficits 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 timeframes (MfE, 2020a). • NZ Climate Change Risk Assessment Risk (MfE, 2020a) found that climate change impacts across all domains will be exacerbated because current	• Using a range of adaptation enablers (Table 11.17) including decision-tools that are fit for purpose (Table 11.18)

	institutional arrangements are not fit for climate change adaptation. Institutional arrangements include legislative and decision-making frameworks, coordination within and across levels of government, and funding mechanisms timeframes. • NZ Climate Change Risk Assessment Risk (MfE, 2020a) identified risks of delayed adaptation and maladaptation, due to knowledge gaps resulting from under-investment in climate adaptation research and capacity building. • Risks to governments and businesses from climate change-related litigation, due to inadequate or mis-timed 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); Peel, Osofsky and Foerster; Bell-James and Collins 2020 • Climate-related litigation in New Zealand (Tombs et al., 2018; Hodder, 2019). • Lack of consistent policy direction from higher levels and frequent policy reversals (Dedekorkut-Howes et al., 2020) • 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, 2018 #1539}(O'Donnell, 2019)	
High to Very High Risk	The transition occurs around 2.0ºC because • There are very large and uneven consequences for vulnerable groups (Boston and Lawrence, 2018)	The transition occurs around 2.5ºC because moderate adaptation includes: • A shift from reactive/incremental adaptation to anticipatory/transformative adaptation (11.3.5.3; 11.8.1) • Mandates clear in law (MfE, 2019)

References

AAS, 2019: *Investigation into the Causes of Mass Fish Kills in the Menindee Region NSW over Summer of 2018-2019*. Australian Academy of Science Secretariat, 162 [Available at: https://www.science.org.au/files/userfiles/support/reports-and-plans/2019/academy-science-report-mass-fish-kills-digital.pdf].

AAS, 2021: *The risks to Australia of a 3°C warmer world*. Australian Academy of Science, 97 [Available at: https://www.science.org.au/files/userfiles/support/reports-and-plans/2021/risks-australia-three-deg-warmer-world-report.pdf].

ABARES, 2017: *Farm performance and climate Climate-adjusted productivity for broadacre cropping farms*. Australian Government Department of Agriculture and Water Resources, 65 [Available at: http://data.daff.gov.au/data/warehouse/9aas/2017/FarmPerformanceClimate/FarmPerformanceClimate_v1.0.0.pdf].

Abram, N. J. et al., 2021: Connections of climate change and variability to large and extreme forest fires in southeast Australia. *Communications Earth & Environment*, **2** (1), doi:10.1038/s43247-020-00065-8.

ACT Government, 2019: *ACT Climate Change Strategy 2019-25*. Australian Capital Territory, Canberra, 100 [Available at: https://www.environment.act.gov.au/__data/assets/pdf_file/0003/1414641/ACT-Climate-Change-Strategy-2019-2025.pdf/_recache].

ACT Government, 2020a: *ACT Wellbeing Framework*. Australian Capital Territory, Canberra, 32 [Available at: https://www.act.gov.au/__data/assets/pdf_file/0004/1498198/ACT-wellbeing-framework.pdf].

ACT Government, 2020b: *Canberra's Living Infrastructure Plan: Cooling the City*. Australian Capital Territory, Canberra,34 pp.

Actuaries Institute, 2020: *Property insurance affordability. Challenges and solutions*. Actuaries Institute, 52 [Available at: https://actuaries.asn.au/Library/Miscellaneous/2020/GIRESEARCHPAPER.pdf].

AFSI, 2020: *Australian Sustainable Finance Roadmap*. Australian Sustainable Finance Initiative, 95 [Available at: https://static1.squarespace.com/static/5c982bfaa5682794a1f08aa3/t/5fcdb70bfe657040d5b08594/1607317288512/Australian+Sustainable+Finance+Roadmap.pdf].

AghaKouchak, A. et al., 2020: Climate Extremes and Compound Hazards in a Warming World. *Annual Review of Earth and Planetary Sciences*, **48** (1), 519-548, doi:10.1146/annurev-earth-071719-055228.

AIMS, 2021: Coral bleaching events.

Astill, S. and E. Miller, 2018: 'The trauma of the cyclone has changed us forever': self-reliance, vulnerability and resilience among older Australians in cyclone-prone areas. *Ageing and Society*, **38** (2), 403-429, doi:10.1017/s0144686x1600115x.

Austin, E. K. et al., 2018: Drought-related stress among farmers: findings from the Australian Rural Mental Health Study. *Med. J. Aust.*, **209** (4), 159-165.

Australia Department of Health and Ageing, 2003: *Human Health and Climate Change in Oceania: A Risk Assessment 2002*. 128 pp.

Awatere, S. et al., 2018: *Climate Resilient Māori Land*.

Babcock, R. C. et al., 2019: Severe Continental-Scale Impacts of Climate Change Are Happening Now: Extreme Climate Events Impact Marine Habitat Forming Communities Along 45% of Australia's Coast. *Frontiers in Marine Science*, **6**, 411, doi:10.3389/fmars.2019.00411.

Ballantyne, M., C. M. Pickering, K. L. McDougall and G. T. Wright, 2014: Sustained impacts of a hiking trail on changing Windswept Feldmark vegetation in the Australian Alps. *Australian Journal of Botany*, **62** (4), 263, doi:10.1071/bt14114.

Bayliss, P. et al., 2018: Assessing sea level-rise risks to coastal floodplains in the Kakadu Region, northern Australia, using a tidally driven hydrodynamic model. *Marine and Freshwater Research*, **69** (7), 1064, doi:10.1071/mf16049.

Beautrais, A. L., 2018: Farm suicides in New Zealand, 2007-2015: A review of coroners' records. *Aust N Z J Psychiatry*, **52** (1), 78-86, doi:10.1177/0004867417704058.

Bell, R. G. and J. Hannah, 2019: *Update to 2018 of the annual MSL series and trends around New Zealand*. National Institute of Water & Atmospheric Research Ltd, 20 [Available at: https://www.mfe.govt.nz/sites/default/files/media/Marine/update-to-2018-of-the-annual-MSL-series-and-trends-around-nz.pdf].

Bhend, J., J. Bathols and K. Hennessy, 2012: *Climate change impacts on snow in Victoria*. CSIRO and BoM, 42.

Bickler, S., R. Clough and S. Macready, 2013: *The impact of climate change on the archaeology of New Zealand's coastline: a case study from the Whangarei District*. New Zealand Department of Conservation (DOC). 58 [Available at: https://dcon01mstr0c21wprod.azurewebsites.net/globalassets/documents/science-and-technical/sfc322entire.pdf].

Birkett-Rees, J., D. Bruno and B. Suttie, 2020: *Buchan valley and gippsland lakes cultural mapping project*. Gunaikurnai Land and Waters Aboriginal Corporation, 73 [Available at: https://bridges.monash.edu/articles/report/Gippsland_Lakes_region_predictive_modelling/15094260].

Boer, M. M., V. R. de Dios and R. A. Bradstock, 2020: Unprecedented burn area of Australian mega forest fires. *Nature Climate Change*, **10**, 170-172, doi:https://doi.org/10.1038/s41558-020-0716-1.

BoM, 2019: *Special Climate Statement 70—drought conditions in eastern Australia and impact on water resources in the Murray–Darling Basin*. Commonwealth of Australia, Bureau of Meteorology, 29 [Available at: http://www.bom.gov.au/climate/current/statements/scs70a.pdf].
BoM, 2020: *2020 marine heatwave on the Great Barrier Reef*. Bureau of Meteorology, 4 [Available at: http://www.bom.gov.au/environment/doc/2020-GBR-marine-heatwave-factsheet.pdf].
BoM and CSIRO, 2020: *State of the Climate 2020*. Bureau of Meteorology and Commonwealth Scientific Industrial and Research Organisation, Organisation, B. o. M., I. Commonwealth Scientific and Research.
Bonada, M. et al., 2020: Impact of low rainfall during dormancy on vine productivity and development. *Australian Journal of Grape and Wine Research*, doi:10.1111/ajgw.12445.
Bosomworth, K. and E. Gaillard, 2019: Engaging with uncertainty and ambiguity through participatory 'Adaptive Pathways' approaches: scoping the literature. *Environmental Research Letters*, **14** (9), 093007, doi:10.1088/1748-9326/ab3095.
Boston, J., 2016: Anticipatory governance: how well is New Zealand safeguarding the future? *Policy Quarterly*, **12** (3), doi:10.26686/pq.v12i3.4614.
Boston, J. and J. Lawrence, 2018: Funding climate change adaptation: the case for a new policy framework. *Policy Quarterly*, **14** (2), 40-49.
Bowman, D. M. J. S. et al., 2019: Fire caused demographic attrition of the Tasmanian palaeoendemic conifer Athrotaxis cupressoides. *Austral Ecology*, **44** (8), 1322-1339, doi:10.1111/aec.12789.
Bowman, D. M. J. S. et al., 2014: Abrupt fire regime change may cause landscape-wide loss of mature obligate seeder forests. *Glob. Chang. Biol.*, **20** (3), 1008-1015, doi:10.1111/gcb.12433.
Brookfield, S. and L. Fitzgerald, 2018: Homelessness and natural disasters: the role of community service organisations. *Australian Journal of Emergency Management*, **33** (4), 62-68.
Broome, R. A. and W. T. Smith, 2012: The definite health risks from cutting power outweigh possible bushfire prevention benefits. *Med. J. Aust.*, **197** (8), 440-441, doi:10.5694/mja12.10218.
Brown, C., E. Seville and J. Vargo, 2017: Measuring the organizational resilience of critical infrastructure providers: A New Zealand case study. *International Journal of Critical Infrastructure Prevention*, **18**, 37-49.
Bryant, L. and B. Garnham, 2018: Farming exit and ascriptions of blame: The ordinary ethics of farming communities. *Journal of Rural Studies*, **62**, 62-67, doi:10.1016/j.jrurstud.2018.07.004.
Butler, C. L., V. L. Lucieer, S. J. Wotherspoon and C. R. Johnson, 2020: Multi-decadal decline in cover of giant kelp Macrocystis pyrifera at the southern limit of its Australian range. *Mar. Ecol. Prog. Ser.*, **653**, 1-18, doi:10.3354/meps13510.
CCATWG, 2017: *Adapting to Climate Change in New Zealand: Stocktake Report from the Climate Change Adaptation Technical Working Group*. Group, C. C. A. T. W. [Available at: www.mfe.govt.nz].
CDEM, 2019: *National-Disaster-Resilience-Strategy - Rautaki ā-Motu Manawaroa Aituā*. Ministry of Civil Defence & Emergency Management, 52 [Available at: https://www.civildefence.govt.nz/assets/Uploads/publications/National-Disaster-Resilience-Strategy/National-Disaster-Resilience-Strategy-10-April-2019.pdf].
Challinor, A. J. et al., 2018: Transmission of climate risks across sectors and borders. *Philos. Trans. A Math. Phys. Eng. Sci.*, **376** (2121), doi:10.1098/rsta.2017.0301.
Chang-Fung-Martel, J. et al., 2017: The impact of extreme climatic events on pasture-based dairy systems: a review. *Crop & Pasture Science*, **68** (12), 1158-1169, doi:10.1071/cp16394.
Chiew, F. and I. Prosser, 2011: Water and Climate. In: Water: Science and Solutions for Australia [Prosser, I. (ed.)]. CSIRO Publishing, 150 Oxford Street (PO Box 1139) Collingwood VIC 3066 Australia, 29-46.
Chiew, F. H. S. et al., 2017: Future runoff projections for Australia and science challenges in producing next generation projections. In: *22nd International Congress on Modelling and Simulation (MODSIM 2017)*, 2017/12, 1745-1751.
Clarke, H. and J. P. Evans, 2019: Exploring the future change space for fire weather in southeast Australia. *Theoretical and Applied Climatology*, **136** (1-2), 513-527, doi:10.1007/s00704-018-2507-4.
Climate Emergency Declaration, 2020: Climate emergency declarations in 1,769 jurisdictions and local governments cover 820 million citizens.
CoA, 2015: *National Climate Resilience and Adaptation Strategy*. Commonwealth of Australia, 80 [Available at: https://www.environment.gov.au/system/files/resources/3b44e21e-2a78-4809-87c7-a1386e350c29/files/national-climate-resilience-and-adaptation-strategy.pdf].
CoA, 2018: *National disaster risk reduction framework*. Commonwealth of Australia, 23 [Available at: https://www.homeaffairs.gov.au/emergency/files/national-disaster-risk-reduction-framework.pdf].
CoA, 2019: *State party report on the state of conservation of the great barrier reef world heritage area (Australia)*. Department of the Environment and Energy, 68 [Available at: https://www.environment.gov.au/system/files/resources/bfcd4506-2d94-4dc4-9eab-2cc97b931fac/files/gbr-state-party-report-2019.pdf].
CoA, 2020a: *Royal Commission into National Natural Disaster Arrangements*. Commonwealth of Australia,594 pp.
CoA, 2020b: *Royal Commission Into National Natural Disaster Arrangements Report October 2020 Appendices: Volumes 1-2 - Volume 2*. Australian Government - Attorney General's Department, 594 pp.
CoA, 2021: National Recovery and Resilience Agency.

Collins, L. et al., 2021: The 2019/2020 mega-fires exposed Australian ecosystems to an unprecedented extent of high-severity fire. *Environmental Research Letters*, **16** (4), 044029, doi:10.1088/1748-9326/abeb9e.
Condie, S. A. et al., 2021: Large-scale interventions may delay decline of the Great Barrier Reef. *R Soc Open Sci*, **8** (4), 201296, doi:10.1098/rsos.201296.
Conradie, S. R. et al., 2020: Avian mortality risk during heat waves will increase greatly in arid Australia during the 21st century. *Conserv Physiol*, **8** (1), coaa048, doi:10.1093/conphys/coaa048.
Cradock-Henry, N. A., J. Connolly, P. Blackett and J. Lawrence, 2020: Elaborating a systems methodology for cascading climate change impacts and implications. *MethodsX*, **7**, 100893, doi:10.1016/j.mex.2020.100893.
CSIRO, 2018: Climate change in the Torres Strait: Implications for fisheries and marine ecosystems. *Earth Systems and Climate Change*, **4**, 40.
CSIRO, 2020: *Climate and Disaster Resilience: Technical Reports*. CSIRO, Australia., Csiro, 60 [Available at: https://www.csiro.au/en/Research/Environment/Extreme-Events/Bushfire/frontline-support/report-climate-disaste-resilience].
CSIRO and BOM, 2015: *Climate Change in Australia Information for Australia's Natural Resource Management Regions: Technical Report*. CSIRO and Bureau of Meteorology, Australia.
Cullen, B. R. et al., 2014: Use of modelling to identify perennial ryegrass plant traits for future warmer and drier climates %J Crop and Pasture Science. **65** (8), 758-766, doi:https://doi.org/10.1071/CP13408.
Cusack, L. et al., 2013: Extreme weather-related health needs of people who are homeless. *Australian Journal of Primary Health*, **19**, 250–255.
Darbyshire, R., P. Measham and I. Goodwin, 2016: A crop and cultivar-specific approach to assess future winter chill risk for fruit and nut trees. *Climatic Change*, **137** (3-4), 541-556, doi:10.1007/s10584-016-1692-3.
Darwin City Council, 2011: *Climate Change Action Plan 2011-2020*. Climate Change & Environment, Darwin City Council, 47 [Available at: https://www.darwin.nt.gov.au/sites/default/files/publications/attachments/cod_climatechangeactionplan_web.pdf].
Davies, A., L. Lockstone-Binney and K. Holmes, 2018: Who are the future volunteers in rural places? Understanding the demographic and background characteristics of non-retired rural volunteers, why they volunteer and their future migration intentions. *Journal of Rural Studies*, **60**, 167-175, doi:10.1016/j.jrurstud.2018.04.003.
Davis, C., 2013: Towards the development of long-term winter records for the Snowy Mountains. *Australian Meteorological and Oceanographic Journal*, **63** (2), 303-313, doi:10.22499/2.6302.003.
DCCEE, 2011: *Climate Change Risks to Coastal Buildings and Infrastructure: A supplement to the first pass national assessment*. Australian Government Department of Climate Change, Energy and Efficiency,20 pp.
De, L. L. et al., 2016: Our family comes first: migrants' perspectives on remittances in disaster. *Migration and Development*, **5** (1), 130-148, doi:10.1080/21632324.2015.1017971.
Dedekorkut-Howes, A., E. Torabi and M. Howes, 2020: Planning for a different kind of sea change: lessons from Australia for sea level rise and coastal flooding. *Climate Policy*, 1-19, doi:10.1080/14693062.2020.1819766.
DEHP, 2013: *Coastal Management Plan*. Coastal Planning, Department of Environment and Heritage Protection,16 pp.
Deloitte, 2016: *The economic cost of the social impact of natural disasters*. Deloitte Access Economics, 116 [Available at: http://australianbusinessroundtable.com.au/assets/documents/Report%20-%20Social%20costs/Report%20-%20The%20economic%20cost%20of%20the%20social%20impact%20of%20natural%20disasters.pdf].
Deloitte, 2017: *Building resilience to natural disasters in our states and territories*. 120.
Deloitte, 2019: *The social and economic cost of the North and Far North Queensland Monsoon Trough*. Queensland Reconstruction Authority, 36 [Available at: https://www2.deloitte.com/content/dam/Deloitte/au/Documents/Economics/deloitte-au-dae-monsoon-trough-social-economic-cost-report-160719.pdf].
Deloitte, 2020: *A new choice Australia's climate for growth*. Deloitte Access Economics, Brisbane, 74 [Available at: https://www2.deloitte.com/content/dam/Deloitte/au/Documents/Economics/deloitte-au-dae-new-choice-climate-growth.pdf?nc=1].
DELWP, 2018: *Monitoring, Evaluation, Reporting & Improvement Framework for Climate Change Adaptation in Victoria*. State of Victoria Department of Environment, Land, Water and Planning,24 pp.
DELWP, 2020: *Victoria's water in a changing climate*. The State of Victoria Department of Environment, Land, Water and Planning, 97 [Available at: https://www.water.vic.gov.au/__data/assets/pdf_file/0024/503718/VICWACI_VictoriasWaterInAChangingClimate_FINAL.pdf].
DENR, 2020a: *Delivering the Climate Change Response: Towards 2050 A Three-Year Action Plan for the Northern Territory Government*. Office of Climate Change, Department of Environment and Natural Resources, Northern Territory Government,6 pp.
DENR, 2020b: *Northern Territory Climate Change Response: Towards 2050*. Office of Climate Change, Department of Environment and Natural Resources, Northern Territory Government,11 pp.
DES, 2018: *Preparing a shoreline erosion management plan - Guideline for coastal development*. Queensland Government, 5 [Available at: https://www.qld.gov.au/__data/assets/pdf_file/0011/107300/gl-cd-preparing-a-shoreline-erosion-management-plan.pdf].

Ding, N., H. L. Berry and C. M. Bennett, 2016: The Importance of Humidity in the Relationship between Heat and Population Mental Health: Evidence from Australia. *PLOS ONE*, **11** (10), e0164190, doi:10.1371/journal.pone.0164190.
DOH, 2011: *Heatwave plan for Victoria: Protecting health and reducing harm from heatwaves*. State of Victoria, 30 [Available at: https://www.vgls.vic.gov.au/client/en_AU/search/asset/1161372/0].
Doherty, M. D., A. Malcolm Gill, G. J. Cary and M. P. Austin, 2017: Seed viability of early maturing alpine ash (Eucalyptus delegatensis subsp. delegatensis) in the Australian Alps, south-eastern Australia, and its implications for management under changing fire regimes. *Australian Journal of Botany*, **65** (7), 517, doi:10.1071/bt17068.
Driscoll, D. A. et al., 2019: Impacts of feral horses in the Australian Alps and evidence-based solutions. *Ecological Management & Restoration*, **20** (1), 63-72, doi:10.1111/emr.12357.
Ebi, K. L. et al., 2021: Burning embers: synthesis of the health risks of climate change. *Environ. Res. Lett.*, **16** (4), 044042, doi:10.1088/1748-9326/abeadd.
Eldridge, D. J. and G. Beecham, 2018: The Impact of Climate Variability on Land Use and Livelihoods in Australia's Rangelands. *Climate Variability Impacts on Land Use and Livelihoods in Drylands*, 293-315, doi:10.1007/978-3-319-56681-8_14.
Elrick-Barr, C. E. and T. F. Smith, 2021: Policy is rarely intentional or substantial for coastal issues in Australia. *Ocean & Coastal Management*, **207**, 105609, doi:10.1016/j.ocecoaman.2021.105609.
Enright, N. J. et al., 2015: Interval squeeze: altered fire regimes and demographic responses interact to threaten woody species persistence as climate changes. *Frontiers in Ecology and the Environment*, **13** (5), 265-272, doi:10.1890/140231.
Erhart, D. et al., 2020: *Climate Risk Management Framework for Queensland Local Government*. Local Government Association Queensland [Available at: https://qcrc.lgaq.asn.au/climate-risk-management-framework1].
Espada, R., Jr., A. Apan and K. McDougall, 2015: Vulnerability assessment and interdependency analysis of critical infrastructures for climate adaptation and flood mitigation. *International Journal of Disaster Resilience in the Built Environment*, **6** (3), 313-346, doi:10.1108/ijdrbe-02-2014-0019.
Every, D., 2016: *Disaster Risk Education Community Connections and Emergency Communication with People who are Homeless*. Prepared!for!Emergency Management Planning Communications, Victoria State Emergency Service, 29.
Every, D., K. Thompson and Others, 2014: Disaster resilience: Can the homeless afford it? *Australian Journal of Emergency Management, The*, **29** (3), 52.
Expert Group, 2018: *Cold Hard Facts 3*. 202 [Available at: https://www.airah.org.au/Content_Files/Industryresearch/cold-hard-facts-2018.pdf].
Fairman, T. A., C. R. Nitschke and L. T. Bennett, 2016: Too much, too soon? A review of the effects of increasing wildfire frequency on tree mortality and regeneration in temperate eucalypt forests. *International Journal of Wildland Fire*, **25** (8), 831, doi:10.1071/wf15010.
Fiddes, S. L., A. B. Pezza and V. Barras, 2015: A new perspective on Australian snow. *Atmospheric Science Letters*, **16** (3), 246-252, doi:10.1002/asl2.549.
Fitzer, S. C. et al., 2019: Selectively bred oysters can alter their biomineralization pathways, promoting resilience to environmental acidification. *Glob. Chang. Biol.*, doi:10.1111/gcb.14818.
Fletcher, A. L. et al., 2020: Has historic climate change affected the spatial distribution of water-limited wheat yield across Western Australia? *Climatic Change*, doi:10.1007/s10584-020-02666-w.
Forino, G., J. von Meding and G. Brewer, 2019: Community based initiatives to mainstream climate change adaptation into disaster risk reduction: evidence from the Hunter Valley (Australia). *Local Environment*, **24** (1), 52-67, doi:10.1080/13549839.2018.1548010.
Forino, G., J. von Meding and G. J. Brewer, 2017: Climate Change Adaptation and Disaster Risk Reduction Integration in Australia: Challenges and Opportunities. *Handbook of Disaster Risk Reduction & Management*, 273-294, doi:10.1142/9789813207950_0011.
Frame, D. et al., 2018: *Estimating financial costs of climate change in New Zealand: An estimate of climate change-related weather event costs*. New Zealand Climate Change Research Institute and NIWA, 18.
Frame, D. J. et al., 2020: Climate change attribution and the economic costs of extreme weather events: a study on damages from extreme rainfall and drought. *Climatic Change*, doi:10.1007/s10584-020-02729-y.
Gasparrini, A. et al., 2017: Projections of temperature-related excess mortality under climate change scenarios. *Lancet Planet Health*, **1** (9), e360-e367, doi:10.1016/S2542-5196(17)30156-0.
Ghahramani, A. et al., 2015: The value of adapting to climate change in Australian wheat farm systems: farm to cross-regional scale. *Agriculture, Ecosystems & Environment*, **211**, 112-125, doi:10.1016/j.agee.2015.05.011.
Gibbons, P. et al., 2012: Land management practices associated with house loss in wildfires. *PLOS ONE*, **7** (1), e29212, doi:10.1371/journal.pone.0029212.
Government of Tasmania, 2017: *Tasmanian Planning Scheme – State Planning Provisions*. State of Tasmania, Australia,514 pp.
Guest, C. S. et al., 1999: Climate and mortality in Australia: retrospective study, 1979-1990, and predicted impacts in five major cities in 2030. *Clim. Res.*, **13**, 1-15, doi:10.3354/cr013001.
Guo, Y. et al., 2018: Quantifying excess deaths related to heatwaves under climate change scenarios: A multicountry time series modelling study. *PLoS Med.*, **15** (7), e1002629, doi:10.1371/journal.pmed.1002629.

Haasnoot, M., J. Lawrence and A. K. Magnan, 2021: Pathways to coastal retreat. *Science*, **372** (6548), 1287-1290, doi:10.1126/science.abi6594.

Hague, B. S., B. F. Murphy, D. A. Jones and A. J. Taylor, 2019: Developing impact-based thresholds for coastal inundation from tide gauge observations. *Journal of Southern Hemisphere Earth Systems Science*, **69** (1), 252, doi:10.1071/es19024.

Hall, N. L. and L. Crosby, 2020: Climate Change Impacts on Health in Remote Indigenous Communities in Australia. *International Journal of Environmental Health Research*, 1-16, doi:10.1080/09603123.2020.1777948.

Hanna, C., I. White and B. C. Glavovic, 2021: Managed retreats by whom and how? Identifying and delineating governance modalities. *Climate Risk Management*, **31**, 100278, doi:10.1016/j.crm.2021.100278.

Hardy, D. et al., 2019: *Planning for Climate Change Impacts on Māori Coastal Ecosystems and Economies: A Case Study of 5 Māori-owned land blocks in the Horowhenua Coastal Zone*. Massey University, 116 [Available at: https://www.deepsouthchallenge.co.nz/sites/default/files/2020-03/Hardy%20et%20al.%20CC%20Impacts%20on%20Maori%20FINAL%20LOW%20RES%20Sections%201%20to%204_2.pdf].

Harris, R. M. B. et al., 2018: Biological responses to the press and pulse of climate trends and extreme events. *Nat. Clim. Chang.*, **8** (7), 579-587, doi:10.1038/s41558-018-0187-9.

Harris, R. M. B., D. J. Kriticos, T. Remenyi and N. Bindoff, 2017: Unusual suspects in the usual places: a phylo-climatic framework to identify potential future invasive species. *Biological Invasions*, **19** (2), 577-596, doi:10.1007/s10530-016-1334-8.

Harvey, N., 2019: Protecting private properties from the sea: Australian policies and practice. *Mar. Policy*, **107**, 103566, doi:10.1016/j.marpol.2019.103566.

Harvey, N. and B. Clarke, 2019: 21st Century reform in Australian coastal policy and legislation. *Marine Policy*, **103**, 27-32, doi:10.1016/j.marpol.2019.02.016.

Haskoning Australia, 2016: *Coastal Zone Management Plan for Bilgola Beach (Bilgola) and Basin Beach (Mona Vale)*. Haskoning Australia Pty Ltd, 80 [Available at: https://files.northernbeaches.nsw.gov.au/sites/default/files/2017224002_201707-bilgolabasinczmp-ecertified.pdf].

Heaviside, C., S. Vardoulakis and X.-M. Cai, 2016: Attribution of mortality to the urban heat island during heatwaves in the West Midlands, UK. *Environ. Health*, **15 Suppl 1**, 27, doi:10.1186/s12940-016-0100-9.

Heo, S. et al., 2016: Long-term changes in the heat-mortality relationship according to heterogeneous regional climate: a time-series study in South Korea. *BMJ Open*, **6** (8), e011786, doi:10.1136/bmjopen-2016-011786.

Heron, S. F. et al., 2017: *Impacts of Climate Change on World Heritage Coral Reefs: A First Global Scientific Assessment*. Center, U. W. H., Paris.

Hettiarachchi, S., C. Wasko and A. Sharma, 2019: Can antecedent moisture conditions modulate the increase in flood risk due to climate change in urban catchments? *Journal of Hydrology*, **571**, 11-20, doi:10.1016/j.jhydrol.2019.01.039.

Hodder, J., 2019: *Climate change litigation- who's afraid of creative judges? A paper for presentation to the "Climate Change Adaptation" session of the Local Government New Zealand Rural and Provincial Sector Meeting*. Jack Hodder QC, Wellington.

Hoffmann, A. A. et al., 2019: Impacts of recent climate change on terrestrial flora and fauna: Some emerging Australian examples. *Austral Ecol.*, **44** (1), 3-27, doi:10.1111/aec.12674.

Home Affairs, 2020: *The first national action plan to implement the national disaster risk reduction framework*. Australian Department of Home Affairs, 85 [Available at: https://www.homeaffairs.gov.au/emergency/files/first-national-action-plan.pdf].

Hope, P. et al., 2017: *A Synthesis of Findings from the Victorian Climate Initiative (VicCI)*. Bureau of Meteorology Australia, 56 [Available at: https://www.water.vic.gov.au/__data/assets/pdf_file/0030/76197/VicCI-25-07-17-MR.pdf].

Hughes, J. et al., 2021: Impacts and implications of climate change on wastewater systems: A New Zealand perspective. *Climate Risk Management*, **31**, 100262, doi:10.1016/j.crm.2020.100262.

Hughes, T. P. et al., 2018a: Spatial and temporal patterns of mass bleaching of corals in the Anthropocene. *Science*, **359** (6371), 80-83, doi:10.1126/science.aan8048.

Hughes, T. P. et al., 2019a: Global warming impairs stock–recruitment dynamics of corals. *Nature*, **568** (7752), 387-390, doi:10.1038/s41586-019-1081-y.

Hughes, T. P. et al., 2018b: Global warming transforms coral reef assemblages. *Nature*, **556** (7702), 492-496, doi:10.1038/s41586-018-0041-2.

Hughes, T. P. et al., 2019b: Ecological memory modifies the cumulative impact of recurrent climate extremes. *Nat. Clim. Chang.*, **9** (1), 40-43, doi:10.1038/s41558-018-0351-2.

Hunter, J., 2012: A simple technique for estimating an allowance for uncertain sea-level rise. *Climatic Change*, **113** (2), 239-252, doi:10.1007/s10584-011-0332-1.

Hyman, I. T. et al., 2020: Impacts of the 2019–2020 bushfires on New South Wales biodiversity: a rapid assessment of distribution data for selected invertebrate taxa. *Technical Reports of the Australian Museum online*, **32**, 1-17, doi:10.3853/j.1835-4211.32.2020.1768.

ICNZ, 2021: Cost of natural disasters. Insurance Council of New Zealand.

Infometrics and PSConsulting, 2015: *Flood Protection: Option Flexibility and its Value for Greater Wellington Regional Council*. Infometrics and PS Consulting,27 pp.
Iorns Magallanes, C., V. James and T. Stuart, 2018: Courts as Decision-Makers on Sea Level Rise Adaptation Measures: Lessons from New Zealand. *Climate Change Management*, 315-335, doi:10.1007/978-3-319-70703-7_17.
Iorns Magallanes, C. and J. Watts, 2019: *Adaptation to Sea-level Rise: Local Government Liability Issues : Research Report for the Deep South National Science Challenge*. Deep South National Science Challenge.
IPCC, 2018: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V. (ed.)]. In press pp.
IPCC, 2019: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [Pörtner, H. O. (ed.)]. In press pp.
IPCC, 2021: *Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press.
Jacobs, B. et al., 2016: Adaptation Planning Process and Government Adaptation Architecture Support Regional Action on Climate Change in New South Wales, Australia. In: Innovation in Climate Change Adaptation [Filho, W. L. (ed.)]. Springer International Publishing, Switzerland, 17-29.
Jay, O. et al., 2021: Reducing the health effects of hot weather and heat extremes: from personal cooling strategies to green cities. *Lancet*, **398** (10301), 709-724, doi:10.1016/S0140-6736(21)01209-5.
Jiang, W. et al., 2021: Compositional Changes in Grapes and Leaves as a Consequence of Smoke Exposure of Vineyards from Multiple Bushfires across a Ripening Season. *Molecules*, **26** (11), doi:10.3390/molecules26113187.
Johnson, D., M. Parsons and K. Fisher, 2021: Engaging Indigenous perspectives on health, wellbeing and climate change. A new research agenda for holistic climate action in Aotearoa and beyond. *Local Environ.*, **26** (4), 477-503, doi:10.1080/13549839.2021.1901266.
Jozaei, J., M. Mitchell and S. Clement, 2020: Using a resilience thinking approach to improve coastal governance responses to complexity and uncertainty: a Tasmanian case study, Australia. *J. Environ. Manage.*, **253**, 109662, doi:10.1016/j.jenvman.2019.109662.
Judd, B., 2019: Kapi Wiya: Water insecurity and aqua-nullius in remote inland Aboriginal Australia. *Thesis Eleven*, **150** (1), 102-118, doi:10.1177/0725513618821969.
Kean, J. et al., 2015: *Effects of climate change on current and potential biosecurity pests and diseases in New Zealand*.
Kendrovski, V. et al., 2017: Quantifying Projected Heat Mortality Impacts under 21st-Century Warming Conditions for Selected European Countries. *Int. J. Environ. Res. Public Health*, **14** (7), doi:10.3390/ijerph14070729.
Kiem, A. S. et al., 2016: Natural hazards in Australia: droughts. *Climatic Change*, **139** (1), 37-54, doi:10.1007/s10584-016-1798-7.
King, A. D., D. J. Karoly and B. J. Henley, 2017: Australian climate extremes at 1.5 °C and 2 °C of global warming. *Nature Climate Change*, **7** (6), 412-416, doi:10.1038/nclimate3296.
King, D. N., G. Penny and C. Severne, 2010: The climate change matrix facing Māori society. In: Climate change adaptation in New Zealand: Future scenarios and some sectoral perspectives [Jones, N. W. B. (ed.)]. New Zealand Climate Change Centre,Wellington, 100-111.
Kirkegaard, J. A. and J. R. Hunt, 2011: Increasing productivity by matching farming system management and genotype in water-limited environments. *Journal of Experimental Botany*, **61**, 4129-4143, doi:doi:10.1093/jxb/erq245.
Kirono, D. G. C. et al., 2020: Drought projections for Australia: Updated results and analysis of model simulations. *Weather and Climate Extremes*, **30**, 100280, doi:10.1016/j.wace.2020.100280.
Kjellstrom, T. et al., 2016: Heat, Human Performance, and Occupational Health: A Key Issue for the Assessment of Global Climate Change Impacts. *Annu. Rev. Public Health*, **37**, 97-112, doi:10.1146/annurev-publhealth-032315-021740.
Kompas, T., V. H. Pham and T. N. Che, 2018: The Effects of Climate Change on GDP by Country and the Global Economic Gains From Complying With the Paris Climate Accord. *Earth's Future*, **6** (8), 1153-1173, doi:10.1029/2018ef000922.
Kool, R., J. Lawrence, M. Drews and R. Bell, 2020: Preparing for Sea-Level Rise through Adaptive Managed Retreat of a New Zealand Stormwater and Wastewater Network. *Infrastructures*, **5** (11), 92, doi:10.3390/infrastructures5110092.
Lawrence, J. et al., 2020a: *Supporting decision making through adaptive tools in a changing climate: Practice guidance on signals and triggers*. Victoria University of Wellington, 67 [Available at: https://www.deepsouthchallenge.co.nz/sites/default/files/2020-03/Supporting%20decision%20making%20through%20adaptive%20tools%20in%20a%20changing%20climate%20Practice%20guidance%20on%20signals%20and%20triggers.pdf].

Lawrence, J., P. Blackett and N. A. Cradock-Henry, 2020b: Cascading climate change impacts and implications. *Climate Risk Management*, **29**, 100234, doi:10.1016/j.crm.2020.100234.
Lawrence, J. et al., 2020c: Implementing Pre-Emptive Managed Retreat: Constraints and Novel Insights. *Current Climate Change Reports*, **6**, 66-80, doi:https://doi.org/10.1007/s40641-020-00161-z.
Lawrence, J. et al., 2019: Correction to: Dynamic Adaptive Policy Pathways (DAPP): From Theory to Practice. *Decision Making under Deep Uncertainty*, C1-C1, doi:10.1007/978-3-030-05252-2_18.
Lawrence, J. et al., 2015: Adapting to changing climate risk by local government in New Zealand: institutional practice barriers and enablers. *Local Environment*, **20** (3), 298-320, doi:10.1080/13549839.2013.839643.
Leblanc, M., S. Tweed, A. Van Dijk and B. Timbal, 2012: A review of historic and future hydrological changes in the Murray-Darling Basin. *Global and Planetary Change*, **80-81**, 226-246, doi:10.1016/j.gloplacha.2011.10.012.
Lees, A. M. et al., 2019: The Impact of Heat Load on Cattle. *Animals (Basel)*, **9** (6), doi:10.3390/ani9060322.
Levy, R. et al., 2020: *Te tai pari o Aotearoa – Future sea level rise around New Zealand's dynamic coastline*. New Zealand Coastal Society, 10 [Available at: https://www.coastalsociety.org.nz/assets/Publications/Special-Issues/SP4-Low-res-version.pdf?].
LGNZ, 2017: *New Zealand Local Government Leaders' Climate Change Declaration*. Local Government New Zealand, 8 [Available at: https://www.lgnz.co.nz/assets/Uploads/0827d40e5d/Climate-Change-Declaration.pdf].
LGNZ, 2019: *Vulnerable: The quantum of local government instrastructure exposed to sea level rise* [Simonson, T. and G. Hall (eds.)]. Local Government New Zealand, 51 [Available at: http://www.lgnz.co.nz/our-work/publications/vulnerable-the-quantum-of-local-government-infrastructure-exposed-to-sea-level-rise].
Lindenmayer, D. and C. Taylor, 2020a: Extensive recent wildfires demand more stringent protection of critical old growth forest. *Pacific Conservation Biology*, **26** (4), 384, doi:10.1071/pc20037.
Lindenmayer, D. B. and C. Sato, 2018: Hidden collapse is driven by fire and logging in a socioecological forest ecosystem. *Proc. Natl. Acad. Sci. U. S. A.*, **115** (20), 5181-5186, doi:10.1073/pnas.1721738115.
Lindenmayer, D. B. and C. Taylor, 2020b: New spatial analyses of Australian wildfires highlight the need for new fire, resource, and conservation policies. *Proc. Natl. Acad. Sci. U. S. A.*, **117** (22), 12481-12485, doi:10.1073/pnas.2002269117.
Liss, A., R. Wu, K. K. H. Chui and E. N. Naumova, 2017: Heat-Related Hospitalizations in Older Adults: An Amplified Effect of the First Seasonal Heatwave. *Sci. Rep.*, **7**, 39581, doi:10.1038/srep39581.
Lough, J. M., K. D. Anderson and T. P. Hughes, 2018: Increasing thermal stress for tropical coral reefs: 1871-2017. *Sci. Rep.*, **8** (1), 6079, doi:10.1038/s41598-018-24530-9
10.1038/s41598-018-24530-9.
Love, J., R. Thapa, M. Drielsma and J. Robb, 2019: *Climate change impacts in the NSW and ACT Alpine region: Impacts on biodiversity*. NSW Department of Planning, I. a. E., Sydney, Australia.
Lukasiewicz, A., S. Dovers and M. Eburn, 2017: Shared responsibility: the who, what and how. *Environmental Hazards*, **16** (4), 291-313, doi:10.1080/17477891.2017.1298510.
Lundquist, C. J. et al., 2011: Predicted impacts of climate change on New Zealand's biodiversity. *Pacific Conservation Biology*, **17**, 179-191.
Luo, Q., K. Behrendt and M. Bange, 2017: Economics and Risk of Adaptation Options in the Australian Cotton Industry. *Agric. Syst.*, **150**, 46–53, doi:10.1016/j.agsy.2016.09.014.
Macintosh, A., A. Foerster and J. McDonald, 2015: Policy design, spatial planning and climate change adaptation: a case study from Australia. *J. Environ. Planning Manage.*, **58** (8), 1432-1453.
Mallon, K. et al., 2019: *Change Risk to Australia's Built Environment: A Second Pass National Assessment*. 82 [Available at: https://xdi.systems/wp-content/uploads/2019/10/Climate-Change-Risk-to-Australia%E2%80%99s-Built-Environment-V4-final-reduced-2.pdf].
Mathew, S., B. Zeng, K. K. Zander and R. K. Singh, 2018a: Exploring agricultural development and climate adaptation in northern Australia under climatic risks. *Rangeland J.*, **40** (4), 353-364, doi:10.1071/rj18011.
Mathew, S., B. Zeng, K. K. Zander and R. K. Singh, 2018b: Exploring agricultural development and climate adaptation in northern Australia under climatic risks. *The Rangeland Journal*, **40** (4), 353, doi:10.1071/rj18011.
Matteo, M. D. et al., 2019: Controlling rainwater storage as a system: An opportunity to reduce urban flood peaks for rare, long duration storms. *Environmental Modelling & Software*, **111**, 34-41, doi:10.1016/j.envsoft.2018.09.020.
Matthews, V. et al., 2019: Differential Mental Health Impact Six Months After Extensive River Flooding in Rural Australia: A Cross-Sectional Analysis Through an Equity Lens. *Frontiers in Public Health*, **7**, doi:10.3389/fpubh.2019.00367.
Matusick, G. et al., 2018: Chronic historical drought legacy exacerbates tree mortality and crown dieback during acute heatwave-compounded drought. *Environmental Research Letters*, **13** (9), 095002, doi:10.1088/1748-9326/aad8cb.
McInnes, K. et al., 2015: Information for Australian impact and adaptation planning in response to sea-level rise. *Australian Meteorological and Oceanographic Journal*, **65** (1), 127-149, doi:10.22499/2.6501.009.
McInnes, K. L. et al., 2016: Natural hazards in Australia: sea level and coastal extremes. *Clim. Change*, **139** (1), 69-83.
McNamara, K. E., R. Westoby and S. G. Smithers, 2017: Identification of limits and barriers to climate change adaptation: case study of two islands in Torres Strait, Australia. *Geographical Research*, **55** (4), 438-455, doi:10.1111/1745-5871.12242.
MfE, 2017: *Coastal Hazards and Climate Change: Guidance for Local Government* [Bell, R. G., J. Lawrence, S. Allan, P. Blackett and S. A. Stephens (eds.)]. Ministry for the Environment, 284 p + Appendices [Available at:

http://www.mfe.govt.nz/publications/climate-change/coastal-hazards-and-climate-change-guidance-local-government].

MfE, 2019: Environment Aotearoa 2019 | Ministry for the Environment.

MfE, 2020a: *National Climate Change Risk Assessment for Aotearoa New Zealand: Main report – Arotakenga Tūraru mō te Huringa Āhuarangi o Āotearoa: Pūrongo whakatōpū*. Ministry for the Environment, 133 [Available at: chrome-extension://bomfdkbfpdhijjbeoicnfhjbdhncfhig/view-file.html].

MfE, 2020b: *New directions for resource management in New Zealand*. Resource Management Review Panel, 531 [Available at: https://www.mfe.govt.nz/sites/default/files/media/RMA/rm-panel-review-report-web.pdf].

Moore, J. A. Y. et al., 2012: Unprecedented Mass Bleaching and Loss of Coral across 12° of Latitude in Western Australia in 2010–11. *PLOS ONE*, **7** (12), e51807, doi:10.1371/journal.pone.0051807.

Moran, M., P. Petrie and V. Sadras, 2019: Effects of late pruning and elevated temperature on phenology, yield components, and berry traits in Shiraz. *American Journal of Enology and Viticulture*, **70** (1), 9-18, doi:10.5344/ajev.2018.18031.

Morrison, C. and C. Pickering, 2013: Limits to Climate Change Adaptation: Case Study of the Australian Alps. *Geographical Research*, **51** (1), 11-25, doi:10.1111/j.1745-5871.2012.00758.x.

Mushtaq, S., 2016: Economic and policy implications of relocation of agricultural production systems under changing climate: Example of Australian rice industry. *Land use policy*, **52**, 277-286, doi:10.1016/j.landusepol.2015.12.029.

Naccarella, A., J. W. Morgan, S. C. Cutler and S. E. Venn, 2020: Alpine treeline ecotone stasis in the face of recent climate change and disturbance by fire. *PLOS ONE*, **15** (4), e0231339, doi:10.1371/journal.pone.0231339.

Natural Capital Economics, 2018: *Heatwaves in Victoria: A Vulnerability Assessment*. Department of Environment, Land, Water and Planning, Victoria, 102 [Available at: https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0029/399440/Heatwaves_VulnerabilityAssessment_2018.pdf].

Nicholls, N., 2005: Climate variability, climate change and the Australian snow season. *Aust. Meteorol. Mag.*, **54** (3), 177-185.

Nidumolu, U. et al., 2014: Spatio-temporal modelling of heat stress and climate change implications for the Murray dairy region, Australia. *Int J Biometeorol*, **58** (6), 1095-108, doi:10.1007/s00484-013-0703-6.

Nidumolu, U. B., P. T. Hayman, S. M. Howden and B. M. Alexander, 2012: Re-evaluating the margin of the South Australian grain belt in a changing climate. *Climate Research*, **51**, 249-260, doi:10.3354/cr01075.

Nitschke, M. et al., 2016: Evaluation of a heat warning system in Adelaide, South Australia, using case-series analysis. *BMJ Open*, **6** (7), e012125, doi:10.1136/bmjopen-2016-012125.

Nolan, R. H. et al., 2020: Causes and consequences of eastern Australia's 2019-20 season of mega-fires. *Glob. Chang. Biol.*, **26** (3), 1039-1041, doi:10.1111/gcb.14987.

NSW Government, 2016: *NSW Climate Change Policy Framework*. Office of Environment and Heritage,12 pp.

O'Donnell, T., 2019: Coastal management and the political-legal geographies of climate change adaptation in Australia. *Ocean & Coastal Management*, **175**, 127-135, doi:10.1016/j.ocecoaman.2019.03.022.

O'Donnell, T., T. F. Smith and S. Connor, 2019: Property rights and land use planning on the Australian coast. In: Research Handbook on Climate Change Adaptation Policy: Update on Progress [Keskitalo, E. C. and B. P (eds.)]. Edward Elgar, UK & USA.

OEH, 2018a: *Our future on the coast. NSW Coastal Management Manual Part B: Stage 1 – Identify the scope of a coastal management program*. State of NSW and Office of Environment and Heritage, 39 [Available at: https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Water/Coasts/coastal-management-manual-part-b-stage-1-170672.pdf].

OEH, 2018b: *Our future on the coast: An overview of coastal management in NSW*. Office of Environment and Heritage, 16 [Available at: https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Water/Coasts/coastal-management-overview-170648.pdf].

OEH, 2018c: *Our Future on the Coast: NSW Coastal Management Manual Part A - Introduction and mandatory requirements for a coastal management program*. State of NSW and Office of Environment and Heritage, 29 [Available at: https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Water/Coasts/coastal-management-manual-part-a-170671.pdf].

Orwin, K. H. et al., 2015: Effects of climate change on the delivery of soil-mediated ecosystem services within the primary sector in temperate ecosystems: a review and New Zealand case study. *Glob Chang Biol*, **21** (8), 2844-60, doi:10.1111/gcb.12949.

Osborne, K. et al., 2017: Delayed coral recovery in a warming ocean. *Glob. Chang. Biol.*, **23** (9), 3869-3881, doi:10.1111/gcb.13707

10.1111/gcb.13707. Epub 2017 May 9.

Parliament of Victoria, 2010: *2009 Victorian Bushfires Royal Commission*. Victorian Bushfire Royal Commission, 42 [Available at: http://royalcommission.vic.gov.au/Commission-Reports/Final-Report.html].

Paulik, R. et al., 2020: National-Scale Built-Environment Exposure to 100-Year Extreme Sea Levels and Sea-Level Rise. *Sustainability*, **12** (4), 1513, doi:10.3390/su12041513.

PCE, 2015: *Preparing New Zealand for rising seas: Certainty and Uncertainty*. Parliamentary Commissioner for the Environment, 93 [Available at: https://www.pce.parliament.nz/media/1390/preparing-nz-for-rising-seas-web-small.pdf].
Pepler, A., B. Trewin and C. Ganter, 2015: The influence of climate drivers on the Australian snow season. *Australian Meteorological and Oceanographic Journal*, **65** (2), 195-205, doi:10.22499/2.6502.002.
Perceval, M. et al., 2019: Environmental factors and suicide in Australian farmers: A qualitative study. *Arch. Environ. Occup. Health*, **74** (5), 279-286, doi:10.1080/19338244.2018.1453774.
Perera, R. S., B. R. Cullen and R. J. Eckard, 2020: Changing patterns of pasture production in south-eastern Australia from 1960 to 2015. *Crop and Pasture Science*, **71** (1), doi:10.1071/cp19112.
Pescaroli, G. and D. Alexander, 2016: Critical infrastructure, panarchies and the vulnerability paths of cascading disasters. *Natural Hazards*, **82** (1), 175-192, doi:10.1007/s11069-016-2186-3.
Phelan, L., 2011: Managing climate risk: extreme weather events and the future of insurance in a climate-changed world. *Australasian Journal of Environmental Management*, **18** (4), 223-232, doi:10.1080/14486563.2011.611486.
Phelan, L., R. Taplin, A. Henderson-Sellers and G. Albrecht, 2011: Ecological Viability or Liability? Insurance System Responses to Climate Risk. *Environmental Policy and Governance*, **21** (2), 112-130, doi:10.1002/eet.565.
Post, D. A. et al., 2014: Decrease in southeastern Australian water availability linked to ongoing Hadley cell expansion. *Earth's Future*, **2** (4), 231-238, doi:10.1002/2013ef000194.
Potter, N. J., F. H. S. Chiew and A. J. Frost, 2010: An assessment of the severity of recent reductions in rainfall and runoff in the Murray–Darling Basin. *Journal of Hydrology*, **381** (1-2), 52-64, doi:10.1016/j.jhydrol.2009.11.025.
Productivity Commission, 2017: *Better Urban Planning: Final Report*.
QFCI, 2012: *Queensland Floods Commission of Inquiry*. Queensland Government, Government, Q., 654.
QFES, 2019: *State Heatwave Risk Assessment 2019*. The State of Queensland (Queensland Fire and Emergency Services),108 pp.
Queensland Government, 1995: *Coastal Protection and Management Act (1995)*.
Queensland Government, 2011: *Understanding Floods: Questions and Answers*. Queensland Government,36 pp.
Queensland Government, 2020: *Planning Act 2016*.366 pp.
Radcliffe, J. C., D. Page, B. Naumann and P. Dillon, 2017: Fifty years of water sensitive urban design, Salisbury, South Australia. *Frontiers of Environmental Science & Engineering*, **11** (4), doi:10.1007/s11783-017-0937-3.
Radhakrishnan, M., A. Pathirana, R. Ashley and C. Zevenbergen, 2017: Structuring Climate Adaptation through Multiple Perspectives: Framework and Case Study on Flood Risk Management. *Water*, **9** (2), 129, doi:10.3390/w9020129.
Ramm, T. D., C. S. Watson and C. J. White, 2018: Strategic adaptation pathway planning to manage sea-level rise and changing coastal flood risk. *Environ. Sci. Policy*, **87**, 92-101, doi:10.1016/j.envsci.2018.06.001.
Ratnayake, H. U. et al., 2019: Forecasting wildlife die-offs from extreme heat events. *Animal Conservation*, **22** (4), 386-395, doi:10.1111/acv.12476.
Robb, A. et al., 2019: Development Control And Vulnerable Coastal Lands: Examples Of Australian Practice. *Urban Policy and Research*, **37** (2), 199-214, doi:10.1080/08111146.2018.1489791.
Rocklov, J., K. Ebi and B. Forsberg, 2011: Mortality related to temperature and persistent extreme temperatures: a study of cause-specific and age-stratified mortality. *Occupational and Environmental Medicine*, **68** (7), 531-536, doi:10.1136/oem.2010.058818.
Rogers, B. C. et al., 2020: Water Sensitive Cities Index: A diagnostic tool to assess water sensitivity and guide management actions. *Water Research*, 116411, doi:10.1016/j.watres.2020.116411.
Rogers, C., A. Gallant and N. Tapper, 2018: Is the urban heat island exacerbated during heatwaves in southern Australian cities? *Theor. Appl. Climatol.*, 1-17, doi:10.1007/s00704-018-2599-x.
Rolfe, M. I. et al., 2020: Social vulnerability in a high-risk flood-affected rural region of NSW, Australia. *Natural Hazards*, **101** (3), 631-650, doi:10.1007/s11069-020-03887-z.
Rouse, H. L. et al., 2017: Coastal adaptation to climate change in Aotearoa-New Zealand. *N. Z. J. Mar. Freshwater Res.*, **51** (2), 183-222, doi:10.1080/00288330.2016.1185736.
RSNZ, 2016: *Climate change implications for New Zealand*. Royal Society of New Zealand, 68.
Rychetnik, L., P. Sainsbury and G. Stewart, 2019: How Local Health Districts can prepare for the effects of climate change: an adaptation model applied to metropolitan Sydney. *Aust. Health Rev.*, **43** (6), 601-610, doi:10.1071/AH18153.
SA Government, 2019a: *Directions for a Climate Smart South Australia*. Government of South Australia,12 pp.
SA Government, 2019b: *Murray-Darling Basin Royal Commission Report*. South Australia Government,746 pp.
Saintilan, N. et al., 2020: Thresholds of mangrove survival under rapid sea level rise. *Science*, **368** (6495), 1118-1121, doi:10.1126/science.aba2656.
Salinger, M. J. et al., 2020: Unparalleled coupled ocean-atmosphere summer heatwaves in the New Zealand region: drivers, mechanisms and impacts. *Climatic Change*, doi:10.1007/s10584-020-02730-5.
Salinger, M. J. et al., 2019: The unprecedented coupled ocean-atmosphere summer heatwave in the New Zealand region 2017/18: drivers, mechanisms and impacts. *Environ. Res. Lett.*, **14** (4), 044023.

Schneider, P., B. Glavovic and T. Farrelly, 2017: So Close Yet So Far Apart: Contrasting Climate Change Perceptions in Two “Neighboring” Coastal Communities on Aotearoa New Zealand’s Coromandel Peninsula. *Environments*, **4** (3), 65, doi:10.3390/environments4030065.

Schuster, S., 2013: Natural hazards and insurance. In: Climate Adaptation Futures [Palutikof, J., S. Boulter, A. Ash, M. Stafford Smith, M. Parry, M. Waschka and D. Guitart (eds.)]. John Wiley & Sons, Brisbane, Australia, 133-140.

Scott, H. and S. Moloney, 2021: Completing the climate change adaptation planning cycle: monitoring and evaluation by local government in Australia. *Journal of Environmental Planning and Management*, 1-27, doi:10.1080/09640568.2021.1902789.

Sellberg, M. M. et al., 2018: From resilience thinking to Resilience Planning: Lessons from practice. *Journal of Environmental Management*, **217**, 906-918, doi:10.1016/j.jenvman.2018.04.012.

Sheng, Y. and X. Xu, 2019: The productivity impact of climate change: Evidence from Australia's Millennium drought. *Econ. Model.*, **76**, 182-191, doi:10.1016/j.econmod.2018.07.031.

Silva, L. G. M. et al., 2020: Mortality events resulting from Australia's catastrophic fires threaten aquatic biota. *Global Change Biology*, doi:10.1111/gcb.15282.

Simpson, N. P. et al., 2021: A framework for complex climate change risk assessment. *One Earth*, **4** (4), 489-501, doi:10.1016/j.oneear.2021.03.005.

Sinclair, K., A. Rawluk, S. Kumar and A. Curtis, 2017: Ways forward for resilience thinking: lessons from the field for those exploring social-ecological systems in agriculture and natural resource management. *Ecol. Soc.*, **22** (4), doi:10.5751/ES-09705-220421.

Slatyer, R., 2010: Climate change impacts on Australia’s alpine ecosystems. *ANU Undergraduate Research Journal*, **2**, doi:10.22459/aurj.02.2010.05.

Smith, H. et al., 2017: *Adaptation Strategies to Address Climate Change Impacts on Coastal Māori Communities in Aotearoa New Zealand: A Case Study of Dairy Farming in the Horowhenua- Kāpiti Coastal Zone*. Massey University, 140 [Available at: https://drive.google.com/file/d/1BLzuGU9-bpz_p05RMTzYXSUWw3GYzrfF/view?usp=drive_open&usp=embed_facebook].

Smith, K. and G. Lawrence, 2014: Flooding and Security: A Case Study of Community Resilience in Rockhampton. *Rural Society*, 5230-5249, doi:10.5172/rsj.2014.5230.

State of Tasmania, 2017: *Climate Action 21: Tasmania's Climate Change Action Plan 2017 - 2021*. Tasmanian Climate Change Office Department of Premier and Cabinet,36 pp.

Steffen, W., J. Hunter and L. Hughes, 2014: *Counting the costs: Climate change and coastal flooding*. Climate Council of Australia, 82 [Available at: https://www.climatecouncil.org.au/resources/coastalflooding/].

Steffen, W. et al., 2019: *Compound costs: How climate change is damaging Australia's economy*. Climate Council of Australia, 32 [Available at: https://www.climatecouncil.org.au/wp-content/uploads/2019/05/Costs-of-climate-change-report.pdf].

Stephens, S., 2015: The effect of sea-level rise on the frequency of extreme sea levels in New Zealand. *National Institute of Water and Atmospheric Research: Hamilton, New Zealand*.

Stephens, S. A., R. G. Bell and I. D. Haigh, 2020: Spatial and temporal analysis of extreme storm-tide and skew-surge events around the coastline of New Zealand. *Natural Hazards and Earth System Sciences*, **20** (3), 783-796, doi:10.5194/nhess-20-783-2020.

Stephens, S. A., R. G. Bell and J. Lawrence, 2017: Applying Principles of Uncertainty within Coastal Hazard Assessments to Better Support Coastal Adaptation. *J. Mar. Sci. Eng.*, **5** (3), 40, doi:10.3390/jmse5030040.

Stephens, S. A., R. G. Bell and J. Lawrence, 2018: Developing signals to trigger adaptation to sea-level rise. *Environmental Research Letters*, **13** (10), 104004, doi:10.1088/1748-9326/aadf96.

Storey, B. and I. Noy, 2017: Insuring property under climate change. *Policy Quarterly*, **13** (4), doi:10.26686/pq.v13i4.4603.

Storey, B. et al., 2017: Insurance, Housing and Climate Adaptation: current knowledge and future research. *Motu Economic and Public Policy Research*, **27**.

Swales, E. A., R. G. Bell and A. Lohrer, 2020: Estuaries and Lowland Brackish Habitats. In: Coastal Systems and Sea Level Rise: What to Look for in Future [C. Hendtlass, S. Morgan and D. Neale (eds.)]. NZ Coastal Society, 55-64.

Swiss Re, 2021: *The economics of climate change: no action not an option*. Swiss Re Management Institute, 30 [Available at: https://www.swissre.com/dam/jcr:e73ee7c3-7f83-4c17-a2b8-8ef23a8d3312/swiss-re-institute-expertise-publication-economics-of-climate-change.pdf].

Tait, A. and P. Pearce, 2019: Impacts and implications of climate change on Waituna Lagoon, Southland. *Sci. Conserv.*

TAO, 2020: *Sustainable Finance Forum: Roadmap for Action*. The Aotearoa Circle [Available at: https://static1.squarespace.com/static/5bb6cb19c2ff61422a0d7b17/t/5f9f7a83aa6e763a1b0f6759/1604287127400/20207-000234_Sustainable+Finance+Forum+Final.pdf].

Tapper, N. J., In Press: Creating Cooler, Healthier and More Liveable Australian Cities Using Irrigated Green Infrastructure. In: Urban Climate Science for Planning Healthy Cities [Ren, C. and G. McGregor (eds.)]. Springer.

Tasmanian Climate Change Office, 2012: *Coastal Adaptation Pathways. Developing Coastal Adaptation Pathways with Local Communities.* . [Available at: http://www.dpac.tas.gov.au/__data/assets/pdf_file/0017/229130/Example_Interim_Local_Area_Report_Coastal_module_3.PDF].

Taylor, C. et al., 2018: Trends in wheat yields under representative climate futures: Implications for climate adaptation. *Agric. Syst.*, **164**, 1-10.
Thompson, J. A., 2016: A MODIS-derived snow climatology (2000-2014) for the Australian Alps. *Climate Research*, **68** (1), 25-38, doi:10.3354/cr01379.
Thomsen, M. S. et al., 2019: Local Extinction of Bull Kelp (Durvillaea spp.) Due to a Marine Heatwave. *Frontiers in Marine Science*, **6**, 84, doi:10.3389/fmars.2019.00084.
Timbal, B. and H. Hendon, 2011: The role of tropical modes of variability in recent rainfall deficits across the Murray-Darling Basin. *Water Resources Research*, **47** (12), doi:10.1029/2010wr009834.
Tombs, D and B. France-Hudson, 2018: Climate change compensation. *Policy Quarterly*, **14** (4), 50-56.
Tong, S. et al., 2014: The impact of heatwaves on mortality in Australia: a multicity study. *BMJ Open*, **4** (2), e003579, doi:10.1136/bmjopen-2013-003579.
TSRA, 2014: *Torres Strait Climate Change Strategy 2014-2018*. Land and Sea Management Unit, Torres Strait Regional Authority,36 pp.
TSRA, 2016: *Torres Strait Regional Adaptation and Resilience Plan 2016-2021*. Environmental Management Program, Torres Strait Regional Authority,108 pp.
TSRA, 2018: *Torres Strait Climate Change and Health – First Pass Risk Assessment*. Prepared by BMT Global for the Environmental Management Program, Torres Strait Regional Authority, Thursday Island, Queensland.
Turton, S. M., 2017: Expansion of the tropics: revisiting frontiers of geographical knowledge. *Geographical Research*, **55** (1), 3-12, doi:10.1111/1745-5871.12230.
van Dijk, A. I. J. M. et al., 2013: The Millennium Drought in southeast Australia (2001-2009): Natural and human causes and implications for water resources, ecosystems, economy, and society. *Water Resources Research*, **49** (2), 1040-1057, doi:10.1002/wrcr.20123.
van Oldenborgh, G. J. et al., 2021: Attribution of the Australian bushfire risk to anthropogenic climate change. *Natural Hazards and Earth System Sciences*, **21** (3), 941-960, doi:10.5194/nhess-21-941-2021.
van Wettere, W. H. E. J. et al., 2021: Review of the impact of heat stress on reproductive performance of sheep. *J. Anim. Sci. Biotechnol.*, **12** (1), 26, doi:10.1186/s40104-020-00537-z.
Vergés, A. et al., 2016: Long-term empirical evidence of ocean warming leading to tropicalization of fish communities, increased herbivory, and loss of kelp. *Proc. Natl. Acad. Sci. U. S. A.*, **113** (48), 13791-13796, doi:10.1073/pnas.1610725113.
Vertessy, R. V. et al., 2019: *Final Report of the Independent Assessment of the 2018-19 Fish Deaths in the Lower Darling*. Independent panel for the Australian Government, 99 [Available at: https://www.mdba.gov.au/sites/default/files/pubs/Final-Report-Independent-Panel-fish-deaths-lower%20Darling_4.pdf].
Vicedo-Cabrera, A. M. et al., 2021: The burden of heat-related mortality attributable to recent human-induced climate change. *Nat. Clim. Chang.*, **11** (6), 492-500, doi:10.1038/s41558-021-01058-x.
Victoria State Government DELWP, 2016: *Victoria's Climate Change Adaptation Plan 2017-2020*. Victoria State Government DELWP, Melbourne.
WA Government, 2016: *Water for Growth: Urban - Western Australia's water supply and demand outlook to 2050.* Government of Western Australia, Department of Water, 25 [Available at: https://www.water.wa.gov.au/__data/assets/pdf_file/0016/8521/110200.pdf].
Wahl, M. et al., 2015: The responses of brown macroalgae to environmental change from local to global scales: direct versus ecologically mediated effects. *Perspectives in Phycology*, **2** (1), 11-29, doi:10.1127/pip/2015/0019.
Wang, B. et al., 2018: Australian wheat production expected to decrease by the late 21st century. *Glob. Chang. Biol.*, **24** (6), 2403-2415, doi:10.1111/gcb.14034.
Ward, M. et al., 2020: Impact of 2019-2020 mega-fires on Australian fauna habitat. *Nat Ecol Evol*, doi:10.1038/s41559-020-1251-1.
Wardell-Johnson, G. W., M. Calver, N. Burrows and G. Di Virgilio, 2015: Integrating rehabilitation, restoration and conservation for a sustainable jarrah forest future during climate disruption. *Pac. Conserv. Biol.*, **21** (3), 175-185.
Warmenhoven, T. et al., 2014: *Climate Change and Community Resilience in the Waiapu Catchment*. MPI,76 pp.
Warnken, J. and R. Mosadeghi, 2018: Challenges of implementing integrated coastal zone management into local planning policies, a case study of Queensland, Australia. *Marine Policy*, **91**, 75-84, doi:10.1016/j.marpol.2018.01.031.
Waters, E. and J. Barnett, 2018: Spatial imaginaries of adaptation governance: A public perspective. *Environment and Planning C: Politics and Space*, **36** (4), 708-725, doi:10.1177/2399654417719557.
Watson, P. J., 2020: Updated Mean Sea-Level Analysis: Australia. *Journal of Coastal Research*, **36** (5), 915, doi:10.2112/jcoastres-d-20-00026.1.
Wernberg, T. et al., 2016: Climate-driven regime shift of a temperate marine ecosystem. *Science*, **353** (6295), 169-172, doi:10.1126/science.aad8745
10.1126/science.aad8745.
Wheeler, S. A., A. Zuo and A. Loch, 2018: Water torture: Unravelling the psychological distress of irrigators in Australia. *Journal of Rural Studies*, **62**, 183-194, doi:10.1016/j.jrurstud.2018.08.006.
White, C. J. et al., 2016: *Tasmania's State Natural Disaster Risk Assessment*. University of Tasmania, Hobart, 191 [Available at: http://climatefutures.org.au/wp-content/uploads/2016/07/TSNDRA-2016.pdf].

White, I. and J. Lawrence, 2020: Continuity and change in national riskscapes: a New Zealand perspective on the challenges for climate governance theory and practice. *Cambridge Journal of Regions, Economy and Society*, doi:10.1093/cjres/rsaa005.

Williams, R. J. et al., 2015: An International Union for the Conservation of Nature Red List ecosystems risk assessment for alpine snow patch herbfields, South-Eastern Australia. *Austral Ecology*, **40** (4), 433-443, doi:10.1111/aec.12266.

Wong, T. H. F., N. Tapper, J., and S. P. Luby, 2020: Planetary health approaches for dry cities: water quality and heat mitigation. *British Medical Journal*, **371**, doi:10.1136/bmj.m4313

WSAA, 2016: *Climate Change Adaptation Guidelines*. Water Services Association of Australia, Australia, W. S. A. o., 89.

Yazd, S. D., S. A. Wheeler and A. Zuo, 2019: Exploring the Drivers of Irrigator Mental Health in the Murray–Darling Basin, Australia. *Sustainability*, **11** (21), 6097, doi:10.3390/su11216097.

Zhang, X. S. et al., 2016: How streamflow has changed across Australia since the 1950s: evidence from the network of hydrologic reference stations. *Hydrology and Earth System Sciences*, **20** (9), 3947-3965, doi:10.5194/hess-20-3947-2016.

Zscheischler, J. et al., 2018: Future climate risk from compound events. *Nat. Clim. Chang.*, **8** (6), 469-477, doi:10.1038/s41558-018-0156-3.

Zylstra, P. J., 2018: Flammability dynamics in the Australian Alps. *Austral Ecology*, **43** (5), 578-591.