Australian Government

Australian Climate Service

2025

Australia's National Climate Risk Assessment

The Australian Climate Service is a partnership of:

Australian Government Bureau of Meteorology

CSIRO

Australian Bureau of Statistics

Australian Government Geoscience Australia

Acknowledgement of Traditional Owners

The Australian Climate Service pays respect to Aboriginal and Torres Strait Islander peoples and their diverse Nations.

We acknowledge their deep cultural, social, environmental, spiritual and economic connection to their lands and waters.

The Australian Climate Service values the role that Aboriginal and Torres Strait Islander peoples' knowledge and cultural values play in understanding and responding to Australia's climate and natural hazard risks.

Photo: Nitmiluk Gorge, NT, Australia. Source: Matt Scherf

Executive summary

Australia is experiencing more frequent and severe extreme weather events due to the changing climate.

The impact of these is already being felt by every part of our society.

Australia's first National Climate Risk Assessment (National Assessment) delivers an improved understanding of climate risks Australia is experiencing now and may experience in the future. This is the first time information has been developed and synthesised in this way to provide insights on how climate risk affects different sectors and regions of the country.

This is an important first step in informing the nation. It is only by understanding who or what may be at risk, and to what extent, that Australia can support and enable effective preparedness and action. The effectiveness of action, and how the risks are evolving, will need to be monitored over time, with adjustments made as necessary to mitigate the risks.

This National Assessment supports the Australian Government's National Adaptation Plan. The information and resources developed as part of the National Assessment can help others to assess risks, identify any opportunities and prioritise actions that safeguard the things that Australians care about – our people and communities, our economy, our natural environment, our infrastructure and our essential services.

This National Assessment complements climate risk assessments completed by state and territory governments. The national scale data provides context and addresses information gaps; high-resolution local data should be used for assessment and planning purposes where available.

The intent of the National Assessment is to characterise the current and future climate risks facing Australia. Understanding, monitoring and planning for these risks is crucial across all parts of society. The methodology was developed by the Australian Climate Service in partnership with the Australian Government's Department of Climate Change, Energy, the Environment and Water. It aligns with other risk management practices that provide the necessary information for effective preparedness and response. The approach has drawn on international experience (particularly Canada, New Zealand, the United Kingdom and Europe), and on best practice information from the International Panel on Climate Change (IPCC). It also incorporates insights and feedback from state and territory governments, independent subject matter experts and recent industry-led climate risk assessments.

This is Australia's first National Assessment and it has been completed over a 2-year timeframe. The analysis was guided by early identification with stakeholders of where there were gaps in national understanding of risks.

The National Assessment provides a sound evidence base for decision-making and provides a good foundation to build on. Ongoing monitoring and capability will be required to enhance our understanding of climate risks and to support effective preparedness and adaptation.

Climate risks are not static. Responding to climate changes requires an ongoing flow of information and decision support resources to guide decisions and action over time. The Australian Climate Service is committed to strengthening Australia's knowledge base to support effective adaptation.

Key findings

Changing hazards

- Australia's climate is changing and will continue to change into the future. The country is likely to experience more intense and extreme climate hazards, and in some cases in areas where people and places haven't experienced these hazards before.
- Climate science indicates that our future extreme weather is likely to differ significantly from the past. Changes in the timing, duration, intensity and spatial patterns of hazards are likely, with many events occurring more frequently, in combination or affecting new locations.
- The change in distribution, timing and severity of extreme weather events means that historical observations on their own are not likely to be a good indicator of future risk.
- Australia currently experiences compounding and cascading hazards, and this is going to increase. Concurrent events, and reduced time between severe events will become more common.

Risks to people

- Individuals and households already disadvantaged are the most vulnerable to the impacts of a changing climate. Actions that address underlying disadvantage can reduce the impacts of climate change.
- Aboriginal and Torres Strait Islander peoples will experience unique impacts from climate change. The changing climate threatens the health of Country, access to Country and could challenge self-determination and have flow-on impacts on their social and physical health and wellbeing.
- Extreme heat, floods, bushfires, poor air quality and communicable diseases will escalate health risks. Those with pre-existing health conditions, including mental ill-health, are most at risk. This includes the very young and our older populations. People who work outdoors will also be at increased risk.

Risks to places

- Climate impacts are experienced differently across Australia. There are several key areas that have been identified as watchpoints:
  - Sea level rise and increased coastal hazards will significantly impact coastal communities and cities. By 2050, the number of coastal communities located in high and very high risk areas nationally will increase. If populations remained as they are today, this would equate to >1.5 million people living in areas that will experience sea level rise and coastal flooding risks by 2050.
  - Northern Australia is likely to experience escalating challenges as its proneness to hazards increases as global temperature rise. This will put pressure on health, critical infrastructure, natural species and ecosystems, and primary industries. It will also pose additional challenges to emergency responders.
  - Outer urban areas of cities stand out as watchpoints. These areas are particularly susceptible to adverse impacts because of their circumstances (location, demographics, proneness to hazards).
  - Remote communities are vulnerable today due to limitations in power and telecommunications supply and weak supply chains. This vulnerability will increase as critical infrastructure and supply chains face increased disruptions.

Risks to our way of life

- Extreme events will affect some communities more than others. High-risk communities are likely to experience domestic migration, which in turn could disrupt local economies, social networks, traditional identities and cultural heritage.
- An escalation of risks in one system is highly likely to have a ripple effect across sectors, services and structures. Extreme events will lead to property damage, increased insurance costs and even loss of homes, particularly in coastal areas vulnerable to sea level rise and erosion. These impacts will contribute to the cost of living, placing further stress on household budgets.
- Australians will be impacted by loss of important ecosystems and species by the middle of the century, without implementing direct intervention and adaptation actions. Ecosystems provide clean air and water, food security through pollination, raw materials for medicines, natural disaster protection, and regulate the local climate. Australia's plants and animals have evolved to fit their local climatic conditions.
- More frequent and more intense extreme events will affect the way of life in different ways across Australia – from impacts to sport and recreation, to unreliable infrastructure, like energy sources during heatwaves. There will be additional pressure on emergency responders and defence resources. Increased severe floods and bushfires will degrade water quality, placing pressure on already limited water sources.

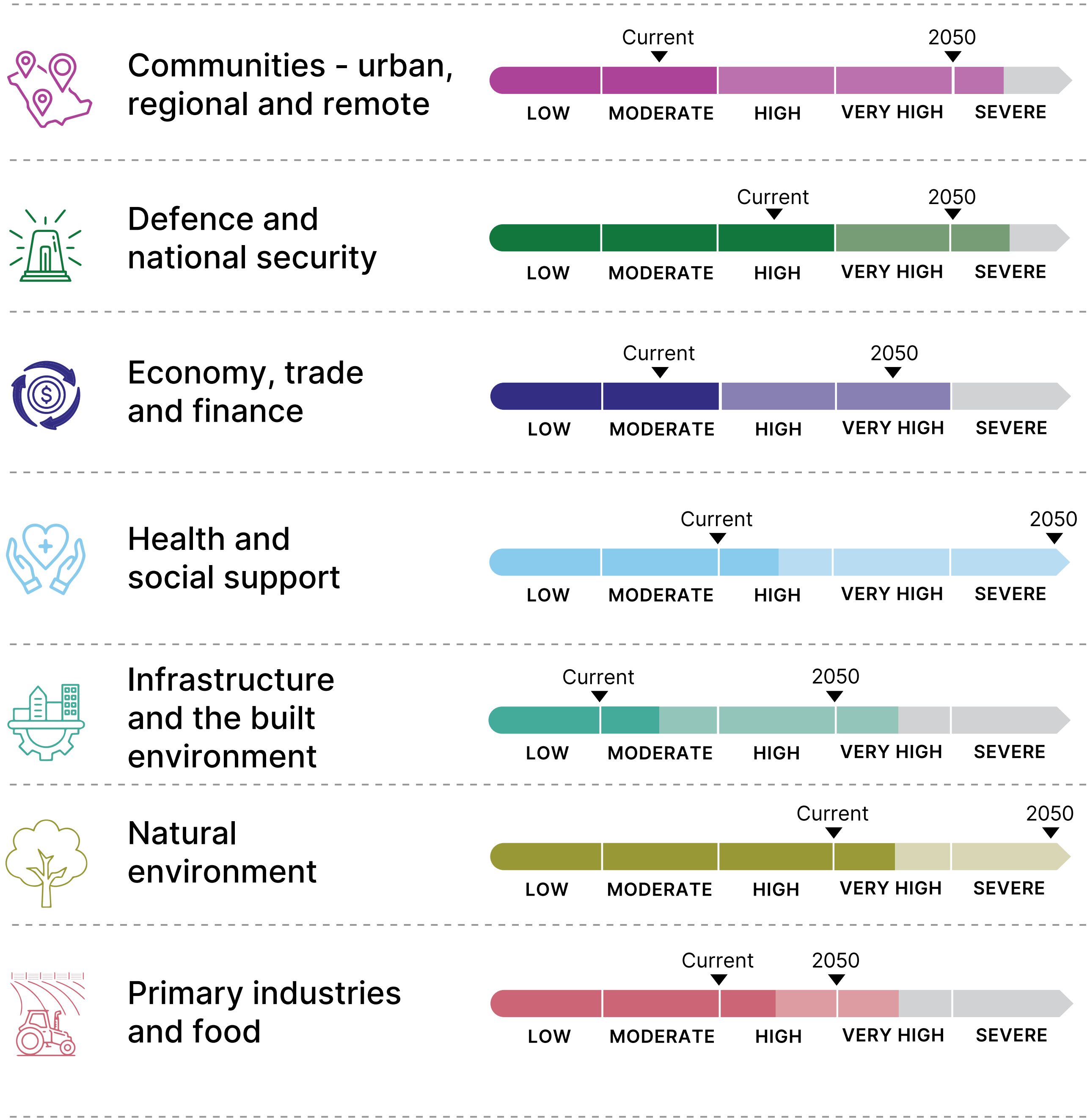
Climate risks to Australia's key systems

Systems are a fundamental construct in the National Assessment and the National Adaptation Plan.

They represent natural groupings of elements that interact closely, and which together form a national view of things Australians value.

The Australian Climate Service has rated risks to Australia's key systems, both now and in the future. The risk ratings categorise impacts into 5 levels – Low, Moderate, High, Very High and Severe – based on specific criteria. These ratings consider the percentage of the population affected, the extent of geographical impact, and the severity of consequences for vulnerable communities, public health, natural systems and national security.

These ratings aim to inform decision-makers on the severity of expected impacts. It should be noted that future ratings assume no change in adaptation investment or approach.



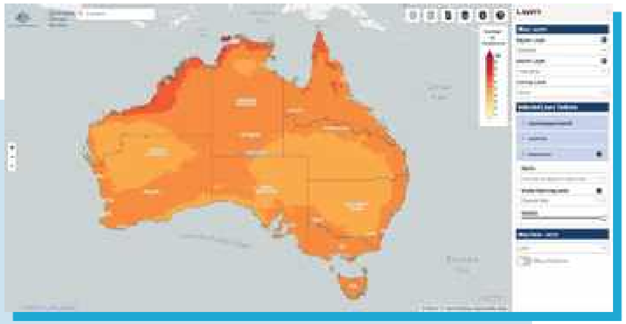
Key resources

Key resources have been developed as part of the National Assessment.

These key resources are supported by additional intelligence and data on the Australian Climate Service website.

Australia's National Climate Risk Assessment: An Overview

Australia's National Climate Risk Assessment Report



Data, information and insights to assist planning and adaptation are available on the Australian Climate Service website: **acs.gov.au**

Summary of National Assessment in numbers

10 PRIORITY **HAZARDS**

11 REGIONS FOR ANALYSIS

8 KEY FUNCTIONAL **SYSTEMS**

>15 NEW NATIONAL **DATASETS**

41 KEY **WORKSHOPS**

2,013 **WORKSHOP** PARTICIPANTS

254 **CLIMATE RISK** EXPERTS & AUTHORS

56 **NATIONALLY SIGNIFICANT RISKS** IDENTIFIED IN FIRST PASS ASSESSMENT

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7 **NATIONALLY SIGNIFICANT RISKS** TO ABORIGINAL AND TORRES STRAIT ISLANDER PEOPLES

7 **INDEPENDENT EXPERTS** PROVIDING EXPERT GUIDANCE ACROSS THE NATIONAL ASSESSMENT

11 **PRIORITY CLIMATE RISKS** SELECTED BY THE AUSTRALIAN GOVERNMENT FOR SECOND PASS ASSESSMENT

>15 TECHNICAL SUPPORTING **REPORTS**

Contents

Introduction

The National Climate Risk Assessment Report, delivered by the Australian Climate Service, provides a comprehensive analysis of the potential risks and impacts from a changing climate.

It identifies risks across various sectors, including our economy, agriculture, health, infrastructure and ecosystems.

The National Assessment:

- consolidates current understanding of Australia's risks and delivers a baseline of current and emerging risks
- provides insights into current and future risks emerging from global warming and projected increases to extreme weather events, with quantitative analysis of priority risks where available
- considers how hazards, vulnerabilities, exposure and cascading impacts interact to amplify risk, and provides insights into adaptation that could address multiple risks
- provides new information and resources for governments at all levels, industry, academia, and Aboriginal and Torres Strait Islander peoples and communities to understand national risks and possible adaptation actions.

The methodology developed for the National Assessment identified 8 key systems that support Australian society and are most at risk from climate change.

In the first pass of the National Assessment, 56 nationally significant risks across these systems were recognised and then 11 priority risks were identified by the Australian Government for further analysis. The second pass of the National Assessment has analysed each of these 11 priority risks to gain richer and deeper insights previously unavailable at a national scale in Australia.

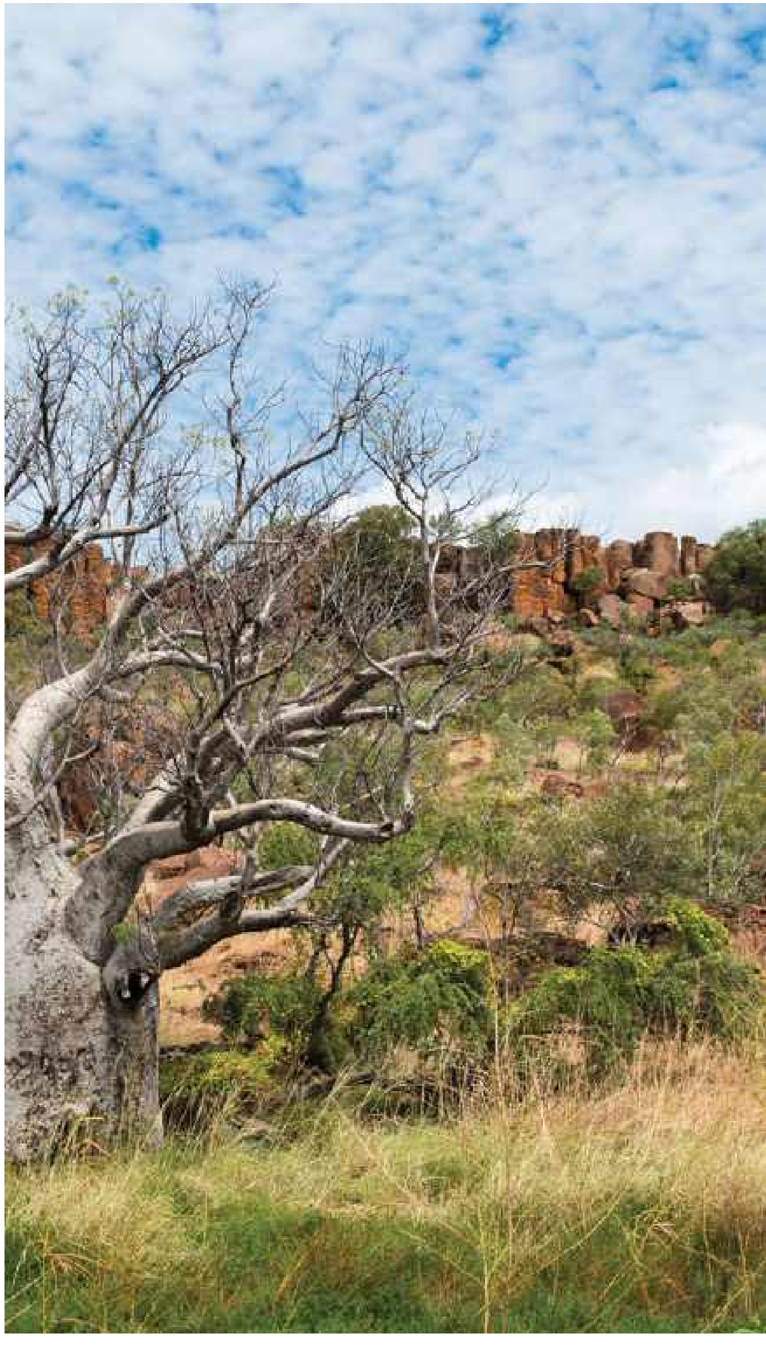
The National Assessment followed a culturally sensitive process to identify 7 new nationally significant risks for Aboriginal and Torres Strait Islander peoples. These 7 risks are added to the 56 nationally significant risks identified as part of the first pass National Assessment. Further analysis of these nationally significant risks could be developed in collaboration with Aboriginal and Torres Strait Islander peoples and communities in future to support adaptation and resilience to the changing climate.

The report is structured around key systems, with each chapter presenting how priority risks interact within and across systems, demonstrating the connected nature of risks Australia faces from a changing climate.

Where possible, risks and potential impacts have been assessed for 3 different global warming scenarios relative to the current climate, which is +1.2°C. These include 3 possible future scenarios: +1.5°C +2.0°C and +3.0°C; and for 3 timeframes: current, 2050 and 2090.

The analysis presented in this report draws on collaboration with world-leading scientists and diverse experts from the Australian Climate Service partners – the Bureau of Meteorology, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Australian Bureau of Statistics (ABS) and Geoscience Australia – as well as contributions from a range of other organisations.

A wide spectrum of stakeholders – including from the Australian Government, state, territory and local governments, industry, community leaders, academics and other potential users of the National Assessment – have contributed to extensive testing and development of this evidence base.



The National Assessment follows the **National Climate Risk Assessment Methodology** co-developed by the Australian Climate Service and the Department of Climate Change, Energy, the Environment and Water.

This chapter builds on the published methodology and aims to provide further information on the approach used in this first National Assessment.

Background and scope

Delivery of the National Assessment required a coherent framework for analysis.

This framework is described in the Methodology developed at the beginning of the National Assessment (DCCEEW, 2023). This Methodology defines risk assessment regions, scenario horizons and functional systems. It has provided a consistent approach for:

- identifying nationally significant risks and priority risks
- assessing priority risks across systems
- improving understanding of risks and potential impacts for Australia.

The Methodology has been tailored for Australia to suit the scale of the country and its unique environment, climate and people.

The Methodology was informed by user needs, international best practice such as the IPCC *Fifth Assessment Report* and *Sixth Assessment Report* (IPCC, 2014, 2023) and other national climate risk assessments such as those conducted by Canada, New Zealand, Japan, the United Kingdom and the United States (Lulham et al., 2023; Ministry for the Environment, 2020; Ministry of the Environment, Japan, 2020; UK Climate Change Risk Assessment 2022, 2022; US Global Change Research Program, 2023). Limitations of the Methodology and areas for further investigation identified through the National Assessment process are listed after the Key concepts section of this report.

There are 2 overarching types of climate risk that could be considered in a national climate risk assessment: *physical* climate risk resulting from climatic events such as bushfires, storms and floods, including acute, chronic and slow onset events; and *transition* risks resulting from the shift to a low emissions economy and society, including technological changes, policy shifts and changes in consumer preferences.

The National Assessment focuses on physical climate risk only. However, the physical risk arising from the effects of climate hazards on climate transition elements (e.g. the impact of increased temperatures on solar infrastructure that aims to help transition the economy from reliance on fossil fuels) is examined. This is consistent with the approach of national climate risk assessments developed by other OECD countries such as the United Kingdom and New Zealand.

Additionally, the National Assessment is domestically focused, seeking to understand how the changing climate will drive risks within our borders. The assessment recognises the impact of climate change beyond Australia's borders, and identifies transboundary risks such as supply chain disruptions; however, it does not quantify or analyse them. These risks could be considered in future analysis.

Australia's first National Climate Risk Assessment applies a risk-based approach to identify and assess the most significant climate-related threats facing the nation. This approach focuses on the 11 priority risks selected by the Australian Government – risks identified as having the greatest potential consequences and where action may be most needed. It supports decision-makers by providing a clear understanding of where Australia is most exposed and where responses can be most effective.

This risk-based method is consistent with international practice and has been used in countries such as the United Kingdom, Canada and Japan. The assessment identifies residual risk – the risks that remain even after current mitigation and adaptation efforts are in place. These risks help highlight where further action may be required.

As the first national assessment of its kind, there are limitations in the availability of data and evidence to fully assess residual risk. The assessment has expanded the availability of data and resources, providing a baseline to inform future decisions. It will be strengthened over time through improved monitoring, targeted research, and continued adaptation efforts.

The Australian Climate Service led the development of this first National Assessment and will continue to provide information to support climate-related decision-making. Future resources may explore different methods or focus areas to meet evolving decision-maker needs.

Understanding climate risk

Determinants of climate risk

In the context of climate change, risk is determined by the dynamic interaction between hazards, exposure, vulnerability and response (Figure 1).

Hazards, exposure, vulnerability and response will all vary by location and in response to socioeconomic development and decision-making.

While simple 'three-blade' risk framing, which considers how hazards, exposure and vulnerability interact, is a common framing to describe how climate drives risk, the IPCC's *Sixth Assessment Report* (2023) introduced a fourth 'blade' to the propeller which recognises that actions to reduce risk, including actions related to greenhouse gas mitigation, can themselves be a driver of risk. For example, responding to changes in climate by relocating agricultural activities to different parts of the country may increase the value of assets exposed to bushfires, and clearing land may reduce the ability of forests to act as a carbon sink. This 'four-blade' risk framework has been used throughout the National Assessment.

International risk standards also define risk in terms of the probability (or likelihood) of an event occurring and the severity (or consequence) of its impact. Hazard projections include an assessment of likelihood (see the sections on Evaluating risk and Confidence assessment), hazards with a low chance of occurring (e.g. ice sheet collapse) can still present a high risk if the impact is severe (e.g. it may result in significant sea level rise), and so the National Assessment includes risks that could result in high impacts, regardless of whether they have a high or low probability of occurrence.

Figure 1: The dynamic interaction between hazard, exposure, vulnerability and response as determinants of risk (adapted from IPCC, 2022b; Simpson et al., 2021).

Two stages to the National Assessment

The National Assessment used a phased approach with 2 key stages (Figure 2).

The first pass risk assessment

The first pass assessment was a qualitative assessment of Australia's climate risks (DCCEEW, 2024). It included a comprehensive literature scan, a rapid adaptation stocktake and a series of expert elicitation workshops.

The first pass assessment reviewed climate within and across 8 systems that make up our society and environment, and delivered a robust, expert-led identification of risks of national significance (DCCEEW, 2024). A final workshop considered how these risks can compound, cascade and aggregate across multiple systems, and identified a number of cross-system risks.

The first pass assessment provided:

- **a shared understanding of the nationally significant risks facing the nation from climate change**
- **a better understanding of where effort could be focused to respond to climate risks.**

Fifty-six nationally significant climate risks were identified. A subset of 11 priority risks were selected by the Australian Government for a detailed quantitative assessment by the Australian Climate Service.

Further engagement with Aboriginal and Torres Strait Islander peoples was committed to be completed as part of the National Assessment. This engagement aimed to identify the nationally significant risks to Aboriginal and Torres Strait Islander peoples.

A culturally sensitive and appropriate approach over a longer timeframe was undertaken with Aboriginal and Torres Strait Islander people. The collaborative approach explored and identified, through conversations and 2 Gatherings, 7 new nationally significant risks for Aboriginal and Torres Strait Islander peoples.

More information can be found in the *Climate Risks to Aboriginal and Torres Strait Islander Peoples* report.

The second pass risk assessment

The second pass risk assessment analysed 11 priority risks selected by the Australian Government across 7 systems, and identified nationally significant risks in the Aboriginal and Torres Strait Islander Peoples system.

The second pass assessment used both quantitative and qualitative analysis for an in-depth assessment of the 11 priority risks selected by the Australian Government.

The second pass assessment used subject matter expert analysis to understand key risks, as well as climate hazard, exposure, vulnerability and response data. The understanding of risk and potential impacts across these priority risks was applied across the systems to develop an integrated view of the risk to Australia from climate change. This second pass assessment:

- provides a deeper understanding of the risks Australia faces now, in 2050 and in 2090
- is consistent with international best practice (IPCC, 2022b)
- reflects the reality that systems are not silos and that vulnerabilities and risks inevitably interact
- informs how Australia can better manage those risks.

Stakeholder engagement has been a critical part of the work of the National Assessment. Early in the second pass, a broad range of experts from the Australian Government, state and territory governments, academia and industry were consulted to identify the analytical gaps that hindered effective national-scale adaptation decision-making.

Experts have been re-engaged throughout the delivery of the second pass to test early findings and to identify how systems and priority risks are interconnected. They considered how risks in one system cascade and compound risks in other systems, as well as identifying the adaptive opportunities that arise from these interconnections.

Expert advice was integral to evaluating residual risk across systems in the National Assessment. Input was drawn from a diverse group of subject matter experts and practitioners with deep knowledge of climate impacts, adaptation strategies, and system-specific vulnerabilities. An independent Expert Advisory Committee was established to provide guidance on approach and key findings.

First pass assessment

(July – December 2023)

The first pass assessment reviewed climate risks within 8 systems of national importance. It considered how risk can compound, cascade and aggregate across multiple systems.

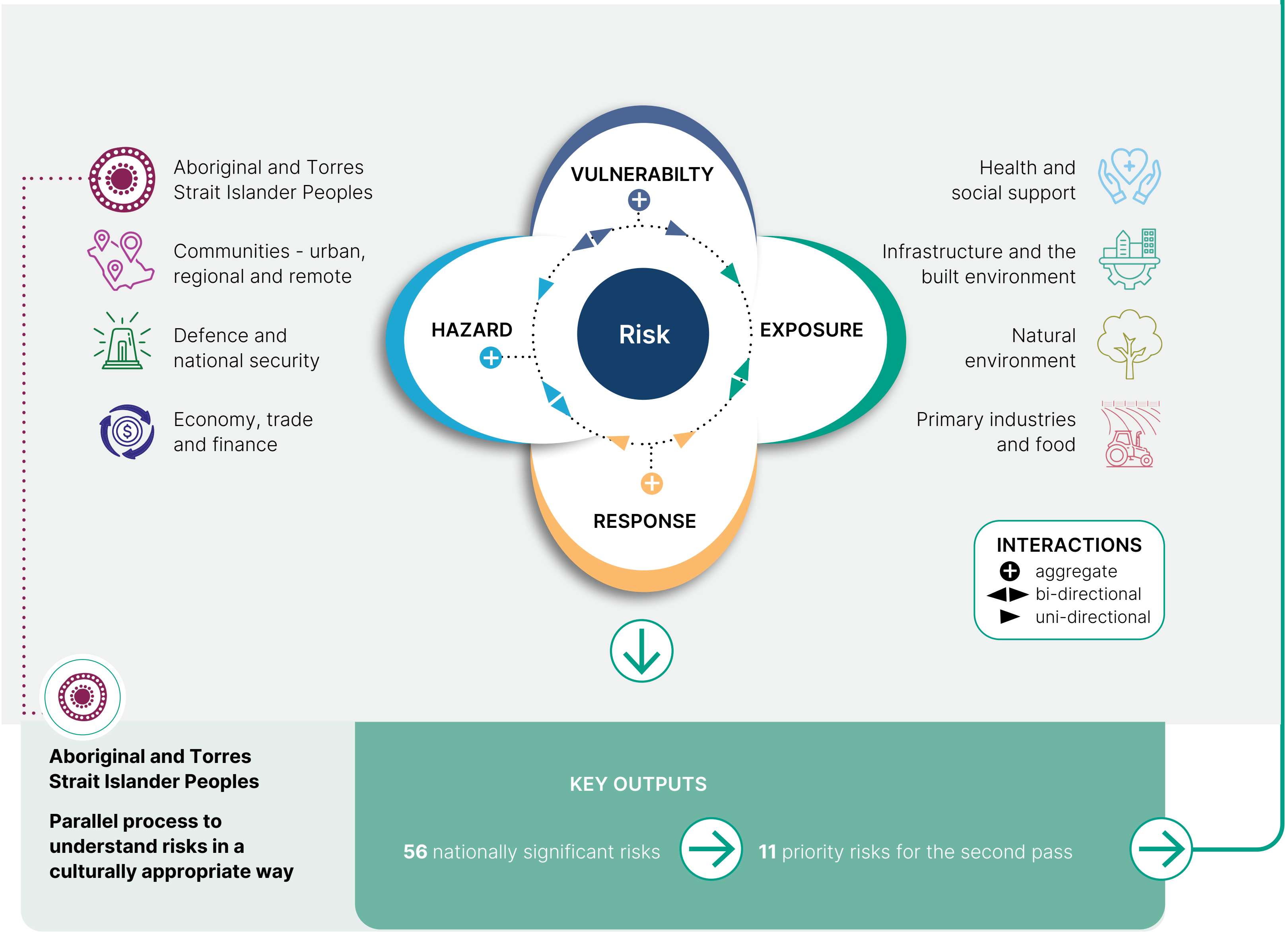


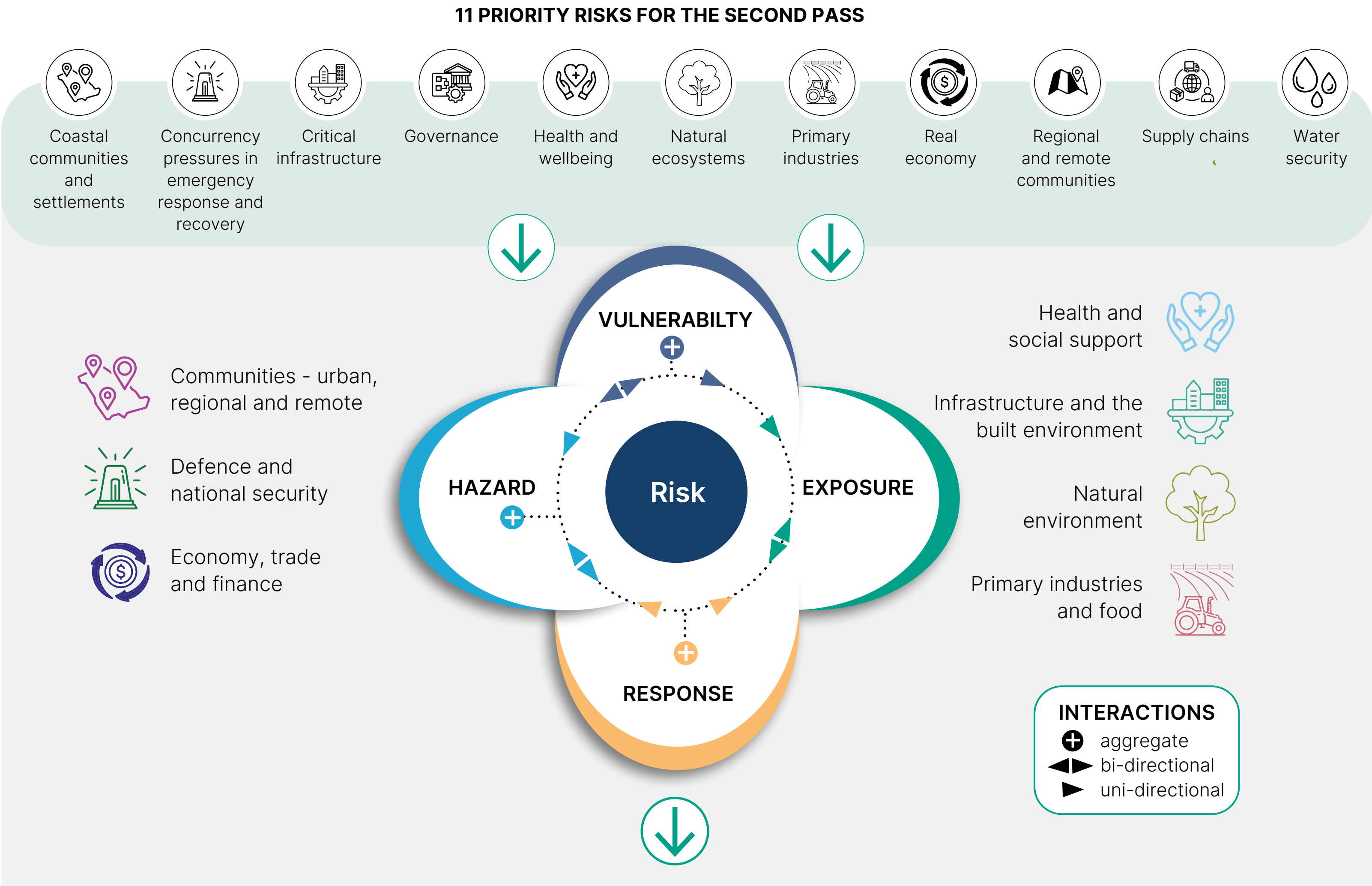
Figure 2: Schematic of the components and process for the National Assessment, adapted from the Intergovernmental Panel on Climate Change (IPCC)

Second pass assessment

(January 2024 – July 2025)

The second pass assessment analysed 11 priority risks across 7 key systems. It has also developed and consolidated other information to highlight the integrated nature of risk and the potential for cascading and compounding impacts identified in the first pass assessment.

7 nationally significant climate risks to Aboriginal and Torres Strait Islander Peoples system identified in parallel process



KEY OUTPUTS

Evidence base
Data, climate information, case studies and insights.

National Climate Risk Assessment
63 nationally significant risks
7 systems analysed across
11 priority risks

Australian Climate Service website
Accessible information for decision-making

Geographic scope of the National Assessment

The National Assessment provides, as far as possible, a consistent national view of climate risk. For the National Assessment, Australia and its maritime regions of responsibility have been considered as 11 regions that decision-makers can use to assess their risk and focus adaptation policies and actions (Figure 3).

The National Assessment regions comprise the state-and territory-based regions and their coastal zones, the Exclusive Economic Zone (oceans) and the Australian Antarctic Territory, with Queensland (Qld) and Western Australia (WA) divided into tropical and subtropical regions. These regions were chosen to reflect the significantly different climates and accompanying hazards between tropical and subtropical areas while maintaining the exposure and vulnerability data boundaries.

Norfolk Island (given its environmental domain exposure and geopolitical significance), Lord Howe Island, the Cocos (Keeling) Islands and Christmas Island, and their associated marine zones, are also included in the scope of the National Assessment.

This risk assessment does not cover international climate risks, but it does highlight some instances where climate-related impacts that occur outside of Australia can directly affect Australian systems. Future assessments should consider international climate risks.

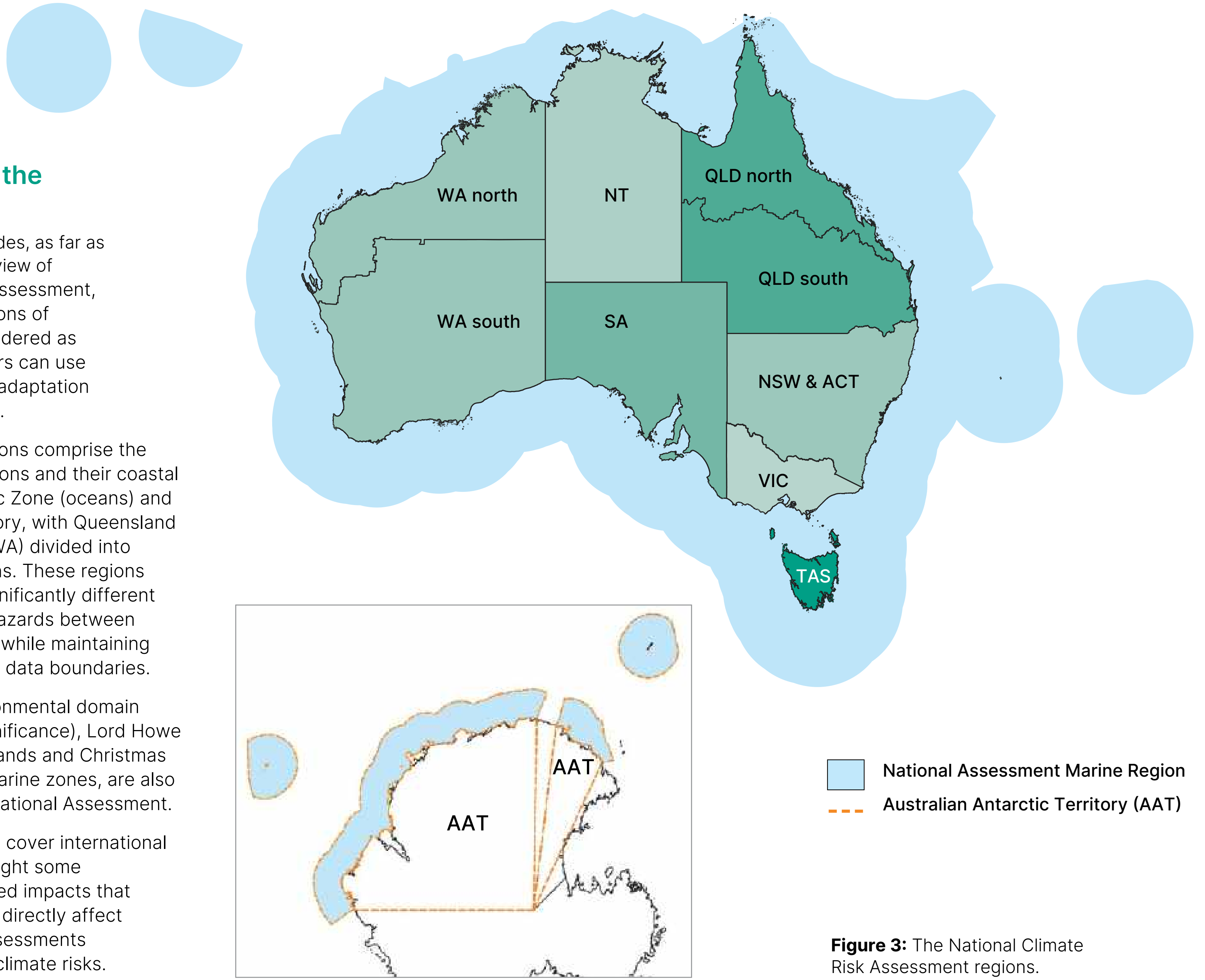


Figure 3: The National Climate Risk Assessment regions.

Key concepts

This chapter outlines the key concepts used to assess risk, including:

- an introduction to Australia's systems used in this National Assessment
- priority risks selected by the Australian Government, analysed in this assessment
- the approach to understanding risk in the context of climate change, including determinants of risk (hazard, exposure, vulnerability and response) and considerations of complex risks
- approach to understanding residual and future risks
- evaluation of the overall system and priority risks, and confidence in this evaluation
- future scenarios used in the National Assessment
- limitations and areas for further investigation.

National Assessment systems

A system is a natural grouping of things that interact to form a unified whole (IPCC, 2022b).

Thinking in systems is important to identify and understand the interconnectedness and interdependencies of different risks and systems across Australian society. The National Assessment considers risks across 8 key systems (Figure 4). This approach helps to identify how changes in one system can flow onto others through compounding and cascading impacts. This amplifies the effects of individual impacts and risks. For instance, the Health and social support, Primary industries and food, and Natural environment systems are are closely interlinked and changes in one can significantly affect the others.

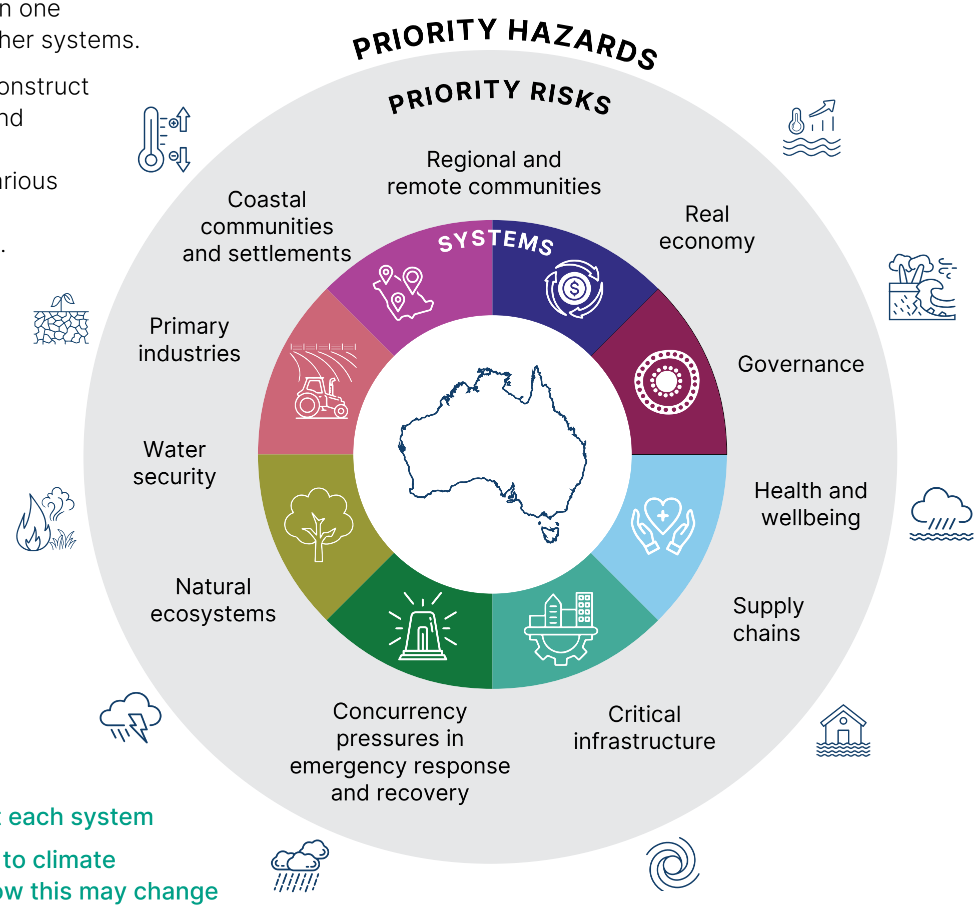
Incorporating systems thinking into climate risk assessments facilitates an understanding of the broader context and the dynamic relationships between different systems. This approach enables the identification of potential co-benefits and trade-offs, as well as the possibility for maladaptation when actions in one system affect outcomes in other systems.

Systems are a fundamental construct in the National Assessment and the National Adaptation Plan, encompassing within them various sectors, industries, domains and elements at risk (Table 1). A systemic view allows for analysis of how changes in other systems and risks contribute to, or have the potential to mitigate, the identified priority risks. Understanding the risk and resilience of these systems in the future will help to keep these systems working sustainably.

The National Assessment aims to understand risk for each system, including:

- relationships to other systems and risks
- climate hazards that affect each system
- exposure and vulnerability to climate hazards, and where and how this may change
- risk profile considering hazards, exposure and vulnerability
- current actions to reduce the impacts of climate change and the residual risk
- potential impacts and consequences in 2050 and 2090, and the likelihood of these.

Figure 4: Climate hazard drivers of the priority risks, which impact the systems that underpin Australia.



Aboriginal and Torres Strait Islander Peoples

In the context of the National Assessment, this system refers to the Indigenous peoples of Australia and their interconnectedness with the land, sea and Country. It encompasses Aboriginal and Torres Strait Islander Lore, customs, cultures, and ways of being, which are all intrinsically linked to the survival of both peoples and ecosystems.

Communities - urban, regional and remote[1]

The Communities system encompasses a wide range of communities across Australia, including regional centres, towns, remote settlements, urban areas and cities. This system covers all natural, social, economic, and built aspects of these communities, which face risks from multiple hazards including coastal hazards.

Defence and national security

The Defence and national security system refers to the structures and functions dedicated to safeguarding Australia. Australia's domestic disaster response is primarily the responsibility of state and territory governments. The Australian Government provides support where state and territory capacities are overwhelmed, including through requests for deployment of the Australian Defence Force and other Australian Government capabilities for disaster response and recovery as required.

Economy, trade and finance

The Economy, trade and finance system is about how we access and use resources and how we work. It encompasses Australia's interconnected insurance and investment markets, import and export markets, the labour market, the production, distribution and consumption of goods and services, and the institutional arrangements governing economic activities and trade networks across all scales.

Health and social support

The Health and social support system refers to population health and wellbeing, as well as the provision, availability, and access to health, wellbeing and social support. This system includes services that encompass healthcare, public and preventative health, aged care, disability services, housing support, employment and financial wellbeing and their supporting infrastructure.

Infrastructure and the built environment

The Infrastructure and the built environment system refers to the intricate networks of human-made structures across Australia. It includes physical buildings, green and blue spaces, and their supporting infrastructure such as transport, telecommunications, water and energy systems.

Natural environment

The Natural environment system refers to Australia's ecosystems and biodiversity. This system includes Australia's lands, waters and oceans.

Primary industries and food

The Primary industries and food system refers to land, marine and estuarine activities dedicated to producing food, fibre, wood, fuel and other products. This system includes agriculture, aquaculture, fisheries and forestry sectors spanning large-scale and smallholder operations, covering the entire chain from production to the consumer.

Table 1: Eight systems used in the National Assessment.

[1] *In the first pass, this was identified as 'Regional and remote communities' and a separate communities and settlements risk was identified. In the second pass, these were combined so that communities of all scales and locations can be considered as using the same criteria.*

Priority climate risks

The first pass of the National Assessment, completed at the end of 2023, provides a consolidated understanding of Australia's risks based on the literature, expert elicitation and previous work, and delivers the first national-level assessment of Australia's climate change risks.

In the National Assessment, the quantitative and qualitative analysis of the priority risks anchors our understanding of how each system is at risk (Table 2). This priority risk analysis is presented in snapshots in the Climate risks to Australia section and the system section of this report to which it most closely aligns (e.g. the Natural ecosystems priority risk snapshot sits in the Natural environment system chapter, and the Concurrency pressures in emergency response and recovery priority risk sits in the Defence and national security system chapter). Insights into how the priority risk contributes to risk in other systems and how impacts can cascade across systems are included in all chapters.

Content and perspectives from the Aboriginal and Torres Strait Islander Peoples system have been integrated into all system chapters.

Each of the projects contributing to the National Assessment has delivered a technical report detailing the scientific methods, results and limitations of its analyses. These are supported by new, publicly available datasets – in particular, by high-resolution downscaled projections for the key climate hazards. The full technical reports for each of the priority risks will be made available on the Australian Climate Service website. Abstracts for these technical reports are available in the Appendix.

Table 2: Priority risks identified for deeper analysis in the second pass.

PRIORITY RISK	RISK STATEMENT
Coastal communities and settlements	Risks to coastal communities from sea level rise, particularly where **legacy and future planning** and decision-making increases the exposure of settlements
Concurrency pressures in emergency response and recovery	Risks to **domestic disaster response and recovery assistance** from the competing need to respond to multiple natural hazard events resulting in concurrency pressures and overwhelming the capacity of all levels of government to effectively respond and to do so while reducing reliance on the Australian Defence Force
Critical infrastructure	Risks to **critical infrastructure** that impact access to essential goods and services
Governance	Risks to adaptation from maladaptation and inaction from **governance structures** not fit to address changing climate risks
Health and wellbeing	Risks to **health and wellbeing** from slow-onset and extreme climate impacts
Natural ecosystems	Risks to **ecosystems, landscapes and seascapes**, including risk of ecosystem transformation or collapse, and loss of nature's benefits to people
Primary industries	Risks to **primary industries** that decrease productivity, quality and profitability and increase biosecurity pressures
Real economy	Risks to the **real economy** from acute and chronic climate change impacts, including from climate-related financial system shocks or volatility
Regional and remote communities	Risks to **regional, remote and Aboriginal and Torres Strait Islander communities** that are supported by natural environments and ecosystem services
Supply chains	Risks to **supply and service chains** from climate change impacts that disrupt goods, services, labour, capital and trade
Water security	Risks to **water security** that underpin community resilience, natural environments, water-dependent industries and cultural heritage

Climate hazards

There are 10 priority climate hazards for the National Assessment.

In consultation with scientists and other experts, 10 hazards were identified as those that are likely to have the greatest impact on Australia's social, economic, built and natural environments over the next century. Natural clusters of hazards that often occur together and have a greater impact when they combine are grouped together as a compound hazard. This clustering was based on expert assessment from hydrologists, climatologists, meteorologists and oceanographers.

This is the first time for Australia that hazards have been grouped in the way they tend to occur. For example, bushfires can cause air quality issues and estuarine flooding depends on both sea level rise and rainfall. Analysing these hazards together creates a more holistic national understanding of risks now and in the future and is a more powerful way to support preparedness and response.

The *Australia's Future Climate and Hazards Report* presents a national view of Australia's current climate and priority hazards and how these are likely to change over the rest of the century under different future climate scenarios (ACS, 2025).

The National Assessment is using climate and hazard projections developed by the Australian Climate Service, detailed in *Australia's Future Climate and Hazards Report* (ACS, 2025).

The top table in Figure 6 represents potential changes to hazards under different global warming levels (+1.5°C, +2°C and +3°C). These potential changes are relative to the current climate (+1.2°C).

The bottom table in Figure 6 represents how hazards related to sea level are expected to change across Australia under future sea level rise increments (0.14m, 0.32m, 0.54m).

Priority hazards

There are 10 priority hazards for the National Assessment.

- Changes in temperature, including extremes
- Drought and changes in aridity
- Bushfires, grassfires and air pollution
- Extratropical storms
- Convective storms, including hail
- Tropical cyclones
- Riverine and flash flooding
- Coastal and estuarine flooding
- Coastal erosion and shoreline change
- Ocean warming and acidification

Australia's Future Climate and Hazards Report provides key analysis of how Australia's climate and hazards are changing in Australia, now and over the coming century.

Why we use global warming levels

Some risk assessments, and previous IPCC reports, consider the trajectory of how the climate may change in line with *Shared Socioeconomic Pathways* (SSPs) or *Representative Concentration Pathways* (RCPs) of greenhouse gases.

The National Assessment predominantly uses global warming levels (Figure 5), as these:

- are consistent with the latest IPCC report and global policy (e.g. the Paris Agreement to keep global warming to well below +2.0°C, if not +1.5°C)
- are relevant for current and future climate projections
- do not require a deep knowledge of future emissions pathways
- do not depend on a particular year in future
- describe what Australia may look like at a particular warming level, even if that level occurs earlier or later than projected.

Some parts of the National Assessment have used SSPs.

Current warming

The IPCC in their *Sixth Assessment Report* defines current global warming as the time of crossing a given warming level based on the 20-year average. This allows for natural variation from year to year. Current global warming is +1.2°C, meaning global average temperatures are +1.2°C warmer than the 1850–1900 pre-industrial average. Because land surfaces warm much faster than oceans, Australia, as a land mass, will reach a given warming level much faster than the globe. Australia's average climate has warmed by +1.5°C since national records began in 1910 (CSIRO and Bureau of Meteorology, 2024).

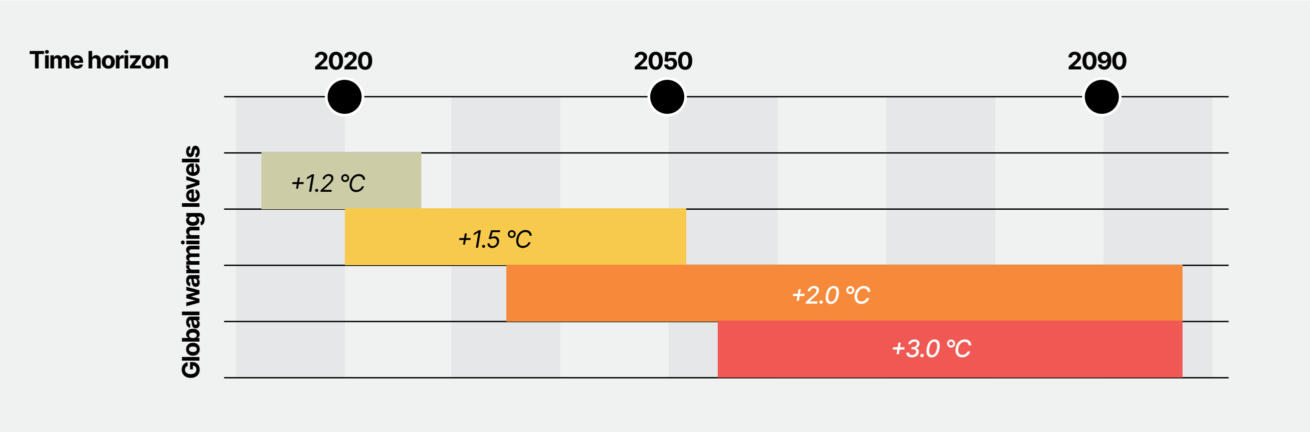


Figure 5: Global warming levels used in the National Assessment and possible times when these levels may be reached.

Confidence ratings provide useful guidance for adaptation decision-making

High and **very high** confidence ratings can be used to identify areas of high exposure to hazards and provide robust information for decision-making. Where a high climate risk rating is applied, this notes the quality of the underpinning exposure and vulnerability information and agreement with literature.

Where confidence is **medium**, additional regional and local information should be sought. For example, national projections can provide context and fill some information gaps, but if local topographical information or fine-scale climate models are available, these should be used to augment the national information. Additional evidence, including exposure, vulnerability and response information, should be used to support adaptation planning and action.

Low confidence still provides information for decision-making. These findings can point to areas that may be at risk but should be supplemented with additional information such as regional modelling, fine-scale local modelling, and local information. Where confidence in hazard projections is low but a range is given, this provides information on the evidence provided by climate models and can be used to develop scenarios for operational and adaptation planning that consider both low and high outcomes. This approach can identify 'no regrets' adaptation actions and improve preparedness that are common across scenarios.

National vs regional confidence: It is worth noting that in many cases, regional climate projections or risk information may be available at higher confidence levels than for national averages.

	Current	Future change relative to current		
	GWL +1.2°C	GWL +1.5°C	GWL +2.0°C	GWL +3.0°C
Severe/extreme heatwave days	4 days	+2 days ○○○	+5 days ○○○	+14 days ○○○
Time spent in drought	19 months per decade	-10% to +36% ○	-8% to +69% ○	-15% to +89% ○○
Fire susceptibility		↑ in south, east ○○○	↑↑ then ↓ in south, ↑ east ○	↑↑ then ↓ in south, ↑ east ○
Frequency of extratropical lows	88 hours per year	No clear change ○	-19% to +8% ○○	-25% to -3% ○○
Frequency of large hail events	5–10 events in east	Insufficient data	↑ in east ○	Insufficient data
Tropical cyclone frequency (cat 4/5)	2–3 per year on average	Little change or small ↑ ○	Little change or ↑ ○	Little change or ↑ ○
Maximum daily runoff	2.6mm	-39% to +47% ○	-53% to +58% ○	-57% to +59% ○
Marine heatwave duration	18 days	+22 days ○○○	+77 days ○○○	+161 days ○○○

	Current rise since 1880	Future change relative to current sea level			
		GWL +1.5/ +2.0°C at 2050	GWL +2.0°C at 2090	GWL +3.0°C at 2090	Planning benchmark
Sea level rise	0.2m	+0.14m	+0.32m	+0.54m	+0.94m
Frequency of coastal flooding	15 days ○○○	+24 days ○○○	+87 days ○○○	+193 days ○○○	+257 days ○○○
Extreme water level frequency	x 1.0 ○○○	x 2.0 ○○○	x 5 ○○○	x 14 ○○○	x 101 ○○○

Figure 6: Summary of how the priority hazards are projected to change across Australia for each global warming level (+1.5°C, +2.0°C and +3.0°C) compared with the current climate (+1.2°C above the preindustrial average). The figure uses climate variables or indices (composites of climate variables) to quantify the changes in the hazards. Fire susceptibility uses the current year as the baseline and indicates direction and strength of change for future GWLs and years. Circles indicate a confidence rating based on the direction of change. 3 circles = *high confidence*, 2 circles = *medium confidence*, 1 circle = *low confidence* (ACS, 2025).

Exposure and vulnerability

The National Assessment identifies factors that contribute to exposure and vulnerability at the national scale and identifies trends where possible.

Exposure and vulnerability are deeply dependent on context and require understanding of the social, economic, natural and built domains and of how the different factors work together.

The integrated assessment of exposure and vulnerability is not as mature as the assessment of future hazards and is an area identified for future development.

The National Assessment – and broader Australian Climate Service activities – uses 4 domains outlined in the *National Climate Resilience and Adaptation Strategy* (2021): social domain, economic domain, built domain and natural domain.

Social domain

The social domain encompasses people and their communities, cultures, institutions, support systems and interactions.

Exposure in the context of the social domain refers to the degree to which people, institutions, communities and support systems are impacted by a given hazard event. Intangible social assets, such as culture and connectedness, can also be exposed.

Populations in certain areas may face higher risk due to their proximity to hazards such as floods, bushfires, tropical cyclones or heatwaves. People and communities in places of greater exposure tend to experience more frequent hazard events. Repeated exposure over time, or the intersection of multiple hazards, increases the risk for communities.

Vulnerability in the social domain generally focuses on the characteristics that make people or communities more susceptible to harm and less able to cope or adapt in the face of hazards.

Note that these characteristics do not inherently make someone vulnerable but must be considered within the context of the structures and systems that support them. For instance, a person with low English proficiency may be more vulnerable during a natural hazard emergency if information is not readily available in their main language.

Social vulnerability is multidimensional, incorporating factors such as income, employment status, health, education, social connectedness and access to services. It can be measured, in part, using socioeconomic data that describe people's characteristics or situations. Large datasets that include comprehensive information about the population are crucial for measuring vulnerability accurately. These datasets enable the aggregation of data to understand the vulnerability profiles of communities.

The extent to which people can cope with or adapt to specific hazards can vary significantly based on their characteristics. Vulnerability often differs within communities and across societies, and can change over time. Improving our understanding of the characteristics of communities helps to ensure that the right support is available where it is needed most.

Economic domain

The economic domain encompasses the production and consumption of goods and services, as well as the financial and economic systems that enable this. It is heavily interconnected with the other domains and risk systems. The production of value and the flow of goods and services through the economy are facilitated in large part by businesses (Chan et al., 2023; Manyika et al., 2021).

Exposure in the context of the economic domain refers to the degree to which businesses, and the economy more broadly, are impacted by a given hazard event. Businesses can be severely affected by natural hazards, with damage or destruction to tangible assets (e.g. buildings and equipment, crop production, human capital) impacting production capacity and therefore economic output.

At-risk elements of the economic domain may be in places directly impacted by hazard events, or they may be indirectly impacted by the consequences of a hazard event. For example, the finance sector experiences indirect effects when assets used as security and a business's ability to repay loans are impacted (Kearns, 2022).

Some non-financial assets relate to economic exposure but are classified within other domains. Road and rail networks are essential for supply chains to transport goods and facilitate productivity. When a major supply chain route is blocked, the movement of goods may be prevented or the costs of moving the goods may increase. For businesses this can mean increases in costs to move products in and out of communities, while for people it can mean increases in the prices of essential goods.

Vulnerability in the economic domain refers to the characteristics of the economic assets and associated systems that make them susceptible to economic harm or less able to adapt to climate hazards. Some industries are more vulnerable to climate hazards than others. Mining, construction, agriculture, power generation/ transmission and some service occupations are particularly at risk from labour productivity reductions due to higher temperatures (The Treasury, 2023a).

Another characteristic of economic vulnerability is employment diversity for geographic areas such as Local Government Areas (LGAs). The agricultural industry is particularly vulnerable to the impacts of drought due to its reliance on natural resources (Department of Agriculture, Fisheries and Forestry, 2023). LGAs with a large proportion of agricultural output are therefore potentially more economically vulnerable when a drought (or bushfire or flood) occurs.

Businesses may also be more vulnerable based on their size. Medium, small and micro enterprises are often more vulnerable to climate hazards as they do not have the capacity to absorb major losses in the same way larger businesses do. Employees of medium, small and micro businesses may also be more economically vulnerable to climate hazards.

Built domain

The built domain comprises all human-made surroundings, structures and supporting infrastructure created using material, spatial and human resources to facilitate life, health, work and play.

Exposure in the built domain relates to both the location and specific attributes of human-made assets. For example, it can include the location and age of a residential dwelling, as well as the building materials used in its construction.

Australians rely on buildings and infrastructure in their everyday lives – a home to live in, a road to travel on and essential infrastructure to provide for their needs. Natural hazards, severe weather and climate change pose a risk to infrastructure, and this may have flow-on effects on people's ability to access essential goods and services.

Vulnerability in the built domain refers to the likelihood of a human-made asset being damaged by a hazard based on the asset's characteristics. Understanding the characteristics that make these assets vulnerable is central to assessing natural hazard risk. However, due to the diversity of built assets and the diverse impacts of different hazards, this vulnerability is difficult to quantify consistently at the national scale.

The data attributes required to assess the vulnerability of a structure differ depending on the type of hazard. For example, to assess the vulnerability of residential dwellings to flood, data attributes that are commonly used include floor height, foundation type, wall material, roof material, ceiling height, number of storeys and the presence of other permanent fixtures (D. J. Smith et al., 2020).

Natural domain

The natural domain encompasses the landscapes, seascapes, ecosystems, cultivated spaces (e.g. farmlands, managed forests), and diverse native and exotic plant and animal life within Australia and its ocean territories.

Exposure in the natural domain relates to the location of natural assets such as plants, animals, land types, Ramsar wetlands and World Heritage sites, and their intersection with hazards.

Australia's biodiversity and ecosystems are among the most diverse on Earth. Our nation is home to more than 1.8 million animal and plant species. Our environment provides essential resources for health and wellbeing, including food, fresh water, wood, fibre, fuel and medicines. It also helps to regulate weather, vegetation, soils, and the quality of water and air, and provides a range of aesthetic, cultural, recreational and spiritual services to people, including Aboriginal and Torres Strait Islander peoples (Australian Climate Service, 2023). Understanding where natural assets are located helps decision-makers to understand whether they may be threatened by a hazard event and to prioritise resources.

Vulnerability in the natural domain refers to the characteristics that make natural assets more or less likely to experience harm. Each asset type (e.g. land, water, animal species) has multiple components with their own characteristics that make them more or less likely to experience harm from different hazards.

By understanding vulnerability to climate hazards in the natural domain, we can take action to reduce it and therefore reduce the likelihood of climate-hazard impacts. There is no singular measure for natural vulnerability due to the extreme diversity of natural assets and ecosystems, the characteristics that make them vulnerable, and the complexity of their interactions with multiple and diverse hazards.

Response

Adaptation is the process of adjusting to actual or expected climate change and its impacts.

In human systems, adaptation seeks to moderate or avoid harm or to exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to the expected climate and its effects (IPCC, 2022b). The National Assessment provides evidence to support adaptation to physical risks but does not include consideration of actions associated with mitigation of climate change (evidence on physical risk and potential impacts can be applied to planning for climate mitigation, but this is not a focus of this report).

Interactions across responses can involve co-benefits or trade-offs with other objectives, such as the trade-off if adaptation in primary industries requires new use of land that displaces existing land use.

'The nature of climate risk involves risks from the responses themselves. The risks of climate change response include the possibility of responses not achieving their intended objectives or having trade-offs or adverse side effects for other societal objectives. In particular, human responses may create novel hazards and unexpected side effects and entail opportunity costs and path dependencies.' (IPCC, 2022b)

Types of response

This National Assessment considers 3 types of response associated with physical risk (Howden et al., 2010) (Figure 7):

1. *Improved management:* this includes enhancing efficiencies or processes within systems without significant changes to the function of the system.
2. *Incremental adaptation:* gradual adjustments and modifications to existing systems and practices without changing their fundamental characteristics.
3. *Transformational adaptation:* fundamental changes to systems and structures, leading to a significant shift in how risks are managed.

The type of response required relates to the magnitude of impacts and risks, the effectiveness of current adaptation actions, the capacity of key actors in the system, and the degree of autonomous change occurring in the system.

These response categories should not be considered as sequential; the actions in each category are quite different and have different effects and timeframes for implementation. Where there is benefit in transformational adaptation, it can be considered and implemented alongside improved management and incremental adaptation.

Opportunities

The physical effects of a changing climate can create opportunities for different sectors and regions, which can arise from changes in temperature, precipitation or global impacts driven by climate change. These opportunities often come with significant co-benefits, such as financial gains, alongside the potential for hazard mitigation, reduced exposure or decreased vulnerability.

Identifying opportunities relies on expert judgement and innovation to identify how a changing climate can open up new ways to deliver increased agricultural productivity or industry benefits, improved health outcomes, to reduce energy demands or other benefits. Climate change opportunities are not as well understood as risks, and acting on perceived opportunities without fully assessing the implications could lead to maladaptation.

Conversely, well-designed adaptation actions can achieve co-benefits, such as building green infrastructure to cool urban areas and support biodiversity, or establishing programs that address the root causes of social vulnerability to enhance societal resilience and reduce risk. Well-designed transformational adaptation has the potential to reduce risk and create opportunities.

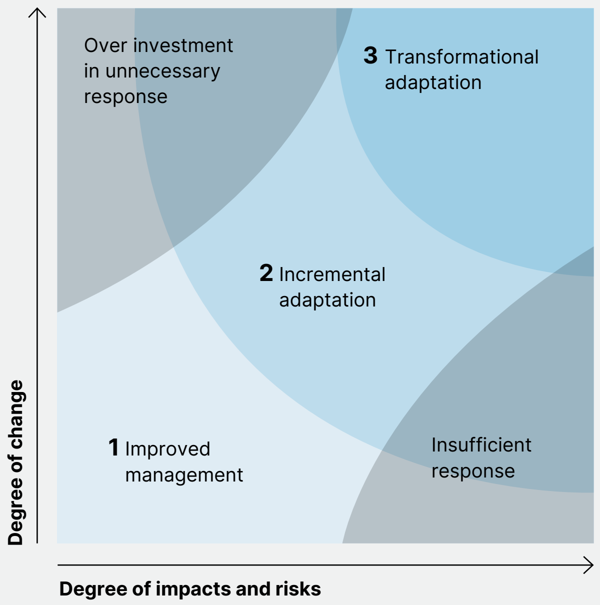


Figure 7: The 3 types of response available for adapting to climate change.

Adapted from the Australian Centre for International Agricultural Research's Climate Change Program (Howden et al., 2010).

Integrating complex risk

The National Assessment took a structured approach to identify how risks interact, compound and evolve across systems and through time to support a broad understanding of the complexity of national climate risk.

The first point of integration occurred during the analysis of the priority risks themselves which considered not only the within system risks, but how risks interact with one another. This process supported a shift away from viewing risks as isolated phenomena, instead recognising that risks often emerge from the interaction of multiple drivers and conditions.

The second point of integration focused on how risks interact within the systems of the National Assessment. Each system chapter presents how priority risks are likely to interact with that system, recognising each system's unique structure, exposures and vulnerabilities. This system-level framing supports the identification of complex risk profiles and informs adaptation responses that are tailored to a broad understanding of the risk in each system.

The third point of integration was to examine how risks and their impacts cascade across system boundaries. Recognising that systems are not isolated, the National Assessment sought to understand how impacts in one system can trigger or amplify risks in others. This cross-boundary perspective, combined with a temporal lens, supports a more integrated understanding of national climate risk.

Complex risk

The National Assessment aims to help governments, industry and communities prepare for, adapt to and mitigate the risks posed by a more challenging climate.

Changes to any one aspect of Australia's climate will not exist in isolation. Rather, impacts in one area or system may cause cascading and compounding impacts in other areas and systems. An integrated perspective provides a strong foundation for adaptation planning, supporting consideration of how adaptation can mitigate risk across systems, or conversely, where there is potential for unintended consequences. The Australian Climate Service has drawn on international methodologies and experiences to develop an approach for assessing complex risks. For example, Simpson et al. (2021), who emphasises:

> ***'We live in a highly networked world where multiple drivers of climate change risk interact, as do the risks themselves. Connections among socioeconomic, environmental and technological systems transmit risk from one system or sector to another, creating new risks or exacerbating existing ones.'***
>
> *(Simpson et al., 2021)*

Understanding complex risk requires a deeper appreciation of how risks interact within and across systems (Figure 8a). A single hazard event such as extreme heat can produce varied and interconnected impacts across multiple systems. For example, in the Health and social support system, extreme heat may lead to increased rates of heat-related illness, placing additional strain on emergency services and hospital infrastructure. At the same time, the same hazard may reduce workforce availability in the Primary industries and food system due to unsafe working conditions, disrupting agricultural production and supply chains. Recognising how risks can compound across different systems is important for understanding the full nature of risk, potentially threatening food security.

Understanding how climate risks evolve over time is also important for capturing their full complexity (Figure 8b). Risks are not static; rather, they unfold in sequences, accumulate, and interact with both existing vulnerabilities and the outcomes of past decisions. The impacts of a single event may not be fully realised in the moment but can intensify over time. For example, inadequate investment in resilient infrastructure may not appear consequential until a series of extreme weather events exposes and amplifies those vulnerabilities. Similarly, decisions made today, such as land use changes, infrastructure development, or emergency response plans, can increase future risk and impacts by increasing exposure or by introducing additional vulnerability into the system, or both. Similar analysis can demonstrate that risks interact across regions and scales, with impacts in one region, for example to critical infrastructure, having the potential to increasing vulnerabilities in other regions or communities.

A. **Systems**

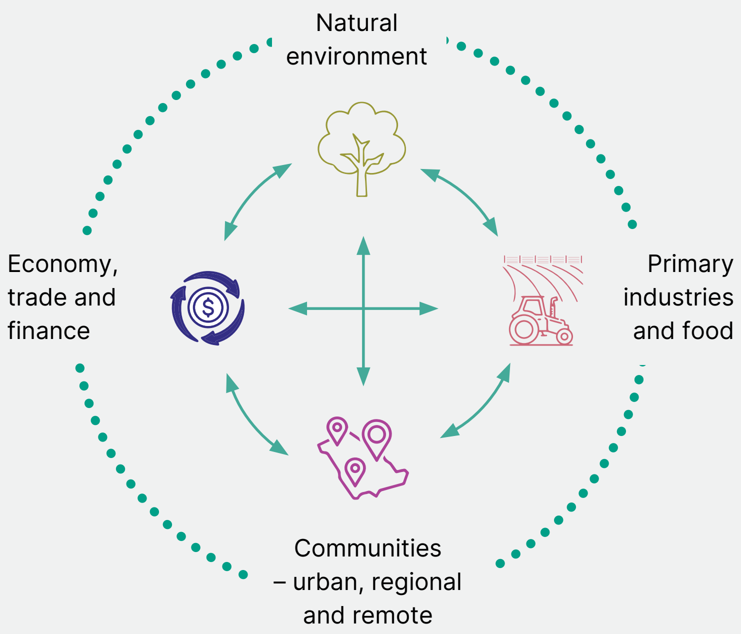


Figure 8a: Interacting climate risks across systems.

Impacts do not remain confined within individual systems; they transfer, compound and cascade across other interconnected systems. This figure illustrates that dynamic interactions will occur between systems, for example, in response to an extreme climate event such as an extreme flood or tropical cyclone. There are likely to be both direct impacts on systems such as the Natural environment, Economy, trade and finance, Primary industries and food, and Communities - urban, regional and remote systems, as well as risks and impacts that propagate between these systems. Understanding these interactions is essential for identifying vulnerabilities, anticipating unintended consequences, and designing effective adaptation strategies.

B. **Time**

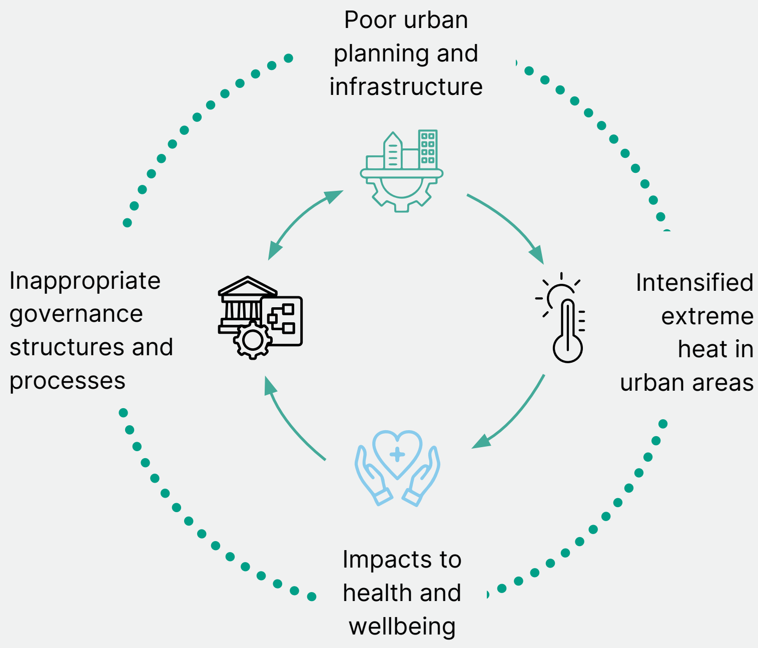


Figure 8b: Climate risk unfolding through time.

Climate risks are dynamic and evolve over time, shaped by past decisions and existing vulnerabilities. This figure illustrates how intensified heat in urban areas can lead to immediate health impacts, which are then compounded by poor planning, inadequate infrastructure, and governance gaps, such as ambiguity in who is responsible for action. A temporal perspective reveals how risks accumulate and interact, highlighting that responses can either reduce or magnify future impacts, and illustrating potential targets for adaptation.

Residual risk in the National Assessment

While mitigation and adaptation can reduce risk, they may not eliminate it entirely.

Residual risk refers to the risk that remains after mitigation and adaptation actions are implemented. When risks are not or cannot be avoided, the result may be loss and damage (United Nations Environment Programme, 2023; van der Geest & Warner, 2020).

To evaluate residual risk, the National Assessment considered:

- current climate impacts and risks, focusing on changes in hazards and their likelihood
- future changes to risk determinants for each system, including hazard, exposure and vulnerability
- existing adaptation efforts, including both planned and autonomous (unplanned) responses.

As this is the first National Assessment, there are inherent limitations in the scope and availability of data to assess residual risk. This assessment provides a foundational understanding, and future iterations are expected to benefit from improved data, expanded monitoring, and evolving adaptation practices.

As part of the National Assessment, the Australian Climate Service commissioned some additional analysis from the new Australian Adaptation Stocktake. This stocktake is a newly compiled database of over 670 adaptation policies, plans and actions across local, state and national levels in Australia. This stocktake provides a view of adaptation underway in each system. It does not include an evaluation of adaptation adequacy or effectiveness.

The stocktake focuses on published actions, which means it may not capture all adaptation efforts, especially those not explicitly labelled as 'climate adaptation'. This assessment does not include new actions proposed in the Australian Government's National Adaptation Plan, developed in response to this National Assessment.

Expert advice was sought within each system to assess whether current adaptation efforts are effective and adequate. This included evaluating autonomous adaptation (responses that occur without formal planning) as a potential way to reduce climate risk. When adaptation is effective, it can inspire further change, leading to more widespread autonomous adaptation over time.

The experts also considered co-benefits from adaptation in other systems. This refers to situations where actions in one area may help reduce risks in another.

The risk ratings provided in the National Assessment reflect these considerations and should be interpreted as residual risk – the level of risk remaining after current adaptation and mitigation efforts.

However, there are important limitations:

- There is limited data on adaptation effectiveness, especially at a national scale.
- Some risks may face limits to adaptation, where even the best efforts cannot prevent intolerable outcomes.
- Path dependency requires further consideration. This is where early choices or actions constrain future options.
- Future societal and climate changes may alter system dynamics, making current adaptation less effective or opening new opportunities.

These factors highlight the importance of ongoing monitoring, innovation, and regular risk-based assessments to inform future decisions.

The risk ratings in the National Assessment do not account for the full potential of future adaptation.

Evaluating risk

The primary purpose of assessing risk is to drive preparedness and action, both adaptation and mitigation action.

Despite the challenges in comparing very diverse systems, evaluating risks in a systematic and standardised way across systems and priority risks maintains a defensible and transparent national approach and aligns with international decision-making processes based on expert advice.

The approach can also be updated as drivers of risk change. The approach used to provide risk ratings in the National Assessment was iterative and grounded in the expertise of a wide group of specialists. Climate change and climate risk are dynamic, so any assessment is valid only for a point-in-time and should be revisited regularly.

The evaluation of relative risk to systems and priority risks in the National Assessment considers a range of impacts and consequences, including impact on the population affected, public safety and health, geographical reach, social cohesion, long-term environmental impact, national resource security, and the potential for cascading impacts across systems and regions. The probability of impacts occurring is challenging to assess in diverse systems and over a range of future warming scenarios, so the evaluation used expert judgement to consider:

- priority risk ratings for 3 timeframes – current, 2050 and 2090
- system risk ratings use 2 timeframes (current and 2050), acknowledging the uncertainty of evaluating systems by 2090 due to their dynamic nature.

An assessment of relative risk is not an assessment of priority for adaptation action.

Prioritising adaptation action should consider relative risk, but should also take into account other factors, such as the lead time to implement different adaptation actions, the cost, the confidence in the action or need to experiment with a range of options, and the relative value of the element at risk. This is out of scope for the National Assessment.

The timeframes consider a 20-year window centred on the year (so the 'current' risk considers impacts that have happened or could happen between 2011 and 2030, while the 2050 risk evaluation considers the 20-year window from 2041 to 2060).

The risk ratings categorise impacts into 5 levels: Severe, Very High, High, Moderate and Low (Figure 9). To help differentiate the 2 different risk ratings (systems versus priority risks), different visual approaches have been adopted.

LOW	MODERATE	HIGH	VERY HIGH	SEVERE
The impacts are minimal, with few enduring effects on vulnerable communities and existing inequalities. There is minor potential for loss of life or significant property damage, and minimal disruption to community stability, livelihoods and natural systems. The risk of long-lasting impacts to national security, resource security, and environmental health is insignificant, with no major threats to biodiversity or natural assets.	The impacts are limited to a few local regions, with minimal effects on a state or national level and on vulnerable communities. There is moderate potential for loss of life or property damage, and limited disruption to community stability, livelihoods and natural systems. The risk to national security, resource security and environmental health is low, with minor threats to biodiversity and sustainable resource use.	The impacts affect multiple regions within one or 2 states, noticeably impacting vulnerable communities and moderately exacerbating inequalities. There is a high potential for loss of life and property damage, with noticeable disruptions to community stability, livelihoods and natural systems. National security, resource security and environmental health face high risks, with threats to biodiversity and sustainable resource use.	The impacts are significant across multiple states, affecting safety and security nationally. Vulnerable communities face substantial impacts, exacerbating inequalities. There is a very high risk of significant loss of life and property damage, with major disruptions to community stability, livelihoods and natural systems. National security, resource security and environmental health face substantial threats.	The impacts are widespread across multiple states, severely affecting vulnerable communities and exacerbating inequalities. There is a major risk of significant loss of life and property damage, with severe disruptions to community stability, livelihoods and natural systems. National security, resource security and public health face severe threats.

Figure 9: Risk rating categories to describe the impacts and risks for systems and priority risks.

Confidence assessment

International best practice to guide climate risk decision-making recommends the use of confidence and likelihood ratings to support decision-makers in understanding the probability of the risk and considering the consequences. The Australian Climate Service has applied confidence ratings in 2 areas – for hazard science and findings, and for climate risk.

Hazards

The National Assessment has adopted IPCC guidance (IPCC, 2010) to assign confidence and likelihood to the projected hazard. Confidence in climate projections applied by the IPCC (IPCC, 2010) notes 2 crucial dimensions:

- **the amount of evidence:** limited, medium or robust (e.g. the number of models used)
- **agreement of that evidence:** low, medium or high (e.g. how consistent the model projections are for the future state).

Climate and hazard analysis in the National Assessment is drawn from multiple sources of evidence, including the range of projections from the Australian Climate Service resources, the scientific literature, recent projections of Australian climate in reports (such as Earth Systems and Climate Change Hub, 2020) and past observations and trends (e.g. State of the Climate, 2024).

The degree of certainty (confidence) is determined through extensive reviews of the evidence and published peer-review information (Table 4: top box).

If both the agreement and evidence are medium or high, a likelihood scale can be applied (Table 3, adapted from IPCC, 2010). This considers agreement with past trends, and the degree to which the processes are understood and expresses a probabilistic estimate of the occurrence of an event or outcome.

Term	Likelihood of the outcome
Virtually certain	99 – 100% probability
Very likely	90 – 100% probability
Likely	66 – 100% probability
About as likely as not	33 – 66% probability
Unlikely	0 – 33% probability
Very unlikely	0 – 10% probability
Exceptionally unlikely	0 – 1% probability

Table 3: Likelihood scale (adapted from IPCC (2010)).

More information on hazard risk confidence can be found in the *Australia's Future Climate and Hazards Report.*

Climate risk confidence rating

Climate risk arises from the dynamic interaction of hazards, exposure, vulnerability, and response, each shaped by location, development, and decision-making.

When assessing and communicating climate risk, the Australian Climate Service applies a **simplified confidence rating** in the National Assessment (Table 4, bottom box).

The IPCC bases climate risk confidence assessments on extensive synthesis of peer-reviewed literature. This is the first national assessment for Australia and so in some areas there is limited available published literature at a national-scale.

The Australian Climate Service has developed climate risks using available literature, data and newly developed modelling and expert knowledge as part of the National Assessment, focused on addressing knowledge gaps identified by stakeholders.

Confidence ratings for climate risk findings are developed, considering the IPCC guidance, through expert elicitation.

- **Type, quality and consistency of evidence:** observations, experimental results, process-based understanding, statistical analyses and model outputs, as well as the robustness of evidence as determined by its quality and consistency across multiple, independent sources.
- **Level of expert agreement:** the range of explanations, demonstration of causality, and consensus within the expert community.

Low or medium confidence ratings indicate that the evidence base is not yet robust, but this does not diminish the importance of the insights. These ratings reflect the complex and emerging nature of the issues and the current state of research on each insight.

CONFIDENCE IN CLIMATE AND HAZARD PROJECTIONS

very high confidence	• High agreement, robust evidence
high confidence	• High agreement, medium evidence • Medium agreement, robust evidence
medium confidence	• High agreement, limited evidence • Medium or low agreement, medium evidence
low confidence	• Low agreement, robust evidence • Medium agreement, limited evidence
very low confidence	• Low agreement, limited evidence

CONFIDENCE IN CLIMATE RISK INSIGHTS

high confidence	• Strong evidence and expert confidence
medium confidence	• Medium evidence and expert confidence
low confidence	• Low evidence and expert confidence

Table 4: Confidence ratings for climate and hazard projections (top box) and for climate risk insights (bottom box).

Future scenarios

While advancements in climate models enable the projection of future hazards, projecting future risks remains challenging due to the dynamic interactions between exposure, vulnerability and response.

These are determined by human decisions such as where we choose to live and how we develop our communities.

Climate and hazard projections, socioeconomic pathways, storylines and case studies are essential tools to understand how risks can change through time. By combining these into different scenarios, analysts involved in the National Assessment explored a range of possible outcomes and identified the scale of risks under various conditions. This approach helps to tease out key risks, trends and characteristics of these trends. It also provides valuable information for decision-makers to inform adaptive strategies, prioritise investments, and implement policies that build resilience. High-resolution, locally-sourced information should be used where available in scenarios and case studies to inform decisions at local and regional scales, while national-scale data can provide context and address information gaps.

Plausible future scenarios can support decision-makers to consider the future likelihood of hazards and to evaluate how hazards might impact assets, infrastructure, ecosystems, and communities over time. These scenarios also allow organisations to stress-test existing strategies and plans, helping leaders to explore how their operations might perform under different futures and to test the effectiveness of adaptation strategies. For example, a coastal city might use high global warming scenarios to evaluate flood risks and plan protective infrastructure, while a business might evaluate supply chain disruptions to inform long-term planning.

To enable effective analysis and integration, scenarios for climate and hazards as well as exposure and vulnerability scenarios were utilised across the National Assessment.

Climate scenarios

Climate science and modelling indicate that extreme weather is expected to behave differently in the future compared to the past. Seasonal and spatial changes will shift, and the nature of the hazards, such as their timing, scale and location, may change, potentially impacting Australians in new ways. For example, hazards may be experienced at different times than has previously been observed, or they may overlap or be experienced more frequently in succession.

Climate scenarios are structured representations of possible future climate conditions, designed to explore a range of outcomes in the face of high uncertainty. These scenarios help researchers and decision-makers consider how different trajectories of greenhouse gas emissions, socio-economic developments, technological changes, and policy choices might shape the climate over time. Rather than predicting a single future, climate scenarios offer a framework for examining multiple plausible futures, allowing for better preparation and planning.

These scenarios are also crucial for financial disclosure of climate risk. They allow companies and financial institutions to assess how different climate futures could impact their operations, assets, and long-term viability. By exploring a range of plausible futures, organisations can evaluate both physical risks (e.g. from extreme weather, sea level rise) and transition risks (e.g. from policy changes, market shifts due to decarbonisation) that may affect financial performance.

Australia is already facing risks from a changing climate, and these risk are expected to continue to increase. The National Assessment uses 4 different time horizons to assess the change in risk. It considers the current climate and 3 different global warming scenarios that are likely to be reached by the mid-term (2050) and long-term (2090) horizons, according to the latest international climate science (Figure 5).

To account for natural variability in the climate, average climate projections were used across 20-year timeframes. Socioeconomic modelling (e.g. population changes) in the National Assessment is anchored to the midpoint of each timeframe (i.e. 2020, 2050 and 2090). Sea level rise projections are aligned with these timeframes rather than the global warming levels, as this process is slower and lags warming over land, so sea levels will continue to rise for centuries, regardless of the global warming level reached as the climate changes.

Some of the evidence cited in the report uses alternative climate change scenarios, for example, Shared Socioeconomic Pathways (SSPs) or Representative Concentration Pathways (RCPs). Where these are cited, the global warming equivalent (GWL) is also given for comparison.

Exposure and vulnerability scenarios

To inform national plans for managing the impacts of climate change, it is important for climate risk assessments to consider how socioeconomic change influences and interacts with future exposure and vulnerability. Currently, most risk assessments, including most of the analysis in the National Assessment, primarily rely on static data about socioeconomic characteristics, the built environment and land-use to provide an assessment of how climate change would have an impact on today's environment.

However, population growth, behavioural shifts, industry actions, and potential damages under different levels of global warming will change our society. Further work is needed to develop a mature understanding of how exposure and vulnerability will evolve in Australia as the climate continues to change. A robust set of scenarios showing how our society may evolve will support monitoring of risk and adaptation and could be used in future climate risk assessments.

Shared Socioeconomic Pathways (SSPs) are used by the IPCC to model physical climate hazards based on global narratives of socioeconomic and land-use changes (IPCC, 2023). However, these narratives lack the granularity needed to inform the possible sub-national scale changes. For this first National Assessment some priority risk analysis has used SSPs and all priority risk analysis used consistent reference timings (the current, 2050 and 2090) as reference points to guide their analysis suited to their system area.

Case studies and storylines

It is valuable to illustrate the differences among climate-driven risks, and the impact they may have on Australian communities and environment and experiences, through case studies.

A wide range of case studies have been produced as part of the National Assessment, some of which will be available as separate technical reports and storymaps on the Australian Climate Service website, and others will be further developed and shared by the Australian Climate Service in the future.

Short versions of key case studies are included in relevant chapters of this report:

- Compound estuarine flooding, Launceston
- Northern Rivers flooding and the future under climate change
- Economic impact of the Black Summer bushfires of 2019–20 - tourism
- Heat-health risk across Sydney
- Disruption to the east–west road and rail corridor during February 2022
- Temperate eucalypt forest growth
- Climate pressure on the Great Barrier Reef
- Biosecurity risks from emergency response to drought
- Managed retreat, Grantham: A case of (partial) community relocation.

Storylines are of value where the science is immature or uncertain. For example, for compound extreme events, or to illustrate how risks may develop out to 2090 when quantitative projections are not available. Storylines have been used internationally to help decision-makers consider the best-available information in a practical and achievable manner. Case studies may be combined to create storylines that illustrate how risks and potential impacts may be felt for different elements at risk or for different locations.

Limitations and areas for further investigation

Having a detailed understanding of the challenges Australia faces as the climate changes is a proactive first step that allows Australia to prioritise areas where action is needed most.

Understanding ensures that action is not just reactive, but shapes a resilient future for our communities, the environment and the economy.

This first National Assessment, and its supporting technical reports and data, provides a detailed understanding of climate risks for Australia at a key point in time. It plays an important role in informing an ongoing cycle of climate adaptation and improvement (Figure 10).

The National Assessment was designed to be completed over a 2-year timeline to deliver a baseline assessment which can be built on. During the assessment, key limitations and gaps in our understanding of climate risk emerged. An improved understanding of these areas may change our assessment of the magnitude of risk or our adaptation priorities. To support future decision-making, any future National Assessment could build on the baseline assessment through considering the following:

- **Developing a shared understanding of key outcomes and systems for Australia.** The Australian Climate Service worked with key technical experts for the first National Assessment. To understand different aspects of risk, there is value in engaging with policymakers and decision-makers to build a better understanding of where the greatest impacts may be realised and of our societal tolerance of damage and loss.
- **Better integration of Aboriginal and Torres Strait Islander peoples' perspectives.** Respectfully and appropriately engaging with Aboriginal and Torres Strait Islander peoples to learn from their experience and explore risks and responses to the changing climate takes time. Experience, cultural norms, knowledges and values can differ markedly across communities. The presentation of Aboriginal and Torres Strait Islander peoples' views in the *Climate Risks to Aboriginal and Torres Strait Islander Peoples* report should only be considered as a start of these conversations; further work is needed to develop a deeper understanding of and to evaluate the identified risks to Aboriginal and Torres Strait Islander peoples.
- **Global climate risks and opportunities.** Significant risks and opportunities are likely to be driven by climate change–related actions outside Australia's borders. Various national climate risk assessments from international counterparts have found that the contribution from transboundary risks can be significant. Our biggest trading partners and nearest neighbours will experience the impacts of climate change. This is likely to drive additional risk and may present new markets for Australian products.
- **Economic impacts of climate change including impacts on householders and cost of living**. The full dynamic response of the Australian economy to national and global climate change impacts is poorly understood and current modelling methodologies are likely to significantly underestimate the economic impacts. Non-market contributions, such as the effects of loss of ecological services or heritage and cultural values, are not taken into account; neither are the potential cascading consequences from physical damage due to climate change.

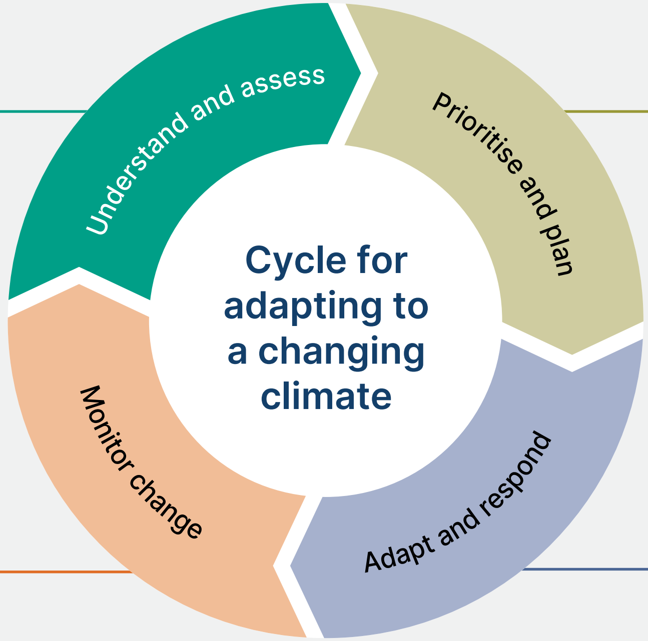
  These challenges are discussed briefly in the Economy, trade and finance chapter, and is an active area for academic and government work. The 2023 *Intergenerational Report*, for example, includes new insights from the Treasury into the physical impacts of climate change, as well as analysis of how climate change could impact selected expenditure, revenue and export channels (The Treasury, 2023a).
- **Climate and hazards.** The maturity of climate and hazard information is varied, with our understanding of some hazards more developed than others. Continued investment in uplifting climate and hazard information would develop a more comprehensive understanding of future climate risk, including developing a greater understanding of future climate and hazard extremes, compound risk and the possible impacts of reaching climate or ecological tipping points.
- **Exposure and vulnerability.** Understanding where exposure is concentrated, and the factors that make communities, people and infrastructure vulnerable to the impacts of climate change, is a complex undertaking and this field is not mature. A significant body of work is needed to improve methods for estimating future exposure and vulnerability and potential interaction with behaviour and policy change. This can then be integrated with the climate and hazard projections in the future to improve understanding of current and future impacts of a changing climate.
- **The effectiveness of mitigation and adaptation actions.** The effectiveness of adaptation actions is not well understood at a national scale and neither are the potential physical impacts of climate change on climate mitigation actions. For example, how the changing climate may reduce the efficiency of new energy infrastructure, and how ecological changes may reduce the effectiveness of carbon sequestration, are not currently well understood.

  Adaptation and mitigation decision-making would benefit from additional research into adaptation effectiveness and from a broader discussion of the relationship between climate change risk and mitigation. This in turn would support a stronger assessment of residual risk for the National Assessment.

Risk, governance and adaptation are not static, so ongoing monitoring, national conversations around effective adaptation pathways, and regular reassessments of climate risk are important for effective and flexible adaptation and the protection of our culture and way of life.

Understand and assess: This National Assessment provides a comprehensive understanding of current and future climate risks in Australia, consolidating information from various sectors into a national perspective.

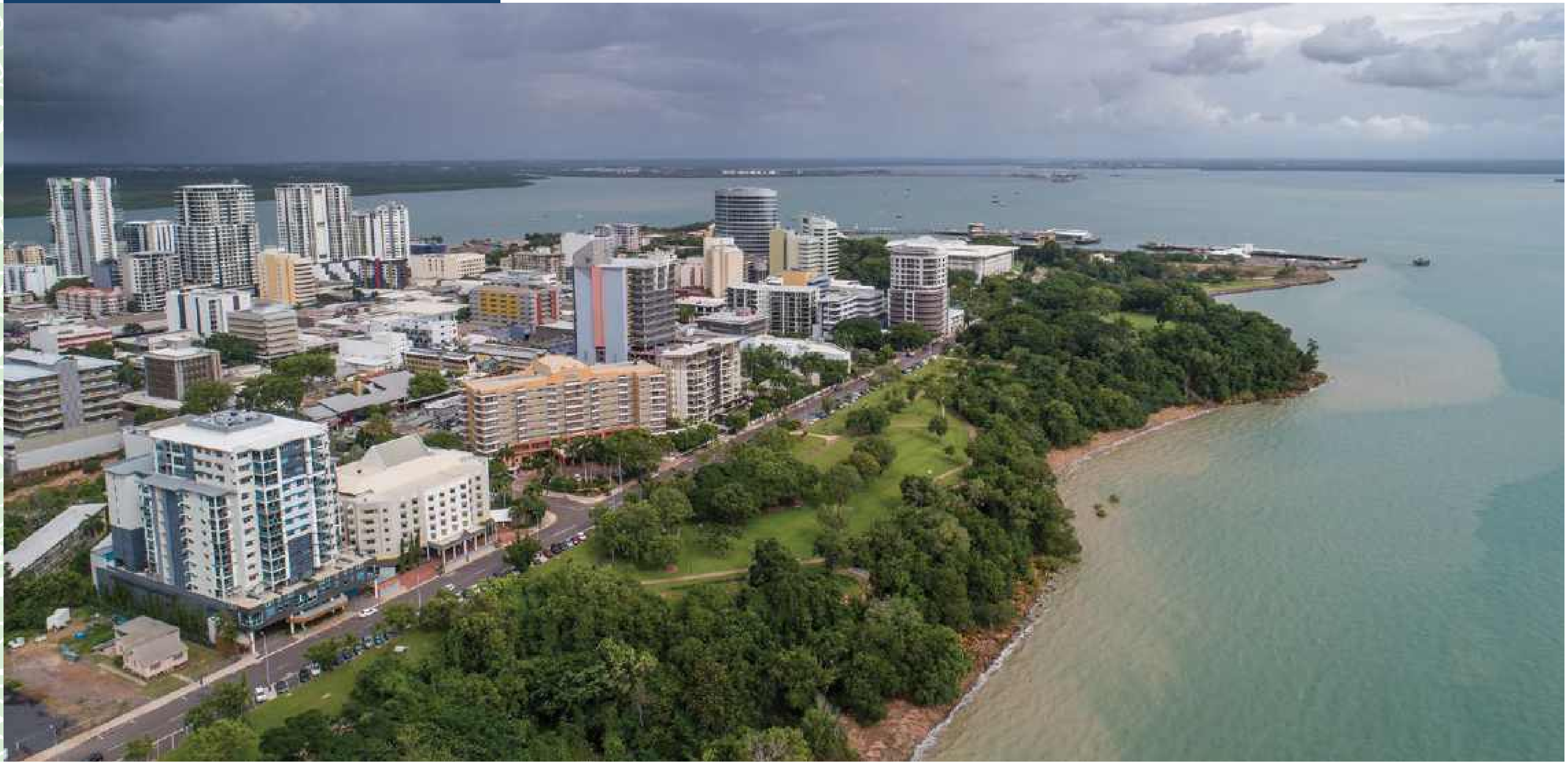
Prioritise and plan: The National Adaptation Plan, prepared by the Australian Government, identifies immediate and future priorities, and outlines actions underway and those needed to respond to complex climate challenges.



Monitor change: To continue to effectively understand and respond to climate risks, monitoring trends, understanding the characteristics of impacts and evaluating and learning from adaptation actions is needed.

Adapt and respond: Addressing climate change requires collective action from individuals, communities, businesses and governments. The National Climate Risk Assessment's analysis and resources can inform planning and implementing adaptation actions.

Figure 10: Schematic showing how the National Assessment contributes to adaptation, emphasising the importance of an iterative process. Understanding limitations and areas for further investigation feeds into this process and allows for the ongoing improvement of adaptation and response.



Climate risks to Australia

Nationally significant climate risks to Australia

At the end of the full National Assessment, 63 nationally significant climate risks have been identified. Eleven of these risks have been assessed in detail and findings have been organised by system. More information on these nationally significant risks can be found in the **First pass assessment report** and the ***Climate Risks to Aboriginal and Torres Strait Islander Peoples*** report.

Risks to Aboriginal and Torres Strait Islander Peoples

Risks to:

- Self-determination
- Land, sea and Country
- Cultural knowledges, practices, values and sites
- People's health, wellbeing and identity
- Economic participation and social and cultural economic development
- Water and food security
- Remote and rural communities

Risks to Communities

Risks to:

- Natural environments and ecosystem services
- Water
- Physical and mental health
- Biosecurity
- Community cohesion and resilience
- Viability of businesses and industries
- Workforce stability and productivity
- Emergency services and recovery
- Supply chain infrastructure
- Governance

Risks to Defence and national security

Risks to:

- Disaster response and recovery
- Migration and displacement
- Social cohesion
- Supply chains
- Personnel health and safety
- Natural environments
- Critical infrastructure
- Essential services

Risks to Economy, trade and finance

Risks to:

- Governments' finances and capacities
- Australian economy
- Individual and household budgets
- Financial system
- Production and consumption of goods and services

Risks to Health and social support

Risks to:

- Individuals and communities at risk
- Heat and extreme weather
- Mental health
- Service delivery and workforce
- Air quality
- Communicable diseases
- Food and water security
- Aboriginal and Torres Strait Islander peoples
- Infrastructure

Risks to Infrastructure and the built environment

Risks to:

- Buildings and community infrastructure
- Transport and telecommunications
- Human health, and medical and emergency services
- Water and wastewater management
- Urban natural environments
- Critical and essential services infrastructure
- Supply chains
- Energy
- Circular economy and waste management
- Building liveability

Risks to Natural environment

Risks to:

- Landscape function
- Vulnerable environments
- Natural resources
- Species loss
- Use and management of natural places
- Rural and Aboriginal and Torres Strait Islander peoples' livelihoods
- Human health and wellbeing
- Natural places and associated values

Risks to Primary industries and food

Risks to:

- Ecosystem services
- Infrastructure
- Health and wellbeing
- Productivity and profitability
- Community
- Trade and export markets

Climate risks to Australia's systems

The National Assessment considers what is at risk nationally from climate change and provides information and observations at a national scale across key systems.

The Australian Climate Service has drawn on new hazard information from *Australia's Future Climate and Hazards Report*.

By using these new hazard projections, assessing climate risks, and understanding their implications, Australia can strengthen its ability to undertake adaptation action at a national scale.

Eleven priority climate risks were selected by the Australian Government for detailed qualitative and quantitative analysis in the second pass assessment.

These risks have been analysed in detail, both within and across key systems to provide insights into how these risks will impact different aspects of Australian society.

The National Assessment has applied a risk-based approach to climate change. Some of the information in this report may be confronting for readers. The Australian Climate Service recommends you share concerns, thoughts and feelings about climate change with trusted friends, family and colleagues, as support networks can have a powerful and positive effect in helping us cope with climate anxiety.

For urgent, immediate help, phone Beyond Blue on 1300 22 4636 or Lifeline on 13 11 14.

Australia's 8 functional systems

- Aboriginal and Torres Strait Islander Peoples
- Communities – urban, regional and remote
- Defence and national security
- Economy, trade and finance
- Health and social support
- Infrastructure and the built environment
- Natural environment
- Primary industries and food

Key cross-system risks

- Coastal communities and settlements
- Governance
- Supply chains
- Water security

Future changes to climate hazards

For decades, Australia's leading climate agencies, the Bureau of Meteorology and the CSIRO, have been at the forefront of advancing knowledge about climate science and natural hazards. The Australian Climate Service draws on this expertise to provide a unified national perspective of climate change and weather-related hazards (Figure 11).

- Our climate has already changed and will continue to change, even if global temperatures stabilise. **Keeping global temperatures at +1.5°C, +2.0°C or +3.0°C above pre-industrial temperatures will stabilise some, but not all, climate impacts** (*high confidence*).
- **Future changes in Australia's climate will not occur gradually or smoothly** (*very high confidence*). Reaching potential climate and ecological tipping points is very likely to result in abrupt changes.
- **As climate hazards change in frequency and increase in severity, it is likely we will experience more compounding, cascading and concurrent hazards in the future** (*medium to high confidence*). For example, heavy rainfall and severe flooding following a tropical cyclone and extratropical low or increased air pollution following an extreme heatwave during a bushfire.
- **While some hazards are likely to occur less often, when they do occur, they may be more intense and occur in different locations than previously.** For example, it is anticipated that Australia will see fewer tropical cyclones, but proportionally more will be severe under all warming levels (*medium confidence*).

More information can be found in the *Australia's Future Climate and Hazards Report*.

RIVERINE FLOODS

A decrease in maximum daily runoff and annual runoff totals is possible (*low confidence*) indicating less frequent riverine flood events. However, **when floods do occur, they are likely to be higher due to higher event rainfall totals** (*medium confidence*)**.** Southern and particularly south-western Australia are projected to experience reduced runoff. In contrast, parts of the east coast and tropics are likely to see an increase in heavy runoff events, which could lead to higher risks of flooding.

DROUGHT

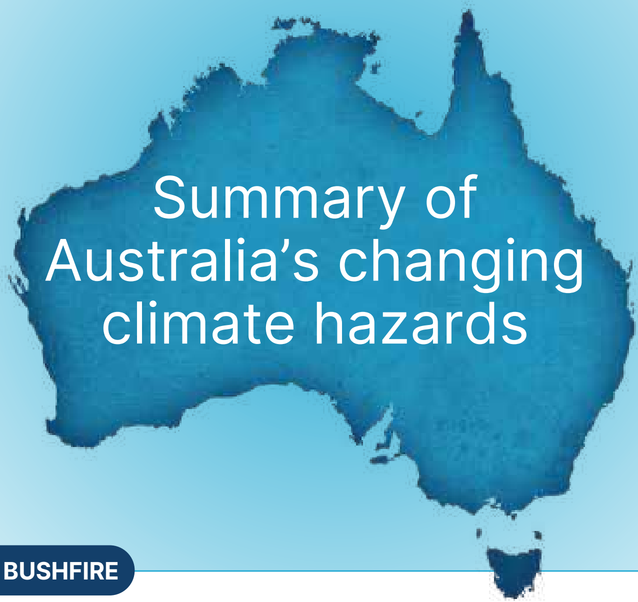
Time spent in drought is likely to increase across most of the country (*low to medium confidence*), particularly in southern and eastern areas. **Drying in the southwest of the nation, where increased time in drought has occurred since the 1970s, is projected to increase** at all future levels of global warming (*high confidence*). Long-term changes towards drier conditions are likely to occur in parts of southern Australia, with higher confidence of such change for southwest Australia.

TROPICAL CYCLONES

The frequency of tropical cyclones is likely to decrease (*medium confidence*), but the proportion of category 4 and 5 events may increase (*low/ medium confidence*). Little change or a small southward shift in tropical cyclone tracks is possible (*low confidence*).

HIGH TEMPERATURES

Extreme temperatures are likely to increase nationwide (*very high confidence*), with the greatest increases over northern Australia, the Great Dividing Range in the southeast, and in desert regions. Severe and extreme heatwave events are projected to double if global warming reaches +2.0°C and more than quadruple under +3.0°C of warming.



BUSHFIRE

Higher temperatures and drier conditions will increase the risk of bushfires in most currently forested areas (*high confidence*). However, some areas may see less intense fires later in the century as forests transition to grassland, reducing fire fuel loads. **Dangerous fire weather days are projected to become more frequent in southern and eastern areas** with a longer fire season and the potential for more megafires (*high confidence*). Northern regions are projected to have an increased susceptibility to savannah fire as rainfall patterns and vegetation change.

COASTAL HAZARDS

Sea levels around Australia will continue to rise (*very high confidence*), with a median projection of half a metre by the end of the century. Far higher levels cannot be ruled out this century if polar ice sheets collapse (*low confidence*). As sea levels rise, **coastal flood events are projected to become more frequent, accompanied by greater levels of coastal erosion and shoreline change** (*high confidence*)**.** By 2090, coastal erosion events may occur around 10 times more often than now.

STORMS

Extratropical storms (including east coast lows) are projected to become less frequent (*medium confidence*); however, they may have greater impacts when they do occur (*medium confidence*). Changes in rainfall intensity and sea levels mean a higher chance of coastal flooding from future extratropical storms. **Convective storms producing large hail may increase in the east** and occur further south (*low confidence*).

OCEAN WARMING AND ACIDIFICATION

Oceans surrounding Australia are expected to become more acidic (*high confidence*) **and warmer, with more frequent and longer marine heatwaves** (*high confidence*). The ocean environment will become more stressful for marine organisms, with a higher chance of coral bleaching. Marine heatwaves will become more frequent, particularly in the Tasman Sea. In Antarctic waters, more acidic oceans will mean some areas may become incapable of supporting the development of shells and coral skeletons.

Figure 11: Summary of how Australia's hazards are changing.

(Source: Australia's Future Climate and Hazards Report)

Aboriginal and Torres Strait Islander Peoples system

Introduction

In the context of the National Assessment, this system refers to the Indigenous peoples of Australia and their interconnectedness with the land, sea and Country.

It encompasses Aboriginal and Torres Strait Islander Lore, customs, cultures, and ways of being, which are all intrinsically linked to the survival of both peoples and ecosystems.

The Australian Climate Service has been collaborating with Aboriginal and Torres Strait Islander peoples to identify nationally significant climate risks for these communities. Through this process, 7 new nationally significant risks have been identified. The risks identified through collaboration should now be considered alongside the 56 nationally significant risks identified in the first pass. These risks can help us to collaborate with Aboriginal and Torres Strait Islander peoples to prepare, plan and adapt to a changing and challenging climate.

Yaama *(Hello – Gamilaroi)* and murrabuu *(Thank you- Gamilaroi)*

I acknowledge and take this opportunity to say a huge murrabuu, for those who collaborated with the Australian Climate Service as part of the National Climate Risk Assessment first and second pass. The energy and commitment from Aboriginal and Torres Strait Islander stakeholders was wonderful to be a party to. The second pass Gatherings were inclusive, informative and impactful. The testimony to the success of each collaborative session can be found within the content of this report.

Professor Phil Duncan

Co-lead of the Aboriginal and Torres Strait Islander Peoples system for the second pass assessment.

Galambany Professorial Fellow, Centre of Applied Water Science, University of Canberra

See the *Climate Risks to Aboriginal and Torres Strait Islander Peoples* report.

Identifying climate risks to Aboriginal and Torres Strait Islander peoples

Aboriginal and Torres Strait Islander peoples from around the nation were spoken with as part of the first pass of the National Assessment. They attended numerous gatherings to discuss climate risks to Country and their communities.

Aboriginal and Torres Strait Islander peoples from around the nation were invited to collaborate with the Australian Climate Service as part of the first pass of the National Assessment. They attended numerous gatherings to discuss climate risks to Country and their communities.

Further engagement with Aboriginal and Torres Strait Islander peoples was undertaken to identify the nationally significant risks to Aboriginal and Torres Strait Islander peoples.

It is important to note that a culturally sensitive and appropriate approach over a longer timeframe was undertaken. The collaborative approach explored and identified through conversations and 2 Gatherings, risks to and potential impacts on Aboriginal and Torres Strait Islander peoples from the other 7 systems.

The Aboriginal and Torres Strait Islander peoples have a deep understanding of the interdependencies within the natural world, honed through generations of observation and interaction with the environment. Aboriginal and Torres Strait Islander peoples' health and wellbeing is closely connected to the health of Country, and so climate change is likely to have disproportionate impacts on their ways of life, health and wellbeing, as well as on their food and water security and economic livelihoods (Figure 12).

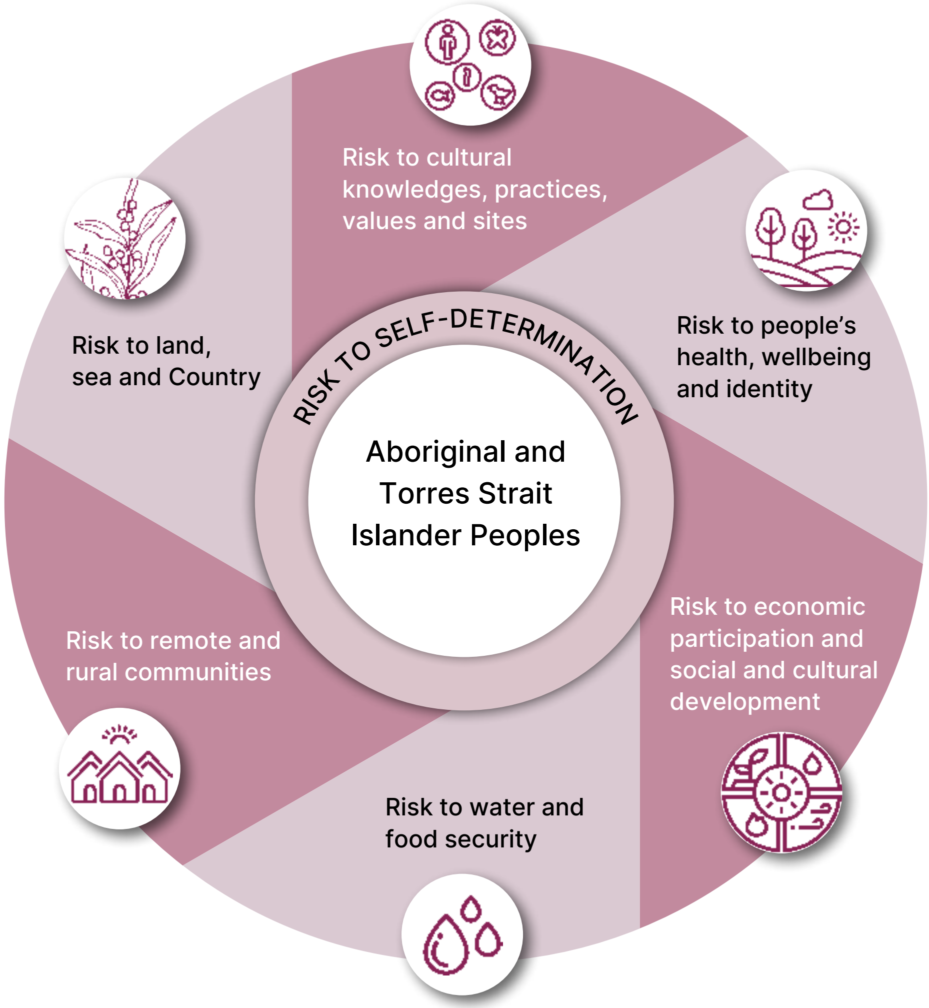


Figure 12: Key risks to Aboriginal and Torres Strait Islander peoples. These are 7 additional nationally significant risks identified in the second pass assessment. *(Source: Aboriginal and Torres Strait Islander Peoples Technical Report)*

The nationally significant risks and their framing presented here have been co-developed with Aboriginal and Torres Strait Islander people.

Nationally significant risks to Aboriginal and Torres Strait Islander Peoples system

Aboriginal and Torres Strait Islander peoples have identified that climate change is a risk to self-determination. Aboriginal and Torres Strait Islander peoples' ability and right to freely pursue their economic, social and cultural development is at risk due to their disproportionate experiences of the effects of climate change. This is an interconnected risk that compounds other key risks.

Risk to land, sea and Country (natural environments, biodiversity, ecosystems) through the changing climate, increased extreme weather events and rising warming waters that impact biodiversity, cultural sites, communities and settlements.

Risk to cultural knowledges, practices, values and sites due to climate impacts on Country and through action on climate change.

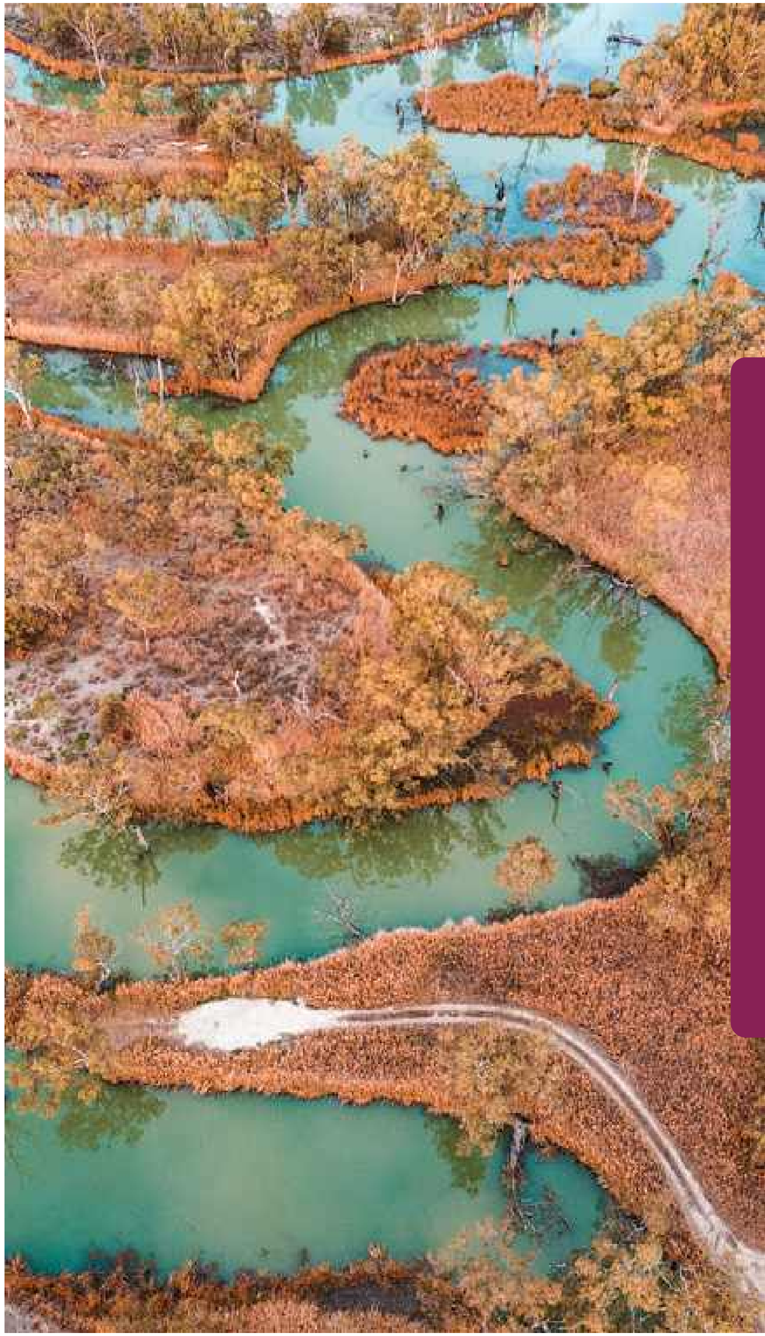
Risk to people's health, wellbeing and identity from the effects of climate change. This causes increased prevalence and acuity of mental and physical health conditions from Country being sick, as well as displacement from Country due to extreme weather.

Risk to economic participation and social and cultural economic development for Aboriginal and Torres Strait Islander peoples, communities and nations from climate hazards and their impacts.

Risk to water and food security as waterways are integral to the quality, longevity and cultural way of life for Aboriginal and Torres Strait Islander peoples. Therefore, the disruption of waterways and related infrastructure due to climate events can have harmful, far-reaching and long-term effects.

Risk to remote and rural communities, which are exposed to increased risks as climate hazards and events increase interruptions to water, energy, medical and telecommunication infrastructure and reduce food and water security through diminished road, air and water access.

The nationally significant risks and their framing presented here have been co-developed with Aboriginal and Torres Strait Islander people.



Communities - urban, regional and remote system

Summary

The Communities system encompasses a wide range of communities across Australia, including regional centres, towns, remote settlements, urban areas and cities. This system covers all natural, social, economic, and built aspects of these communities, which face risks from multiple hazards including coastal hazards.

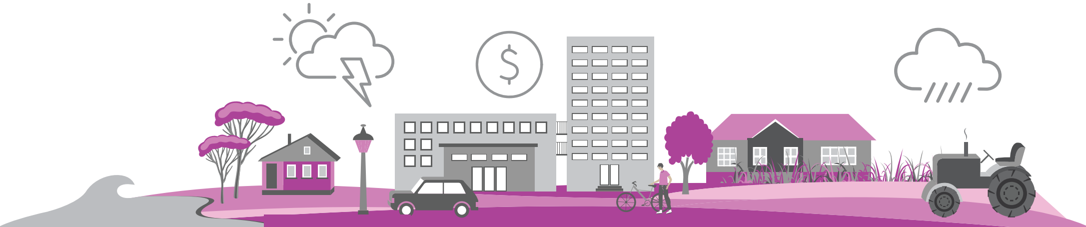
Priority risks

The National Assessment has undertaken quantitative and qualitative analysis for priority risks. The first pass assessment identified 10 nationally significant climate risks for this system. Two priority risks have been analysed as part of the second pass assessment.

- Risks to regional and remote communities, including Aboriginal and Torres Strait Islander communities that are supported by natural environments and ecosystem services.
- Risks to coastal communities and settlements from sea level rise and from legacy-and-future planning and decision-making that increases the exposure of settlements.

Communities – urban, regional and remote

Climate risks are determined by the interaction of risk elements, including hazards, exposures and vulnerabilities. This is a risk summary for the Communities system.



Climate and hazards

- Bushfires
- Changing precipitation patterns, including drought
- Flooding
- Heatwaves
- Sea level rise
- Tropical cyclones

Exposures

- Buildings (residential and commercial)
- Critical and essential goods and services
- Economic drivers (e.g. small businesses, agriculture productivity)
- Essential infrastructure (e.g. major roads, electricity lines)
- Finance and the real economy
- Health services (e.g. GP clinics, hospitals, aged care services)
- Population

Vulnerabilities

- Access to essential resources and services
- Communities and individuals with already heightened vulnerability
- Exposure to multiple hazards and compounding events
- Infrastructure and supply chains that are limited or not climate adapted
- Lack of diversity of industry, reliance on single industries
- Water security pressures

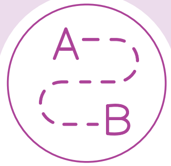
IMPACTS AND RISKS

Multiple rising pressures on coastal communities

Less time to recover from severe events

Inaccessible or unaffordable insurance for high risk areas

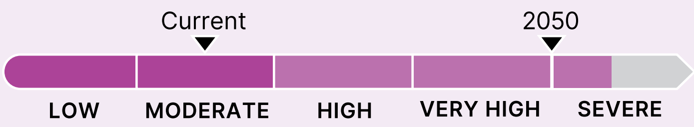
Increasing water security risks and competition for water



More disruptions to supply chains

Increasing demand on health services

Disruption to communities that rely on single industries



Assessment of current risk

The current climate risk to the Communities system is rated as *moderate (high confidence)*.

Communities are facing increased frequency of extreme weather events and rising sea levels, particularly those in northern Australia and coastal areas. These impacts are most severe in areas already exposed to floods, tropical cyclones, bushfires and heatwaves.

Communities are also facing rising insurance costs, degradation of ecosystem services and long-term impacts from repeated extreme weather events on local economies and critical infrastructure. There are already noticeable impacts on communities living with disadvantage and some disruption to social stability and cohesion.

Assessment of future risk

By 2050, the climate risk to the Communities system is projected to escalate to *very high–severe (high confidence)*.

Rising sea levels – projected to reach up to 0.5 m by 2050 and over 0.8 m by 2090 – are expected to significantly affect multiple states, particularly along Australia's east coast. These changes will increase pressure on coastal freshwater systems, such as estuaries and aquifers, through saltwater intrusion, reduced rainfall, and damage to water infrastructure. This threatens the reliability and quality of water supplies for many communities, particularly those in low-lying coastal areas. Communities located within 10 km of soft shorelines will be especially vulnerable to erosion, inundation, and infrastructure damage.

Extreme weather events, including heatwaves, bushfires, flooding and tropical cyclones, will intensify safety and security risks, potentially resulting in loss of life, destabilisation of community structures, and increased migration away from high-risk areas. In Northern Australia, escalating extreme heat is likely to exacerbate existing socio-economic disadvantages, intensifying health, infrastructure, and service delivery challenges. This is an example where risks from other systems will amplify impacts to communities.

Compounding hazards (where multiple climate-related events such as heatwaves, floods and droughts occur simultaneously or in close succession) and repeated events, combined with lower adaptive capacity, are likely to lead to more severe impacts in regional and remote communities. Compounding impacts can also erode community resilience and social cohesion. If responses are perceived as inadequate or inequitable, this may undermine trust in government and institutions.

Climate change impacts will disproportionately affect populations already living in vulnerable circumstances, such as remote Aboriginal and Torres Strait Islander communities, older people, young children and those with pre-existing health conditions. These groups often face greater exposure and less adaptive capacity.

Climate change will create escalating economic costs for all communities. Effective adaptation will require long-term planning, inclusive community engagement, and investment in resilient infrastructure.

Summary of exposures, vulnerabilities, impacts and risks

Communities at highest risk

Communities in northern Australia—including the Northern Territory, Queensland north, and Western Australia north—are exposed to multiple climate hazards, including heatwaves, flooding, tropical cyclones, and bushfires. These regions also have a high proportion of their populations living in high-risk areas. Increases in extreme heat are compounding existing socioeconomic vulnerabilities, such as low income and high poverty rates. These factors particularly affect Aboriginal and Torres Strait Islander communities, as well as older populations. By 2050, the increasing frequency and intensity of many hazards, along with increasing water security challenges, are likely to further increase risks in these areas.

Coastal communities

Coastal and island communities across Australia face heightened risks from rising sea levels, which intensify coastal flooding, erosion, and inundation. Low-lying communities located within 10 km of soft shorelines are particularly vulnerable, with the percentage of areas at high-risk expected to increase significantly by 2050. By 2090, 34% of coastal communities could be at high or very high risk, representing over 3 million people based on current population distributions. Exposure is increasing in both urban and regional coastal areas, with vulnerability shaped by socioeconomic factors, infrastructure density, and adaptive capacity.

Regional communities

Regional communities are highly vulnerable to climate change due to their reliance on climate-sensitive industries, such as agriculture and tourism. These sectors face increasing risks from droughts, heatwaves, floods, and other risks, such as from reduced access to markets or increased biosecurity risks. Limited employment diversity and economic dependence on natural resources heighten the potential for disruption and reduce resilience.

Critical infrastructure, particularly water, transport, and energy systems, is often sparse and lacks redundancy, resulting in slower recovery and greater vulnerability to repeated climate shocks. Socioeconomic factors such as older populations, lower incomes, and limited access to services further reduce adaptive capacity.

Regions in northern and central Australia are more prone to multiple types of climate hazards, particularly extreme heat, compared to other parts of the country. This elevated proneness means communities in these areas are more likely to experience severe events more frequently, placing greater pressure on infrastructure, services, and emergency response systems.

Urban communities

Urban centres and cities, especially those along the coast, are emerging as primary hotspots for sea level rise impacts. Rising sea levels increase risks to critical and community infrastructure, while high population densities and residential buildings near soft shorelines heighten risk to erosion impacts. The relatively high value of assets exposed to hazards, will increase the impacts if risks are realised.

In addition to sea level rise, urban communities are increasingly at risk of extreme weather events. Heatwaves strain energy systems, impact public health, and disrupt transport networks. Flooding from intense rainfall threatens essential community infrastructure and services, while also driving up economic costs due to property damage (insurance coverage and costs), business interruptions, and recovery expenses. Major urban areas will need to prioritise risk-based planning and infrastructure resilience to mitigate these growing threats.

Aboriginal and Torres Strait Islander and remote communities

Remote communities, including Aboriginal and Torres Strait Islander populations, are particularly vulnerable to climate hazards due to their geographic isolation, limited infrastructure, and systemic disadvantage. These communities face heightened risks from extreme events such as heatwaves, floods, droughts and bushfires, which can disrupt essential services and supply chains.

Sea level rise poses a significant threat to homes, livelihoods, and cultural connections, particularly in locations such as the Torres Strait Islands. The loss of access to Country and the ability to practice traditional ways of life can have profound social and emotional impacts. Long distances to service centres and weak infrastructure links also increase energy and supply chain insecurity, underscoring the need for targeted support and adaptation strategies.

Critical and essential services

Climate change poses immediate risks to critical and essential services such as health services, aged care, water supply, energy, and transportation. Rising temperatures, extreme weather events, and shifting rainfall patterns threaten the reliability, efficiency, and accessibility of these services, particularly in high-risk locations.

Infrastructure in exposed areas may struggle to meet growing demand under climate stress, with disruptions affecting vulnerable populations most acutely. To maintain service continuity and reduce long-term risks, development in hazard-prone areas must include climate-informed urban planning, building codes and infrastructure investment.

Finance and the real economy

Climate change is expected to drive escalating economic costs across all communities. Sea level rise will intensify coastal flooding and erosion, exacerbate flood and tropical cyclone impacts, and increase the severity and frequency of extreme events. These changes will notably increase insurance costs, leading to more underinsured or uninsured properties.

Business interruptions caused by extreme events will raise costs for local economies and may have broader impacts on the national economy when disruptions are widespread or prolonged. Effective adaptation actions – including risk-based planning, resilient building codes, and long-term infrastructure investment – will be essential to mitigate financial risks. Inclusive community engagement and forward-looking planning will also be critical to support economic resilience.

Introduction

This chapter provides a synthesis of the Communities – urban, regional and remote system.

It draws on a wide range of technical assessments to provide observations that can enable effective adaptation.

It includes:

- System overview
- Priority risk snapshots
- Key climate hazards for the system
- Exposures, vulnerabilities, impacts and risks relevant to the system
- Adaptation observations and considerations
- Case study

The chapter highlights 2 priority risk snapshots and draws on the analysis from across all the priority risk technical assessments. It is important to note for this first National Assessment that all 63 nationally significant risks have not been fully assessed. It provides a useful national understanding of climate risks and information that can support adaptation. Climate risks are not static – this work is a sound foundation that should be built on over time.

System overview

The Communities - urban, regional and remote system refers to cities, urban areas, regional centres, towns, and remote settlements across Australia.

This system will encounter risks related to climate change, multiple hazards and coastal areas prone to sea level rise, affecting all social, economic, built and natural aspects of these communities. The interdependencies of natural, built and human systems within these communities is complex, resulting in compound risks.

Coastal communities in both urban and rural areas of Australia are already experiencing climate change impacts such as sea level rise, coastal erosion, storm surges and extreme weather events, and risks from these hazards will increase in the future. Risk in these communities is shaped by both historical and future planning and decision-making processes. The legacy of past decisions and the foresight of future planning play crucial roles in determining the vulnerability and resilience of these areas.

Regional, remote and Aboriginal and Torres Strait Islander peoples' communities are particularly vulnerable to climate change impacts. These communities often face attenuated supply and service chains, making them more exposed to disruptions. The cultural connection of Indigenous communities to the land and close daily relationship to the natural environment increase their vulnerability to extreme events. Changes in ecosystem services due to climate change can adversely affect economic and agricultural productivity, impacting the wellbeing and livelihoods of regional and remote communities.

Priority risk snapshot: Coastal communities and settlements

Risks to coastal communities from sea level rise, particularly where legacy and future planning and decision-making increases the exposure of settlements.

Seventy-three percent of Australia's population live in major cities, particularly along the east coast. These major city coastal communities, as well as large regional coastal communities and coastal remote communities, are exposed to rising sea levels and increasing coastal hazards. They are also at risk from legacy planning decisions that did not include adequate sea level rise considerations, which will now increase the vulnerability of settlements.

Rationale

The current risk to coastal communities and settlements is rated as **Moderate**, but it is expected to rise to **High** by 2050 and to become **Severe** by 2090 as sea levels continue to rise (Figure 13). If current population levels remain unchanged, the number of people living in high- or very high-risk areas would increase from 597,000 in 2030 to 1,528,000 in 2050, and to 3,028,000 by 2090. While there is a noticeable impact on local community cohesion and stability, it currently affects only a small proportion of the population. However, as the risk escalates, the broader community will likely experience more significant disruptions. Communities - urban, regional and remote will benefit from improved management and incremental adaptation. Some communities are likely to require transformational adaptation, such as through managed retreat, landscape scale developments and restrictions, and risk-sensitive urban planning.

Key Hazards

- Sea levels are rising around Australia *(very high confidence)*, and more frequent extreme weather events are increasing the risk of inundation and damage to coastal infrastructure and communities.
- Coastal erosion will threaten coastal infrastructure, property, and ecosystems, leading to loss of land and habitat and damage to infrastructure such as homes, roads, and utilities.
- Increasingly extreme events, such as floods, heatwaves, bushfires and tropical cyclones.

RISK RATING	*Current*	*2050*	*2090*
Severe			
Very High			
High			
Moderate			
Low			
ACS RISK CONFIDENCE RATING	***High***	***Medium***	***Low–Medium***

TYPES OF RESPONSE REQUIRED

Improved management: *Enhancing efficiencies within existing systems without major changes*

Incremental adaptation: *Gradual adjustments to systems without altering their core*

Transformational adaptation: *Fundamental changes to systems, significantly shifting risk management*

Response required | *Some level of response required* | *Response not required at this time*

Figure 13: Rating for the Coastal communities and settlements priority risk for current, 2050 and 2090 and the types of responses required to address the risk. For definitions of risk ratings, please see Figure 9.

Exposure

- Australian coastal communities in low-lying areas face increased exposure to sea level rise, intensifying extreme weather events, and accelerated erosion. Land subsidence exacerbates these impacts, while the loss of natural defences like mangroves and reefs reduces protection against waves and erosion.
- The physical structures that make up a community – such as the buildings, infrastructure and natural defences – are all exposed to changing hazards.
- Marked regional variations are observed in the current exposure to sea level rise of residential dwellings across Australia. While most residential dwellings are in low-risk areas across all National Assessment regions, especially in Tasmania, South Australia and Western Australia south, exposure of residential buildings is highly likely to rise markedly in Queensland (especially north) and Victoria.

Vulnerability

- Rising sea levels are already having an impact on vulnerable coastal communities, settlements and people in low-lying areas. Examples include parts of the Torres Strait Islands, coastal LGAs of NSW and Victoria and low-lying areas of north and south Queensland.
- Social and economic factors that contribute to individual or household vulnerability to any adversity also make them more vulnerable to climate change. Communities with low socio-economic background may have fewer resources to cope with and recover from climate impacts.
- Critical infrastructure, such as transportation networks, water supply systems, and energy grids, can be severely impacted by climate events. The resilience of this infrastructure is essential for the safety and wellbeing of communities. Economic dependence on coastal transport networks, limited adaptation resources in smaller towns, and social vulnerability factors, including limited mobility for low-income households, further heighten risks.

Impacts and risks

- Major urban centres and cities in coastal areas are at risk from sea level rise. The high population density in coastal areas, location of residential buildings near soft shorelines, and value of real estate investments all increases risk.
- Aboriginal and Torres Strait Islander peoples are particularly at risk from climate change as remote settlements are often poorly served by critical infrastructure and in locations exposed to multiple hazards, particularly extreme heat. The possible need for relocation would have significant cultural impacts with loss of connection to Country.
- In future, the impacts of rising sea levels compounding with other coastal hazards such as coastal erosion, flooding and saltwater intrusion is likely to compromise community infrastructure and drinking water supplies. Risk will accelerate in high-growth regions of coastal Queensland, South Australia and NSW.
- Sea level rise is increasing the risk of flooding, erosion, tropical cyclone impacts and infrastructure damage, which is already having an impact on coverage of insurance in highly exposed communities. For example, many insurance policies exclude coverage for 'actions of the sea', creating financial challenges for affected residents and businesses, particularly those with high-value properties.
- In highly exposed and vulnerable settlements, chronic sea level rise is highly likely to challenge social cohesion and livability. Severe landscape changes and permanent inundation of low-lying areas may lead to relocation of high-risk communities. Relocation is highly likely to disrupt local economies, social networks, traditional identities and cultural heritage.

Adaptation

- Current adaptation examples for coastal communities target a diverse range of strategies, including coordination (e.g. through projects to align coastal management planning across councils), risk assessment and strategy development (e.g. risk-based vulnerability zoning for land-use planning), institutionalisation (e.g. through coastal risk and adaptation options assessments, and modified building codes and standards appropriate to changing climatic conditions – a vital part of adaptation strategy in exposed coastal communities) and knowledge-building (e.g. through projects to inform communities of coastal risks).
- Eventual retreat and relocation efforts would potentially involve complex planning and resource allocation. Governance risk increases the vulnerability of coastal communities with overlapping or unclear responsibilities for development, restoration and adaptation. Long timeframes, high long-term costs and role ambiguity mean there is a risk of inadequate, inefficient or inequitable resource distribution, raising concerns about equity and access for vulnerable populations.
- There are some early examples of successful nature-based adaptation to coastal hazards such as wetlands and mangroves that can mitigate the effects of coastal hazards and sea level rise.
- In response to growing concerns about insurance accessibility and affordability, new approaches to ensure equitable access to affordable insurance cover for high-risk properties may need to be considered within future responses.

Priority risk snapshot: Regional and remote communities

Risks to regional, remote and Aboriginal and Torres Strait Islander communities that are supported by natural environments and ecosystem services.

Twenty-six percent of Australians live in inner and outer regional Australia, and 2% in remote and very remote areas.

Rationale

The risk to regional and remote communities, including remote and regional Aboriginal and Torres Strait Islander communities, is currently rated as **High**. This risk is projected to remain **High** in 2050 and to become **Very High–Severe** by 2090 (Figure 14). Currently, 26% of the population lives in non-urban areas, and these communities are already experiencing disruptions. The impacts are not evenly distributed, with heat impacts becoming significant in northern regions. By 2050, impacts from heat and other compounding hazards across the country, including drought, are expected to become severe, further exacerbating impacts in these communities. Some communities, including many Aboriginal and Torres Strait Islander communities, have fewer resources for adaptation, low-quality infrastructure and low adaptive capacity, compounding impacts. Improved management opportunities depend on the community characteristics. There are also opportunities for incremental and transformational adaptation in regional and remote communities, including remote and regional Aboriginal and Torres Strait Islander communities. Conditions for transformational adaptation are emerging in some resource-limited communities (e.g. discussions about managed retreat and planned relocation).

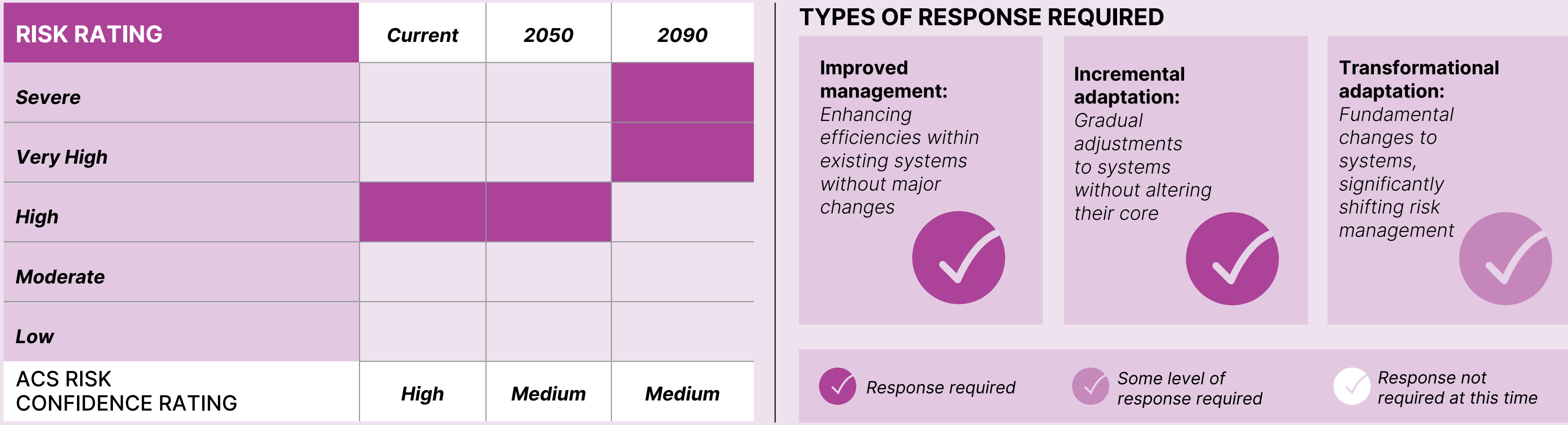


Figure 14: Rating for the Regional and remote communities priority risk for current, 2050 and 2090, and the types of responses required to address the risk. For definitions of risk ratings, please see Figure 9.

Key hazards

- All Australian communities face an increase in extreme, concurrent and cascading events, especially in the northern part of Australia.
- Key hazards include floods, heatwaves, bushfires and tropical cyclones. These are likely to increasingly impact communities, particularly in northern Australia.
- Increased variability of rainfall is highly likely to reduce water security and to increase the frequency and intensity of bushfires, which threatens the natural environment on which communities rely.
- Droughts are a known risk to communities and are projected to become more frequent and prolonged. Time spent in drought is expected to increase across much of Australia, especially in southern and eastern regions. Aridity is also projected to intensify in southwest Western Australia and parts of the southern mainland.

Exposure

- Communities face increasing risks from climate-driven events, with many already residing in areas exposed to floods, storms and bushfires.
- Aboriginal and Torres Strait Islander communities in remote and northern regions are particularly exposed to heat hazards and to attenuated critical infrastructure.
- Low-lying islands in the Torres Strait and regional and remote communities located on soft coastlines are exposed to sea level rise and coastal hazards.
- Regional and remote communities and agriculture have often developed around water sources. These are particularly exposed to extreme flood and coastal inundation.

Vulnerability

- Climate-sensitive industries, in particular agriculture, face productivity challenges due to their dependence on natural resources and outdoor workers. These impacts can cascade to the communities that rely on these industries.
- Risks in regional and remote communities are exacerbated due to increased social vulnerability, particularly affecting Aboriginal and Torres Strait Islander communities and elderly populations.
- Exposure of the natural environment to chronic and extreme climate change impacts increases the vulnerability of communities that rely on the natural environment.
- Small businesses in rural and regional communities are likely to be at risk, particularly in high-risk areas of the Northern Territory, Western Australia and Queensland north.
- Transportation networks, water supply systems and energy grids can be severely affected by climate events. The services provided by this infrastructure are essential for the safety and wellbeing of communities. Communities with poor infrastructure provision, or at the end of attenuated service lines, are more vulnerable.
- Socially vulnerable communities may have fewer resources to cope with and recover from climate impacts. These vulnerable communities may rely heavily on single industries or on the natural environment, which in turn are vulnerable to climate change.

Impacts and risks

- Regional and remote communities, particularly Aboriginal and Torres Strait Islander communities, are at risk from climate change as settlements are often poorly served by critical infrastructure, and are in locations exposed to multiple hazards including extreme heat.
- The values and knowledges of Aboriginal and Torres Strait Island people are at risk.
- Increases in extreme heat, extreme events and increased rainfall variability are likely to result in decreased total agricultural production and changes in the distribution of primary industries, a key source of livelihood in regional and remote communities.
- In rural communities, impacts from hazards on key sectors, such as businesses reliant on natural resources, are reducing employment opportunities for residents and impacting mental health.
- Coastal communities face water security risks due to sea level rise and saline intrusion. Estuarine environments, which are vital for biodiversity and water supply, may no longer be reliable sources
- Climate extremes are likely to impact transport routes, leading to disrupted supply of important commodities to regional and remote communities.

Adaptation

- Cities and large towns are developing lasting water supply solutions to avoid the unacceptable risk of water shortages. However, geographic barriers (e.g. lack of access for desalination plants, lack of suitable aquifers for recharge) and community acceptance of solutions such as recycled water, along with economic and regulatory challenges, may hinder these efforts, potentially adding years or decades to implementation.
- Regional and remote communities can benefit from adaptations across all risks and systems. For example, enhancing ecosystem services, ensuring reliable water supplies, strengthening supply chains, and improving health and social support systems will help to reduce the vulnerability of regional, remote and Aboriginal and Torres Strait Islander communities and to mitigate the increased risks posed by climate-driven events.
- For examples of specific adaptations for regional and remote coastal communities, see *Priority risk snapshot: Coastal communities and settlements*.

Key climate hazards for the system

This section describes the changing climate hazards for the Communities - urban, regional and remote system.

The number of people exposed to compounding climate impacts increases across global warming scenarios, especially in vulnerable regions such as northern Australia and coastal cities. By 2050, severe impacts are expected across all regions from extreme weather events, sea level rise and water security challenges *(medium confidence).*

- Compound events are multiple hazards and/or drivers occurring either simultaneously or sequentially at one or more locations (Zscheischler et al., 2020). The events may amplify impacts compared with those of an isolated individual hazard. For example, humidity itself may not be extreme, but it can cause risks to health when combined with high temperatures.
- Severe, extreme and compound events are highly likely to increase with climate change *(high confidence)* although the complexity of the ways events can compound means that current climate science cannot quantify the probability of compound events in the future. In the analysis presented here, the increase in frequency, severity and location of extremes of individual hazards is considered. This is very likely to underestimate the risk driven by interacting hazards, cascading impacts or the loss of resilience due to events occurring in close sequence (O'Neill et al., 2022; Simpson et al., 2023).
  Evidence: Australia's Future Climate and Hazards Report
- The National Assessment has assessed hazard proneness for 4 of the priority hazards – heatwaves, bushfires, riverine and flash flooding, and tropical cyclones. Hazard proneness refers to the combined frequency, probability, or severity of multiple hazards (Figure 15).

Sea levels are rising around Australia, and more frequent extreme weather events are increasing the risk of inundation and damage to coastal infrastructure and communities *(medium confidence).*

- Before 2050, projected sea level rise is expected to be driven by historical warming; however, after 2050, sea level rise is projected to be strongly dependent on global warming levels. Rates of sea level rise to the north (0.4 to 0.6 cm per year) and southeast of Australia have been significantly higher than the global average (0.3 cm per year) (Hague et al., 2022).
  Evidence: Australia's Future Climate and Hazards Report
- Rising sea levels are already having an impact on coastal communities, settlements and people in low-lying areas, and this is expected to continue into 2090 (Figure 16). Examples include parts of the Torres Strait Islands, coastal communities of NSW and Victoria, and low-lying areas of Queensland (see *Case study: Compound estuarine flood hazards*).
  Evidence: Communities Technical Report
- Coastal erosion will increasingly threaten coastal infrastructure, property and ecosystems, leading to loss of land and habitat and damage to infrastructure such as homes, roads and utilities.
  Evidence: Communities Technical Report
- Additionally, declines in groundwater levels combined with sea level rise threaten freshwater supplies through saltwater intrusion into aquifers, which is likely to require comprehensive and well-resourced adaptation strategies to safeguard.
  Evidence: Communities Technical Report, Australia's Future Climate and Hazards Report, Water Security Technical Report

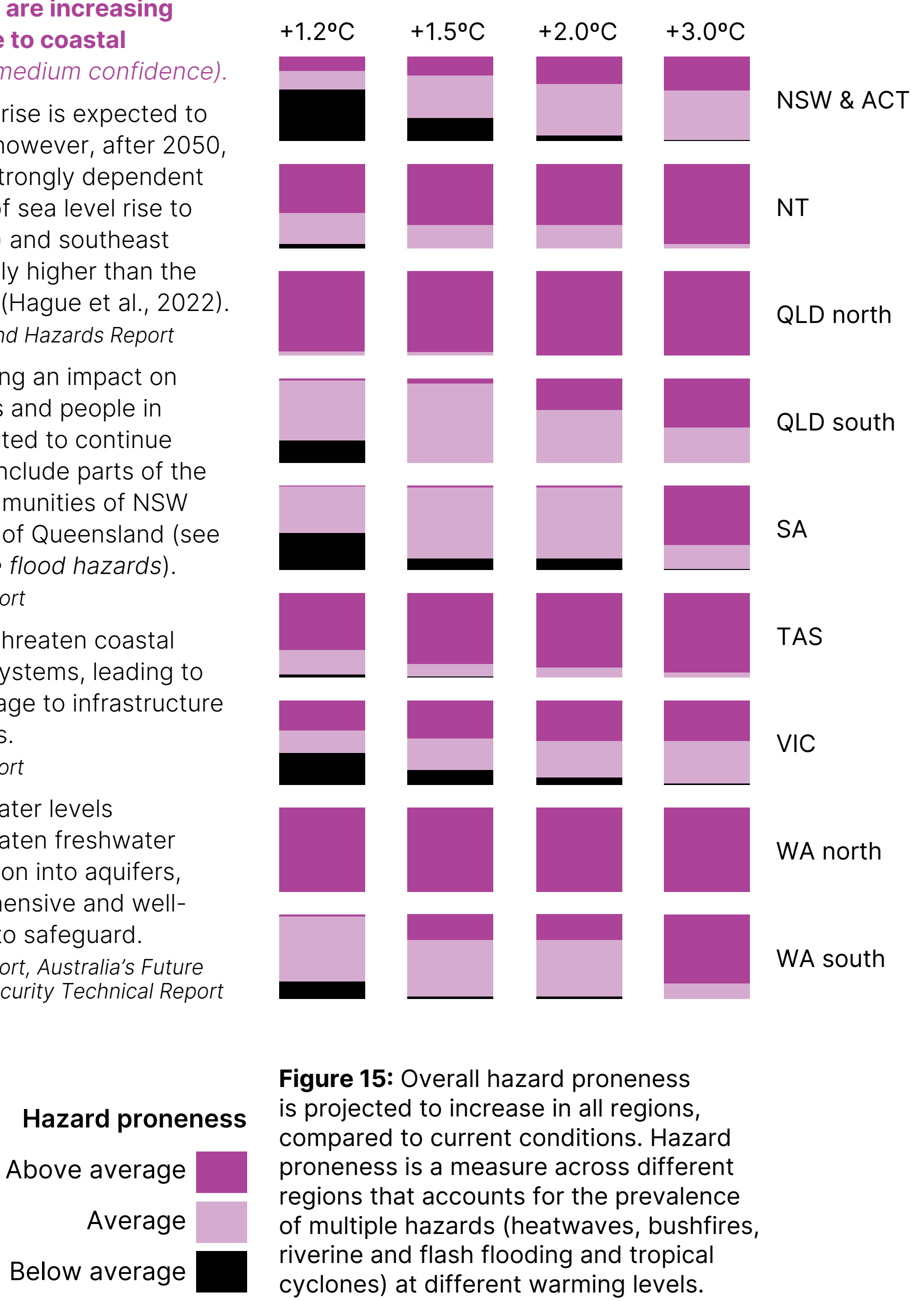


Figure 15: Overall hazard proneness is projected to increase in all regions, compared to current conditions. Hazard proneness is a measure across different regions that accounts for the prevalence of multiple hazards (heatwaves, bushfires, riverine and flash flooding and tropical cyclones) at different warming levels.

Change in extreme total water level

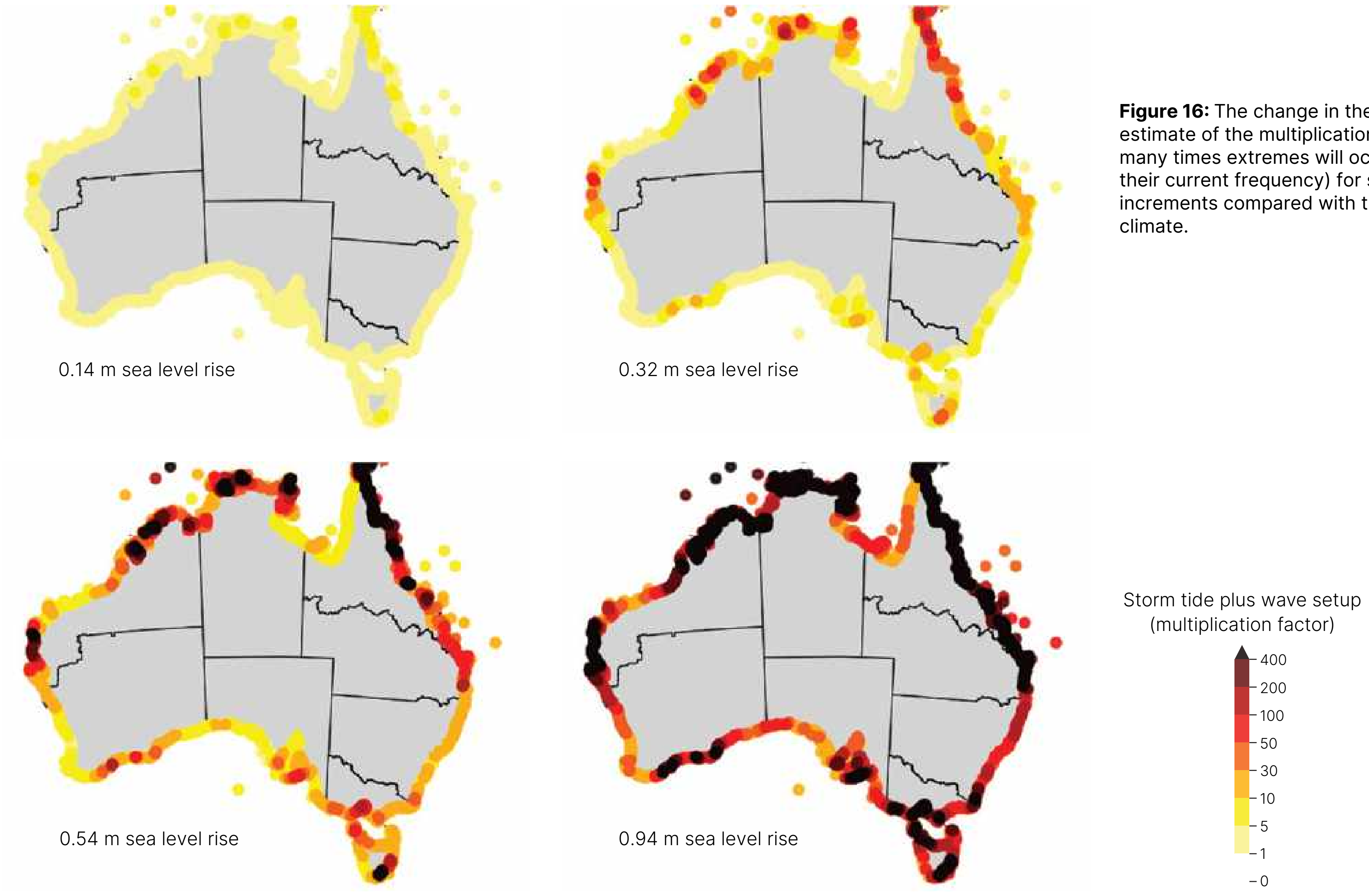


Figure 16: The change in the median estimate of the multiplication factor (how many times extremes will occur relative to their current frequency) for sea level rise increments compared with the current climate.

Exposures, vulnerabilities, impacts and risks

This section provides a summary of impacts and risks associated with the Communities - urban, regional and remote system (Table 5).

These impacts and risks have been identified by understanding the changing climate hazards, as well as exposures and vulnerabilities, that drive them. The assessment of future risk to communities in this report uses current population numbers and distributions. However, local population changes over time will depend on individual and community response to climate impacts; therefore, projections for at-risk communities in 2050 and beyond are likely to over estimate exposure to climate risks.

Table 5: Summary of impacts to the Communities - urban, regional and remote system, derived from analysis in the National Assessment. Further details of the impacts, including information sources, can be found throughout this chapter.

Climate impact	Current	Future			Current climate adaptation examples
	GWL +1.2°C	GWL +1.5°C	GWL +2.0°C	GWL +3.0°C	
Climate-driven hazards will increase	Compounding and extreme climate events are already impacting Australia (e.g. Summer 2019–20 bushfires).	Vulnerable regions across northern Australia and coastal cities will continue to be impacted.	Severe impacts are expected across all regions from extreme weather events and sea level rise.	Extreme impacts are expected across all regions. Impacts are likely underestimated due to a lack of future exposure data and the increasing effects of sequential events.	Regional climate partnerships between remote LGAs. Funding schemes for regional drought and disaster resilience. Knowledge building projects to understand disaster impacts on regional and remote communities.
Sea level rise impacts for communities	Coastal erosion, increased coastal flooding, saltwater intrusion in aquifers, property and infrastructure loss.	Increased frequency of coastal inundation, with vulnerable regions more affected.	Higher impact in low-lying regions; increased erosion and property damage.	Major disruption in coastal zones, with significant displacement of communities.	Environmental solutions such as wetlands and mangroves. Risk-based vulnerability zoning for land-use planning, building codes and standards. Education projects informing communities of coastal risks.
Populations at risk from sea level rise[1]	Over the past century, sea levels around Australia have risen by approximately 20 cm. Rising sea levels already contribute to coastal erosion, inundation of low-lying areas and saltwater intrusion into freshwater systems, posing risks to coastal communities and infrastructure.	597,000 persons, or 6.7% of the coastal population, in high-risk and very high-risk areas by 2030. Greatest increases in exposure are along the east coast of Australia.	1,528,000 persons, or 17.6% of the coastal population in high-risk and very high-risk areas by 2050. Greatest increase in exposure to impact in vulnerable coastal communities, including parts of the Torres Strait Islands, coastal LGAs of NSW and Victoria, and low-lying areas of north and south Queensland.	3,028,000 persons in high-risk and very high-risk areas by 2090, or 34% of the coastal population, if current population levels remain unchanged. Greatest additional increase in exposure in the Northern Territory.	Risk-based vulnerability zoning for land-use planning. Coastal management planning and alignment across councils. Coastal risk and adaptation options assessments Modified building codes and standards. Education projects informing communities of coastal risks.

Climate impact	Current	Future			Current climate adaptation examples
	GWL +1.2°C	GWL +1.5°C	GWL +2.0°C	GWL +3.0°C	
Residential buildings in at-risk locations[2]	Nationally, 8.2% or 751,000 residential buildings are currently located in high-risk areas, and 8.7% or 794,000 are in very high-risk areas.	By 2030, this is expected to rise to 10.2% or 928,000 residential buildings are in very high-risk areas, an additional 134,000 buildings. The Northern Territory is a significant concern. At a future warming scenario of +1.5°C, almost one fifth (19.5%) of residential buildings in the region will be in high- and very high-risk areas, equating to around 52,000 buildings.	Nationally, 8.9% or 789,000 residential buildings may be located in high-risk areas, and 11.1% or 1,015,000 in very high-risk areas, based on a communities multi-hazard risk index. Queensland north experiences the greatest increases, with the number of residential buildings in very high-risk areas projected to increase to 48.4% or 181,000 of the region's residential buildings.	13.5% or 1,224,000 residential buildings in very high-risk areas by 2090. Greatest increases in exposure in the Northern Territory, with a 9.8% increase in residential building totals, representing 7,000 additional buildings.	Coastal risk and adaptation options assessments. Modified building codes and standards. Education projects informing communities of coastal risks.
Small businesses in at-risk locations[2,3]	Nationally, 16% of small businesses are in locations of above-average risk. 64% of small businesses in the Northern Territory and 60% in Queensland north are currently in locations of above-average risk, well above the national rate. Over 50% of small businesses in South Australia, Queensland south and Victoria are in locations of below-average risk.	By 2030, this is expected to rise to 18%, representing an additional 40,000 small businesses. This is driven by large increases in Victoria and NSW & ACT, which increase by 13,000 and 12,000, respectively.	Small businesses in low-risk areas are expected to decrease by 239,000 or 9%, while those in average-risk areas will increase by 160,000. Notable growth in small businesses in average-risk areas includes Victoria by 64,000, NSW & ACT by 57,000 and Queensland south by 44,000. This indicates that risk is likely to rise overall, not just at the extremes.	Nationally, small businesses in locations of above-average risk are estimated to increase to 20%, an increase of 92,000 businesses. In NSW & ACT, over 200,000 businesses will be in locations of above-average risk. 74% of businesses in Queensland north and 66% of businesses in the Northern Territory will be in locations of above-average risk.	

[1]Based on 2021 population [2]Locations at-risk considers exposure to floods, bushfires, tropical cyclones and heatwaves. [3]Based on 2021 business numbers

Communities at highest risk

Communities at most risk are generally those already residing in areas exposed to floods, storms and bushfires with characteristics that make them particularly vulnerable to these hazards. The Northern Territory, Queensland north and Western Australia north are particularly exposed, with significant percentages of their populations in high-risk areas *(medium confidence).*

- Communities most at risk from multiple hazards can be identified by considering the following: (a) the current and projected intensity, frequency and location of hazards that affect the community; (b) information on the extent to which the community is exposed to the hazards under consideration; and (c) information about characteristics that make communities vulnerable. These 3 factors are used to estimate community risk at different global warming levels.
  - The assessment considers Statistical Areas Level 2. These are geographic areas that are defined by the ABS as medium-sized general-purpose areas, each representing a community that interacts together socially and economically. Statistical Areas Level 2 generally have a population of between 3,000 and 25,000.
  - Climate risk for 4 key hazards (floods, bushfires, tropical cyclones and heatwaves) is reported here using 5 categories: very low, low, average, high and very high based on distance from the national mean for risk, considering all factors.
  - Most hazards are considered at global warming levels +1.2°C, +1.5°C, +2.0°C and +3.0°C. Sea level rise, however, is not strongly driven by global warming level, and so it is considered at 2050 and 2090, with a low and a high scenario considered for 2090.
  - Future exposure and vulnerability have not been modelled at the Statistical Area Level 2 level, and so current-day exposure and vulnerability are used with modelled hazard information to derive these estimates. This means that the analysis presented captures how present-day communities' risk would be different under future climate and hazard conditions. It does not fully capture how vulnerability and exposure will change in the future.
    Evidence: Communities Technical Report
- Cities, especially coastal cities have moderate to high exposure to climate hazards but they also have significant variation in socioeconomic vulnerability. Outer urban areas of cities stand out as watch points as while they have moderate levels of both exposure and vulnerability, making them particularly susceptible to adverse impacts and are likely to experience prolonged recovery times.
  Evidence: Communities Technical Report
- Populations in the Northern Territory, Queensland north and Western Australia north are generally at higher risk to floods, bushfires, tropical cyclones and heatwaves today than other parts of the country. In the Northern Territory, 67,000 people (26.5%) reside in high-risk areas, while 110,000 (43.7%) live in very high-risk areas (Figure 16). This suggests a substantial exposure to climate impacts, especially given the region's small population size; Western Australia north has 94,000 people (85.4%) living in very high-risk areas, making it significantly exposed to climate hazards.
  Evidence: Communities Technical Report
- Nationally, 8.2% of residential buildings are currently located in high-risk areas, and 8.7% are in very high-risk areas. By 2030, this is expected to rise to 10.2% (an additional 134,000 buildings) in very high-risk areas. The number of residential buildings in very high-risk areas is projected to increase from 928,000 (10.2%) at +1.5°C of global warming to 1,224,000 (13.5%) at +3.0°C (Figure 18a).
  Evidence: Communities Technical Report
- By 2030, small businesses in areas of greater than average risk will increase nationally from 16.3% to 17.9% (an additional 40,000 businesses).
  Evidence: Communities Technical Report
- At a future warming scenario of +1.5°C, almost one fifth (19.5%) of residential buildings in the Northern Territory will be in high-risk and very high-risk areas, equating to around 52,000 buildings. In Queensland, particularly in the northern region, the number of residential buildings in very high-risk areas is projected to increase slightly across warming scenarios, with 178,000 buildings projected at +1.5°C scenario, 181,000 at +2.0°C, and 185,000 at +3.0°C.
  Evidence: Communities Technical Report
- The growing intensity and frequency of climate-driven hazards could result in higher impacts, raising concerns about the provision, affordability and accessibility of insurance (Productivity Commission, 2012).

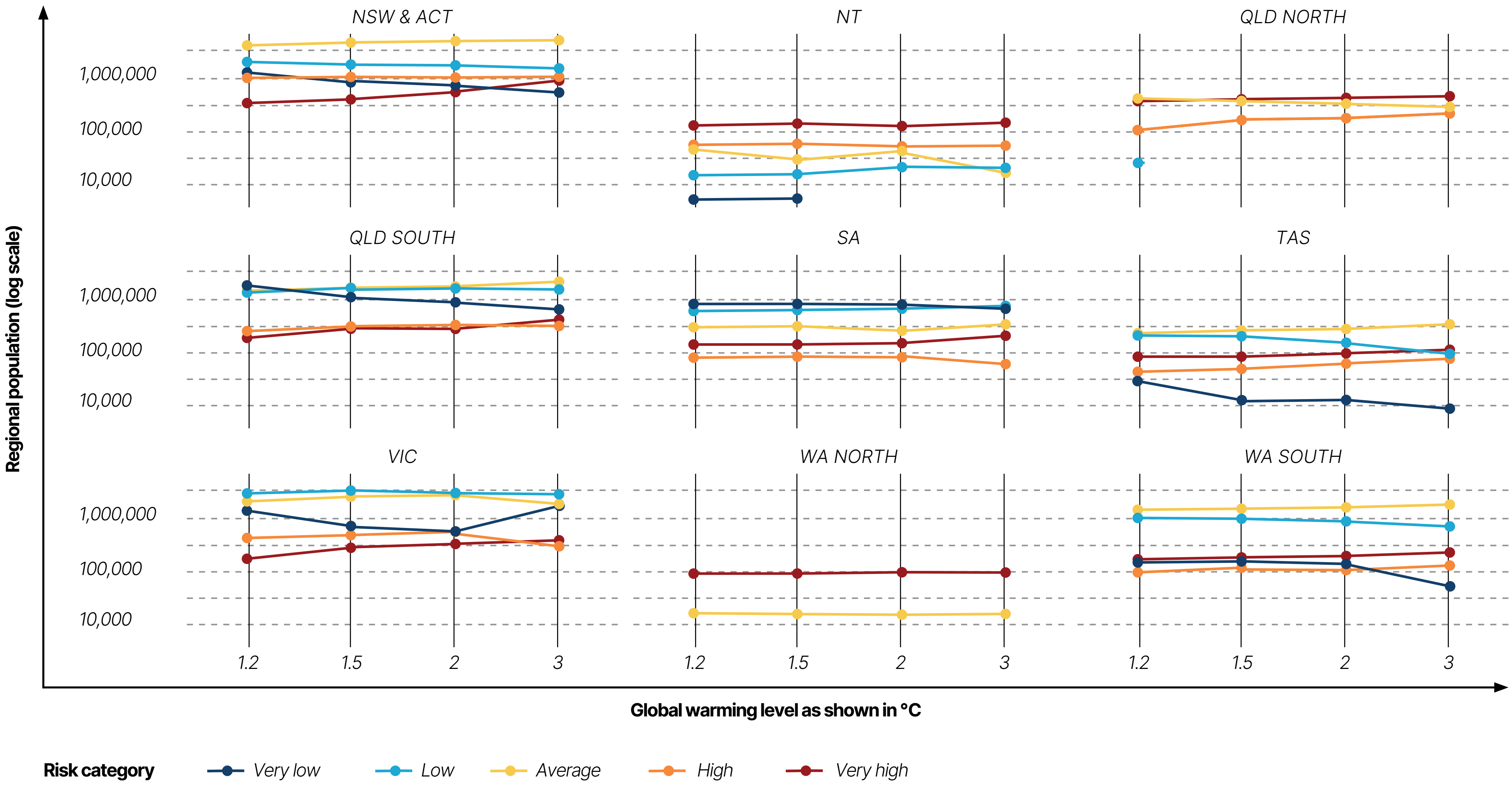


Figure 17: Population at risk due to climate hazards in different National Assessment regions under different global warming levels. *(Source: Communities Technical Report)*

Note: Models use locations and size of current populations.

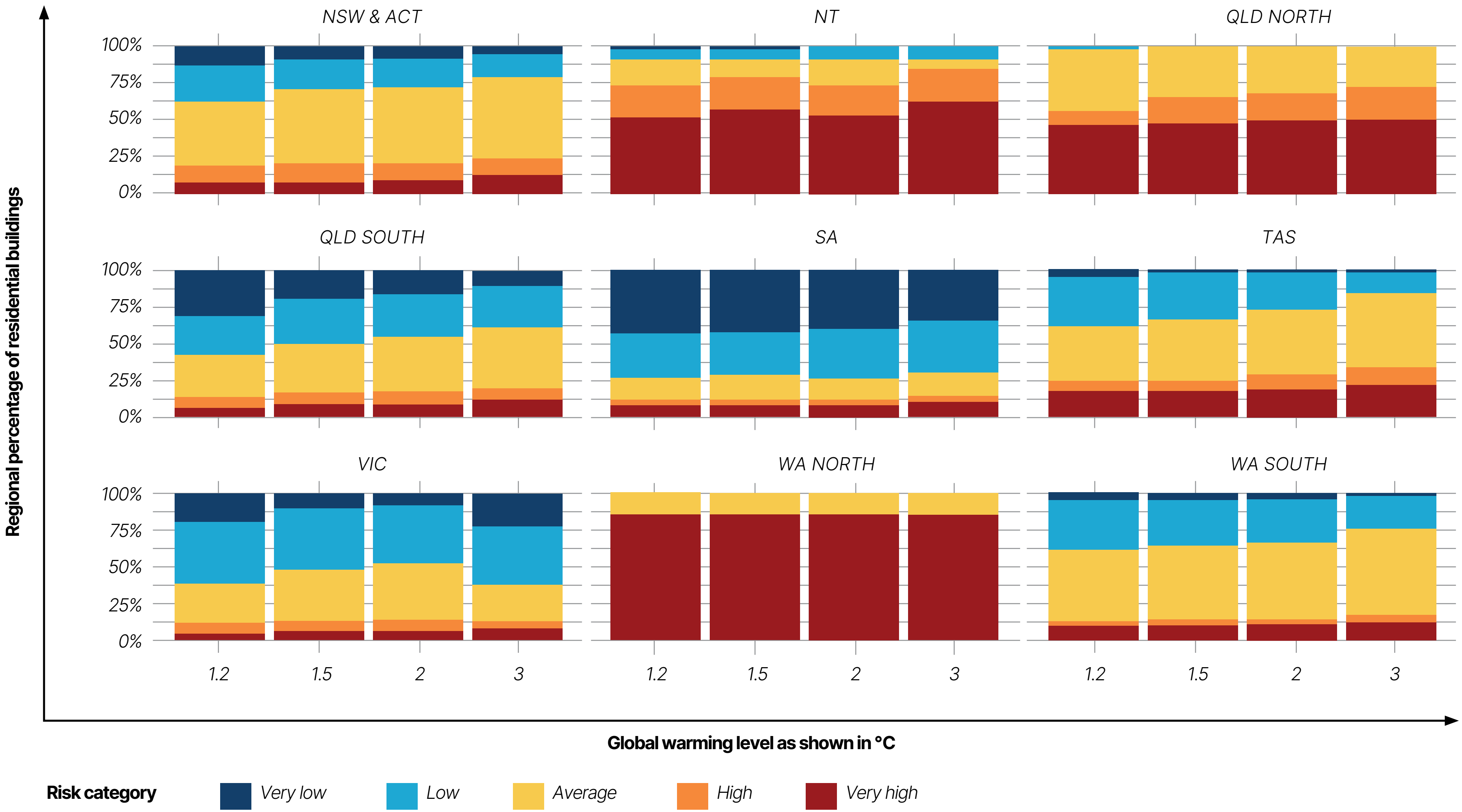


Figure 18a: Residential buildings by risk category per National Assessment region across different global warming levels. *(Source: Communities Technical Report)*

Note: Risk categories consider flood, bushfires, tropical cyclones and heatwaves. Models use locations and conditions of current buildings. The graphic excludes areas of no risk and shows the percentage of buildings in each region that are within a given risk category.

Coastal communities

Coastal communities in Australia will face increasing impacts from sea level rise and heightened coastal hazards, particularly in low-lying areas. All soft shore coastal environments are likely affected,either by erosion, storm surge or inundation *(medium confidence)*. **For the purposes of this report, coastal communities (Statistical Areas Level 2) are defined as buildings and population 10 km from the soft shoreline. A soft shoreline uses natural materials such as sand and vegetation to stabilise and protect the coast, maintaining natural coastal processes and providing ecological benefits.**

- Australian coastal communities face increased exposure to sea level rise due to their geographic location in low-lying areas, intensifying extreme weather events and accelerated erosion. Land subsidence exacerbates these impacts, while the loss of natural defences such as mangroves and reefs reduces protection against waves and erosion (Morris et al., 2019). Economic dependence on coastal transport networks, limited adaptation resources in smaller towns, and social vulnerabilities (including limited mobility for Aboriginal and Torres Strait Islander and low-income communities) further heighten risks.
  Evidence: Communities Technical Report
- Legacy planning has led to unplanned growth in high-risk areas, increasing community exposure (Department of Climate Change, 2009; Gurran et al., 2013). Housing and business occupancy levels can be affected as properties and infrastructures become more susceptible to damage from extreme weather events and sea level rise (Department of Climate Change, 2009).
  Evidence: Communities Technical Report
- Marked regional variations are observed in the current risk levels from sea level rise to residential dwellings across Australia's National Assessment regions. While most residential dwellings are in low-risk (Risk category low (blue); Figure 18b) areas, especially in Tasmania, South Australia and Western Australia south, risk to residential buildings has been identified as likely to rise significantly in Queensland (especially the north) and Victoria.
  Evidence: Communities Technical Report
- Queensland's north and south regions stand out for their high percentages of small businesses located in very high-risk areas. For sea level rise in 2030, 28% of current small businesses in Queensland north will be in average-risk areas, 10% in high-risk areas and 6% in very high-risk areas. In Queensland south, 7% of current small businesses will be in high-risk locations and 6% in very high-risk areas. Small businesses in these regions could face notable impacts (including business interruption), and potentially compounding impacts of inundation, flooding and erosion could make small businesses unviable.
  Evidence: Communities Technical Report
- Out of 700 coastal communities in this study, the percentage at high and very high risk is projected to increase from 8% in 2030 to 18% by 2050. By 2090, this percentage may rise to 34%. If current population levels remain unchanged, the number of people living in high-risk or very high-risk areas would increase from 597,000 in 2030 to 1,528,000 in 2050 and 3,028,000 by 2090 *(medium confidence)*.
  Evidence: Communities Technical Report
- In future, the rising impacts of sea levels compounding with other coastal hazards such as coastal erosion, flooding and saltwater intrusion are likely to compromise aged care facilities, infrastructure and drinking water supplies. Threats to social support infrastructure as well as primary impacts on residences could necessitate strategic adaptation and relocation planning, particularly for high-growth regions like Queensland, South Australia and NSW.
  Evidence: Communities Technical Report
- Additionally, sea level rise compounds the impacts of declining groundwater tables, threatening freshwater supplies in coastal communities through saltwater intrusion. The extent and severity of the compounding risk from declining groundwater tables with sea level rise is identified as a knowledge gap. While reducing groundwater overuse can mitigate risk in some regions, other freshwater resources are at high risk of being lost for good or significantly diminished, as is occurring currently in the Eyre Peninsula in South Australia.
  Evidence: Australia's Future Climate and Hazards Report, Communities Technical Report, Water Security Technical Report.
- All regions will see an increasing number of communities at risk from sea level rise and compounding coastal hazards by 2070 and 2090. This trend is apparent even for low future temperature scenarios, as sea levels will continue to rise even if global warming stabilises. This has economic implications as demonstrated in an example from Victoria which estimates that physical and economic impacts of coastal sea level rise and storm surge across Victoria are $9.44 billion per year to 2040, $14.77 billion per year to 2070 and $23.66 billion per year to 2100 (Kompas et al., 2022).
  Evidence: Communities Technical Report, Real Economy Technical Report
- Sea level rise is increasing the risk of coastal flooding, erosion, tropical cyclone impacts and infrastructure damage, which can displace homes and disrupt livelihoods. Many insurance policies exclude coverage for 'actions of the sea', creating financial challenges for affected residents and businesses, particularly those with high-value properties (Insurance Council of Australia, 2021). Home insurance often inadequately addresses these risks, and while some insurers are starting to incorporate climate risk assessments when providing insurance, coverage remains limited and can vary widely.
  Evidence: Communities Technical Report
- Impacts of sea level rise and coastal inundation not only threaten the future state of property and infrastructure, but are also likely to challenge social cohesion and liveability across high-risk and

Figure 18b: Modelled exposure of residential buildings to sea level rise. *(Source: Communities Technical Report)*

Models measure future sea level rise extents and apply these to locations and condition of current buildings. This graphic excludes areas of no risk and shows the percentage of buildings in each region that are within a given risk category. For 2090, low and high global warming levels that may occur are also considered and illustrated on the graphs.

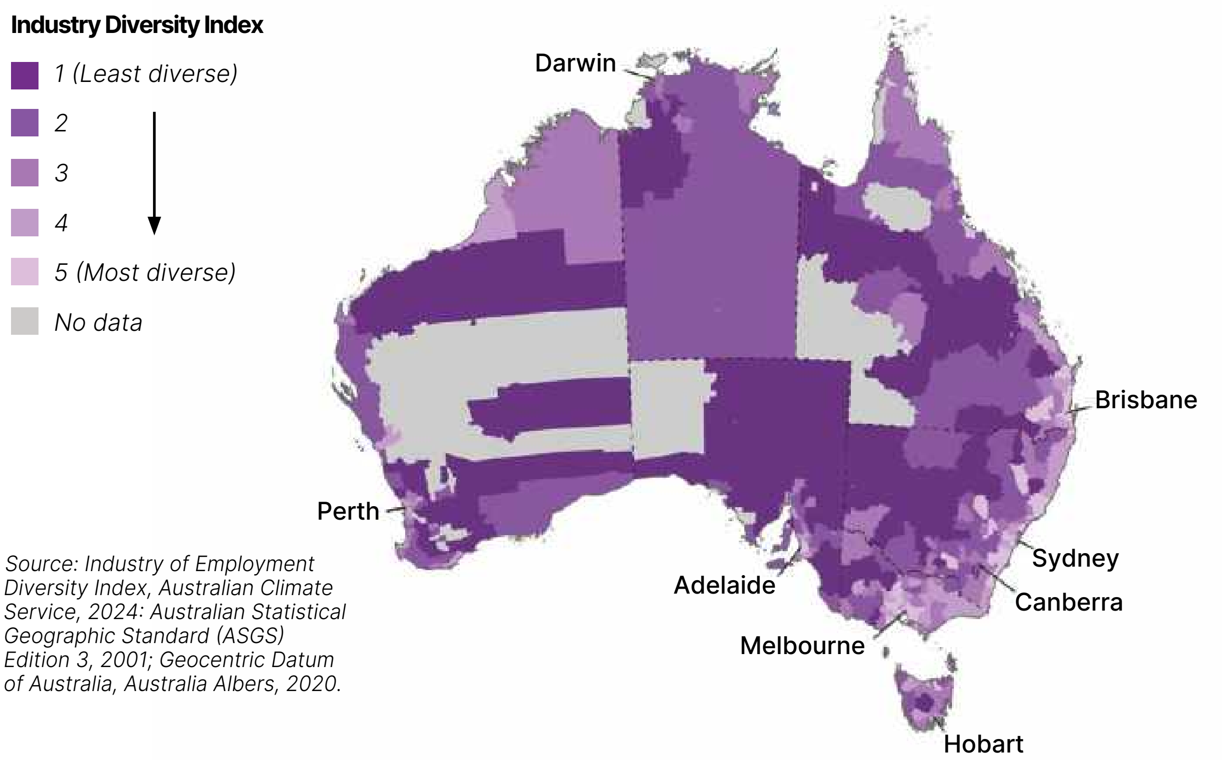
very high-risk areas. Severe landscape changes and permanent inundation of low-lying areas may lead to relocation of high-risk communities (e.g. Graham et al., 2013). Retreat and relocation is highly likely to disrupt local economies, social networks, traditional identities and cultural heritage and would require complex planning and resource allocation (Abel et al., 2011; Department of Climate Change, 2009; Zander et al., 2013).
Evidence: Communities Technical Report, Governance Technical Report

- Non-market economic value lost from sea level rise in the Kimberley's coastal ecosystem and wetlands was assessed to be $4.3 billion by 2050 and $15.8 billion by 2100 (high global warming scenario) (Kompas et al., 2024).

Regional communities

Regional communities with heavy reliance on single industries and on ecosystem services are highly exposed to climate change (Figure 19). Communities across northern Australia also face dangerous increases in extreme heat. Risks in regional and remote communities are exacerbated by increased socioeconomic risk factors (e.g. low income and high poverty rates), with potentially severe impacts on Aboriginal and Torres Strait Islander and older populations *(medium confidence).*

- The Australian Climate Social Vulnerability Index (beta) considers socioeconomic factors that increase community vulnerability to climate change. It includes information on the median weekly household rent, household income, proximity to hospitals, percentage of employees in service industries, education completion rates and labour force participation (Australian Climate Service, 2025b).
- Higher vulnerability profiles include low-income households, Aboriginal and Torres Strait Islander communities, and households in rural areas. These groups are highly likely to be disproportionately affected by climate impacts such as bushfires, heatwaves and flooding. Additionally, residents in rural and remote regions face higher poverty rates compared to those in metropolitan areas (National Rural Health Alliance, 2017).
Evidence: Communities Technical Report
- Around 34% of older Australians reside in rural and remote areas (Australian Institute of Health and Welfare, 2024c). Older people (65 and over) are more vulnerable to extreme heat and other climate-related stresses. Impacts from extreme events make these groups a high concern in relation to managing response and recovery operations.
Evidence: Communities Technical Report, National Disasters and Emergency Management Technical Report



Source: Industry of Employment Diversity Index, Australian Climate Service, 2024: Australian Statistical Geographic Standard (ASGS) Edition 3, 2001; Geocentric Datum of Australia, Australia Albers, 2020.

Figure 19: The Industry of Employment Diversity Index (IEDI) (beta) (Australian Climate Service, 2025a) measures the diversity of industries in which people are employed as an estimate of economic diversification. Low levels of diversity in industry employment are considered to make an area more vulnerable to the effects of climate change and natural hazards. Index scores indicate how similar the employment composition of industries in an LGA is to the well-diversified national composition. IEDI (beta) is derived from 2021 Census of Population and Housing employment data, conducted by the ABS.

- Climate change, particularly increases in extreme heat, extreme events and increased rainfall variability, is likely to decrease total agricultural production. It will also create change and disruption to primary industries, which are key sources of livelihood in regional and remote areas. In rural communities, hazards impacting key sectors, such as businesses reliant on natural resources, are reducing employment opportunities for residents and affecting mental health (Hanigan & Chaston, 2022; Steffen et al., 2019). An estimated 6,000 jobs were lost at the height of the Millennium Drought and approximately 7,000 jobs were lost due to the Black Summer bushfires of 2019–20 (Bowman et al., 2020).
Evidence: Real Economy Technical Report, Primary Industries Technical Report
- Drought is a critical risk to some towns' water supplies, disproportionately impacting vulnerable people with high exposure and vulnerability in regional and remote communities. While larger cities are moving towards climate-independent water sources, the 2017–19 drought highlighted the real risk of larger regional towns such as Tamworth running out of water with no realistic emergency water source. Increased demand during heatwaves, bushfires and flood-related water-quality issues will further strain water security. Compounding this, ageing water infrastructure will also face more frequent and severe climate hazards, resulting in increased shifting and cracking of sewer pipes as soils dry. Long-term landscape drying will further compound these challenges, particularly in regional economies reliant on water-dependent agriculture. Communities lacking alternative water supplies or reliant on annual surface inflows are most vulnerable to future climate water security risks.
Evidence: Communities Technical Report, Water Security Technical Report
- Small businesses in rural and regional communities are likely to be at risk, particularly in high-risk areas of the Northern Territory, Western Australia and Queensland north (Figure 20). It is estimated that by 2030, areas of greater than average risk will increase nationally from 16.3% to 17.9%; this is an additional 40,000 businesses.
Evidence: Communities Technical Report
- Extreme weather events pose significant operational challenges, including damage to property, loss of income during extreme events and increased insurance costs. In NSW, small businesses in very high-risk locations are projected to increase from 87,000 (10%) at +1.5°C of global warming to 138,000 (16%) at +3.0°C of global warming, reflecting a trend of heightened exposure and potential negative impacts.
Evidence: Communities Technical Report, Real Economy Technical Report
- The disparity in risk and impacts between communities, particularly rural and remote communities compared with capital cities, can deepen social divisions and increase tensions among different social groups. The short-term displacement and long-term relocation of populations due to climate-related disasters further challenges community networks and the ability of local governments to maintain social cohesion. Relocation is especially consequential and difficult for those with strong cultural ties to place, particularly for Aboriginal and Torres Strait Islander communities.
Evidence: Governance Technical Report

Urban communities

Major urban centres and cities across coastal areas emerge as primary hotspots for risks from sea level rise. Exposure is increased in coastal areas that have high population density, residential buildings in close proximity to soft shorelines, and erosion due to higher sea levels and shoreline characteristics. The relatively high values of assets at risk increase the impacts if risks are realised *(high confidence).*

- Urban areas with increasing exposure to sea level rise include Darlinghurst, Haymarket, Millers Point, Kogarah, Double Bay and Darling Point in Sydney; South Melbourne; and in the east, west and north of Melbourne's central business district. Expanding coastal urban suburbs and waterfront developments will increase future impacts from sea level rise, storm surges and extreme weather events.
Evidence: Communities Technical Report
- The high concentration of population and infrastructure in coastal cities places critical assets at risk from flooding and storm surges. Economic dependence on coastal transport networks, limited adaptation resources in smaller towns, and existing social vulnerabilities, including limited mobility for Aboriginal and Torres Strait Islander and low-income communities, heighten risks for these communities.
Evidence: Communities Technical Report
- Additionally, sea level rise threatens freshwater supplies in cities through saltwater intrusion, which is likely to require comprehensive and innovative adaptation strategies to safeguard water security in these communities. Saltwater intrusion threatens water availability from coastal aquifers and ecosystems in all regions. Sea level rise along the Victorian coastline is projected to be around 13 cm by 2030 and up to 42 cm by 2070 (CSIRO & Bureau of Meteorology, 2015). This will lead to changes in unconfined aquifers, which will impact groundwater used for multiple purposes including domestic, commercial and industrial uses.
Evidence: Water Security Technical Report

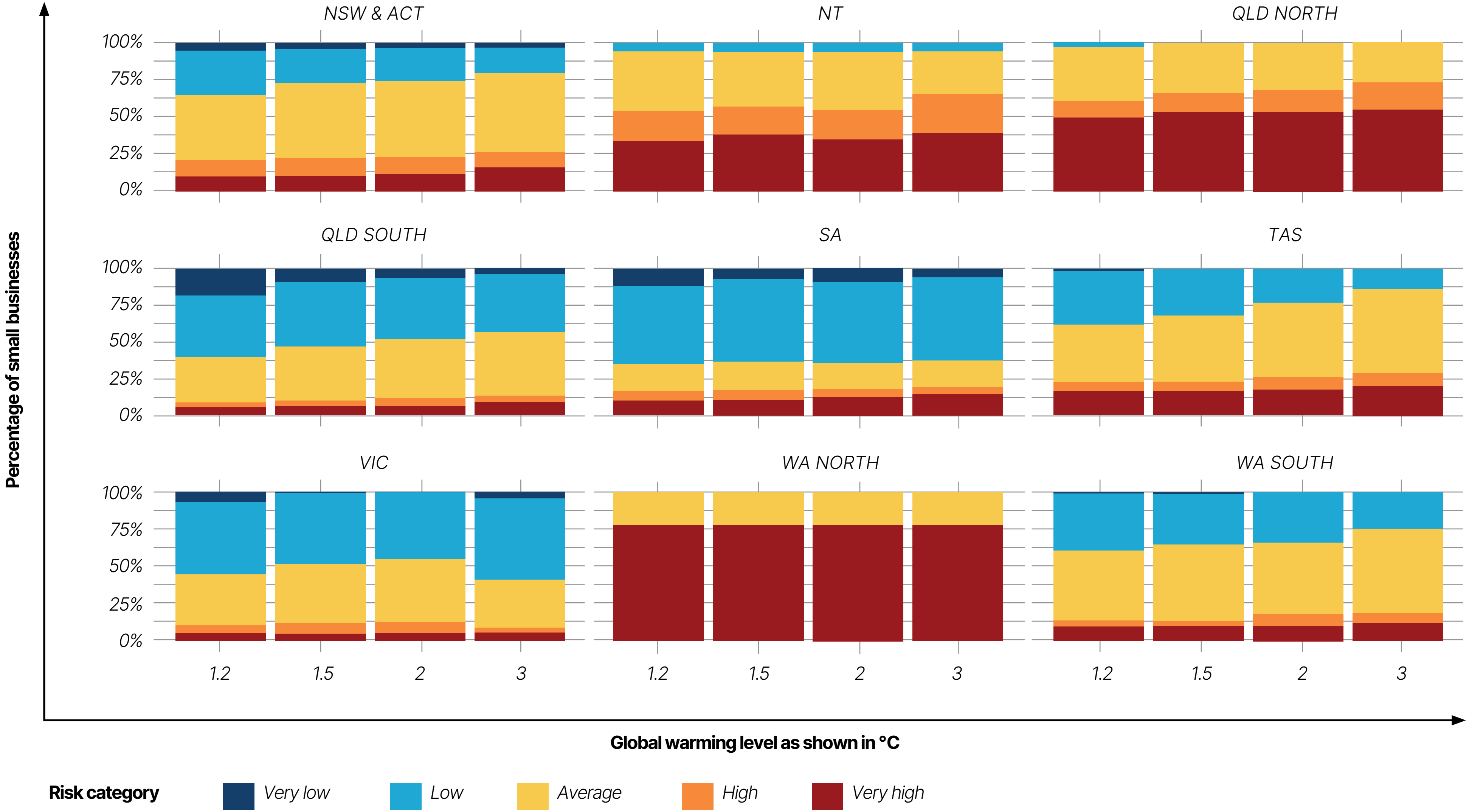


Figure 20: Percentage of small businesses in at-risk locations per National Assessment region across different global warming levels. *(Source: Communities Technical Report)*

Note: Risk categories consider flood, bushfires, tropical cyclones and heatwaves. Models use locations and conditions of current businesses. The graphic excludes areas of no risk and shows the percentage of businesses in each region that are within a given risk category.

- Existing critical infrastructure in cities (including ports, airports, power stations and transport networks) are expected to be increasingly exposed to sea level rise, storm surges and coastal inundation. The exposure of major Australian ports to coastal inundation is especially pronounced in Queensland, where several LGAs, including Mackay Regional and Gladstone Regional, rank in the top 10% for potential social costs of critical infrastructure disruption.
  Evidence: Critical Infrastructure Technical Report
- The incidence of climate-related health conditions, such as heat stress and vector-borne diseases, is almost certain to increase, putting additional pressure on health services in all communities. The heightened risk to health and wellbeing could lead to greater social inequalities, with lower socioeconomic areas experiencing more severe impacts (Australian Climate Service, 2024). There is considerable variation in heat-health risk across Australia, but there is also a high contrast in areas in close proximity (e.g. risk hotspots and cool-spots in close proximity), particularly in the peri-urban fringes of capital cities and in regional towns.
  Evidence: Health and Wellbeing Technical Report, Air Quality and Communicable Disease Technical Report

Remote communities

Remote communities, including a significant number of Aboriginal and Torres Strait Islander communities, are particularly at risk from all categories of extreme hazard events. Remote coastal communities such as in the Torres Strait Islands and coastal northern Queensland are also threatened by sea level rise, putting at risk not only homes and livelihoods, but connection to Country and the ability to practise culture *(high confidence).*

- Rural and remote communities in Australia are characterised by long-distance supply chains often serviced by a sparse transport network. Extreme weather events in recent years have shown that these transport routes can be impacted, leading to disrupted supply of important commodities to remote communities.
  Evidence: Supply Chains Technical Report, Communities Technical Report
- Smaller rural and regional communities are particularly vulnerable because they often have limited access to services and rely heavily on infrastructure for their livelihoods. They may need external assistance to effectively protect against climate hazards. Additionally, these communities are highly dependent on natural ecosystems for essential services such as food, water and biodiversity.
  Evidence: Aboriginal and Torres Strait Islander Peoples Technical Report
- Risks from extreme events are compounded in northern Australia by projected increases in extreme heat, with greater extremes in fire weather. Without adaptation and innovation, extreme heat may make some areas unliveable, while floods, tropical cyclones and bushfires can result in large areas and communities being isolated for significant periods of time.
  Evidence: Australia's Future Climate and Hazards Report
- Extreme weather events such as heatwaves, bushfires and flooding are highly likely to disrupt transport, energy and telecommunications supply to remote communities by damaging critical infrastructure. This can interrupt supply chains and increase maintenance costs. For example, heat can warp rail tracks, and heavy rainfall can lead to road washouts (Department of Infrastructure, Transport, Regional Development, Communications and the Arts, 2023).
- Aboriginal and Torres Strait Islander consultations as part of the National Assessment highlighted that these extreme weather events can exacerbate the disproportionate risks for communities associated with already unsatisfactory infrastructure. One such risk is the loss of opportunity for education, which is likely to occur if school buildings are unable to withstand all hazards. Another risk identified was the lack of access to Country, potentially reducing the opportunity to teach Lore, care for Country and practise ceremonies.
  Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering
- Over the last 3 decades, sea level rise in the Torres Strait has been higher than Australian and global averages, likely exacerbated by land subsidence. The sea level rise trend for 1993–2022 is 0.61 cm per year compared with an Australian average of 0.37 cm per year (Hague et al., 2022). Rates of sea level rise are increasing, indicating acceleration (Wang et al., 2021). Coastal flood frequencies in the Torres Strait will keep increasing as sea level rise continues (Hague & Talke, 2024). Instead of occurring approximately 10 days per year, occurrences of flooding are likely to double by 2050.
  Evidence: Australia's Future Climate and Hazards Report
- Aboriginal and Torres Strait Islander consultations highlighted that remote and regional communities, particularly those without adequate telecommunications infrastructure or access to information in traditional languages, face increased risks. Their inability to receive timely disaster warnings, climate risk alerts, and essential information about emergency responses and health services has the potential to leave Aboriginal and Torres Strait Islander communities vulnerable to greater harm during emergencies. This communication limitation heightens exposure to disasters and disrupts Aboriginal and Torres Strait Islander peoples' and communities' ability to access vital support and resources.
  Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering

- The values and perspectives of Aboriginal and Torres Strait Island peoples, including the importance of connection to Country, are at risk when there may be a perceived need to relocate people and communities in response to disrupted supply or other irreversible sociocultural impacts. Relocation is highly likely to disrupt local economies, social networks, traditional identities and cultural heritage (see Department of Climate Change, 2009; Zander et al., 2013). Retreat and relocation efforts would potentially involve complex planning and resource allocation, raising concerns about equity and access for vulnerable populations (Abel et al., 2011).
  Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering, Communities Technical Report, Governance Technical Report
- Aboriginal and Torres Strait Islander women play a pivotal role in their communities' wellbeing, cohesion and cultural preservation. Increasing climate extremes and severe natural hazard events impact these women, creating flow-on risks that may challenge their ability to fulfil these crucial roles. In addition, the burden on women of unpaid care work is exacerbated during disasters as they often take on the responsibility of supporting the health of their Country, family and community. The risk of family violence increases during such times, further compounding the challenges faced by women in these communities.
  Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering
- Water security is also a risk consideration in coastal communities. Estuarine environments are places of high natural environmental value (e.g. mangroves, salt marshes, fish nurseries) and also tend to be reliable water sources, so communities and agriculture have developed around them. Sea level rise, saline intrusion and loss of freshwater through flow in groundwater could result in water sources no longer being viable. This risk is particularly evident for southern Western Australia and NSW coastal regions. It is also a very significant risk for remote Aboriginal communities in the Northern Territory.
  Evidence: Water Security Technical Report

Critical and essential services

Critical and essential services, including health, aged care, water supply, energy and transportation, face immediate risks from climate change. The reliability and efficiency of infrastructure and services is threatened by rising temperatures, extreme weather events and shifting precipitation patterns *(medium confidence).*

- Climate hazards, including rising temperatures, increased frequency and severity of extreme weather events, and shifting precipitation patterns, present risks to the reliability and efficiency of access to infrastructure and services for communities. The exposure of hospitals, aged care homes and other health facilities increases the risk to groups that are already in vulnerable circumstances (e.g. aged people, children, people with disabilities and other disadvantaged groups). For example, the Northern Territory and Western Australia north have a high proportion of aged care services in high-risk locations, increasing vulnerability in this region.
  Evidence: Communities Technical Report
- Electricity infrastructure is vulnerable to extreme heat, with the most exposed networks in the far north and northwest of Australia. Exposure is expected to increase for all regions around the middle of the century. This poses challenging operational risks because the likelihood of all networks being affected simultaneously increases. Shortages in equipment, skilled workers and supplies may make preventative action more difficult, leaving some communities more exposed to potential outages during extreme heat.
  Evidence: Australia's Future Climate and Hazards Report, National Assessment Phase 0 Electricity and Heat Case Study Report
- Disruptions to critical services will likely lead to significant economic losses. The increased frequency of service disruptions and infrastructure damage can affect community wellbeing, leading to decreased quality of life and increased health risks (Australian Climate Service, 2024). Ageing infrastructure and repeated exposure to extreme events will increase vulnerability to climate-induced stresses (Department of Home Affairs & Cyber and Infrastructure Security Centre, 2023).
  Evidence: Communities Technical Report
- Extreme weather events such as floods and heatwaves cause interruptions to the supply chains. For example, heat can warp rail tracks and heavy rainfall can lead to road washouts (Infrastructure Australia, 2021). Sea level rise will exacerbate flooding risks for coastal roads and rail and may disrupt access to ports, while increased temperatures will further stress roads and railways, leading to more frequent and severe damage (Department of Infrastructure, Transport, Regional Development, Communications and the Arts, 2023). These disruptions increase the vulnerability of regional and remote communities that rely on long supply chains.
  Evidence: Communities Technical Report, Supply Chains Technical Report

Finance and the real economy

Climate change is expected to drive escalating economic costs across all communities. Sea level rise will intensify coastal flooding and erosion, exacerbate flood and tropical cyclone impacts, and increase the severity and frequency of extreme events. These changes will notably increase insurance costs, leading to more underinsured or uninsured properties.

Business interruptions caused by extreme events will raise costs for local economies and may have broader impacts on the national economy when disruptions are widespread or prolonged.

The cascading consequences of climate-driven impacts pose a significant threat to the financial system, yet the risk and transmission pathways remain poorly understood *(high confidence).*

- Future costs and economic implications of sea level rise in Australia are projected to be substantial, with estimates indicating potential damages reaching billions annually by 2100. Key regions, particularly coastal areas, may face significant economic losses, with reductions in gross state/territory product and widespread impacts on residential and commercial properties. Kompas et al. (2022) projected that the physical and economic impacts of coastal sea level rise and storm surge in Victoria could reach $9.44 billion annually by 2040, $14.77 billion by 2070 and $23.66 billion by 2100. These figures translate to reductions of 1.73%, 2.06% and 2.68% of gross state product for those respective years. A limitation of the accounting is its failure to account for impacts on heritage properties and cultural values, which means this is likely to underestimate the actual costs.
Evidence: Real Economy Technical Report
- As climate impacts worsen, insurance affordability in high-risk regions is very likely to become a growing concern. Households in these regions are likely to face further increases in insurance premiums in the future, decreasing affordability of full insurance and leading to properties at risk of being underinsured (Australian Competition and Consumer Commission, 2020; Vij et al., 2022). In 2024, modelling indicates that 15% of households could be offered insurance premiums worth more than 4 weeks of gross household income, up from 12% in 2023 (Paddam et al., 2024).
Evidence: Communities Technical Report
- Decreases in affordability or accessibility of insurance are very likely to increase this number, particularly for people who are already the most at risk from climate-related disasters. One quarter of those impacted by the 2019 Townsville floods did not have insurance (Australian Competition and Consumer Commission, 2020).
Evidence: Communities Technical Report
- Following extreme weather events, individuals and businesses may struggle to recover from damages without sufficient support, especially as repeated events are likely to result in increased costs for construction and repair. Insurance providers may also become more selective about offering coverage in high-risk areas, leading to limited availability of insurance options for property owners (Higgins et al., 2024). In some cases, insurers may choose to withdraw coverage altogether for properties deemed too high risk to insure, leaving property owners vulnerable to financial losses in the event of a disaster (Prinsley, 2024).
Evidence: Communities Technical Report
- Increasingly, financial institutions need to consider coastal erosion as a potential credit risk, especially for high-value properties in coastal areas. Businesses face challenges because commercial property insurance generally excludes actions of the sea. Across all regions, commercial buildings are present in high-risk locations, with some regional differences in the number of commercial buildings consistently exposed to severe climate threats. For example, in the Northern Territory, 43% of commercial structures are in very high-risk areas, compared to 9% nationally. Queensland north also faces substantial risks, with 47% of commercial buildings in high-risk areas. NSW has 5% of buildings in very high-risk areas in the current climate; however, this percentage increases with higher temperature scenarios (Figure 21). Climate impacts include disruptions in business operations, potential economic losses and reduced property values.
Evidence: Communities Technical Report
- Finance stakeholders identified the propagation of climate-driven risks as a very high risk to the finance system. Shocks to business revenues such as through direct loss or reduced value of assets or damage to key economic infrastructure (e.g. electricity, water, transport) transmit into the financial system via declines in cashflows and breaches of loan covenants, or forced sales of assets. These relationships are not well understood or widely evaluated.
Evidence: Real Economy Technical Report

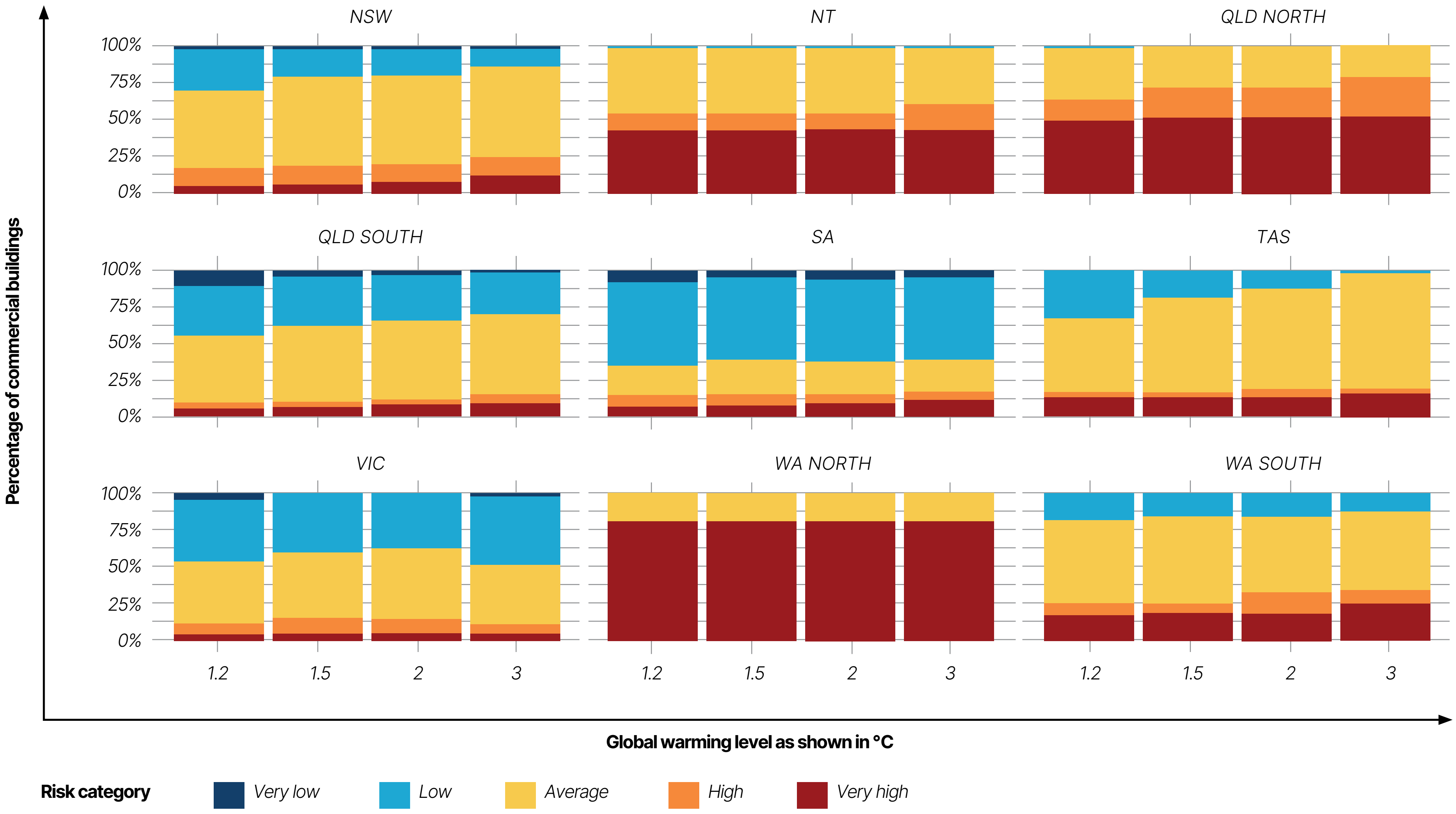


Figure 21: Commercial buildings by risk category per National Assessment region across different global warming levels. *(Source: Communities Technical Report)*

Note: Risk categories consider flood, bushfires, tropical cyclones and heatwaves. Models use locations and conditions of current buildings. The graphic excludes areas of no risk and shows the percentage of commercial buildings in each region.

Adaptation observations and considerations

This section provides information that can support adaptation planning and approaches.

Risk-based planning for physical infrastructure is likely to be effective in reducing community risk, particularly for coastal communities. Examples include building and engineering codes, land-use regulations, and environmental protection laws that reflect future climate risks *(high confidence).*

- Land-use planning that incorporates projections for rising sea levels, extreme weather events and coastal hazards to prevent development in high-risk areas, as well as to ensure infrastructure resilience, will reduce risk. A comprehensive approach to enhancing community resilience could prioritise the preservation and restoration of natural buffers like mangroves and wetlands, which provide essential protection against coastal hazards as well as improved carbon sequestration and habitat for wildlife. Additionally, flexible planning frameworks that allow for adaptive management will enable communities to adjust proactively to changing climate conditions and emerging risks.
  Evidence: Communities Technical Report, Insights from the Adaptation Stocktake, Natural Ecosystems Technical Report
- Current adaptation examples for coastal communities target a diverse range of strategies, including public infrastructure builds such as flood levees as well as household-level resilience upgrades such as home-raising (NHRA, 2023). They also involve risk assessment and strategy development, such as risk-based vulnerability zoning for land-use planning. Coastal risk and adaptation options assessments, and modified building codes and standards appropriate to changing climatic conditions, are likely to be vital to adaptation strategies in exposed coastal communities. Key to the success of this is coordination such as to align coastal management planning across councils. Finally, knowledge building is crucial. This involves projects to inform communities of coastal risks.
  Evidence: Insights from the Adaptation Stocktake
- Sea level rise is highly likely to result in the retreat of some communities (Barnett et al., 2013; Sipe & Vella, 2014; Suncorp Group & Natural Hazards Research Australia, 2023). Advanced, long-term planning is required as abrupt retreat has had negative implications for community health and wellbeing, and increased the costs of disaster response and recovery and of development. However, the Grantham case study in this chapter provides an example of successful managed retreat post-disaster. There are a range of voluntary buyback schemes in place for houses in flood-prone areas (Dyer & Golnaraghi, 2020). For example, the NSW Government provides funding to local councils seeking to reduce residential exposure in floodplain areas (NSW DCCEEW, 2024), but proactive assisted relocation is also an important strategy to reduce risk in hazard-prone areas (NHRA, 2023).
  Evidence: Communities Technical Report
- Long-term planning will need to account for the future risks and costs of maintaining and upgrading infrastructure in high-risk locations. These include urban locations where the value of developments in high-risk areas significantly increases exposure and the cost of long-term risk may not be reflected in current valuation (Fuerst & Warren-Myers, 2021; NHRA, 2023). Risk-based land-use planning, building codes, infrastructure standards and regulation have the potential to reduce future exposure in high-risk locations and coastal areas (Norman et al., 2021).
  Evidence: Communities Technical Report

Coordinated action is important in this system as decisions and impacts from all systems will compound for communities. Current adaptation actions, programs and projects targeting regional and remote communities are often characterised by coordination across and between different levels of government.

- There are significant regional differences in how the exposure of communities to extreme and compound hazards will change in a changing climate. Regions where risk is projected to increase significantly, such as the Northern Territory and Queensland north, are highly likely to require targeted support and resources for adaptation and risk-reduction strategies.
  Evidence: Communities Technical Report
- Regional climate partnerships between remote LGAs can improve knowledge sharing and management of risks to communities. Adaptation actions identified in the *Australian Adaptation Stocktake* that focus on regional and remote communities involve institutionalisation (e.g. funding schemes for regional drought and disaster resilience) and knowledge building (e.g. projects that are mostly focused on understanding the impacts of disasters on regional and remote communities). A number of the adaptation actions also focus on drought as a key hazard. Projects include drought resilience schemes for regional and remote businesses and drought resilience plans for specific LGAs.
  Evidence: Insights from the Adaptation Stocktake
- The geographic location of many remote communities means that critical infrastructure is highly likely to be compromised. Microgrids can increase the resilience of regional and remote communities, including Aboriginal and Torres Strait Islander communities (Wright, 2024) and promote post-disaster recovery (Mishra et al., 2020). Research into understanding the integrated role of supply chains and other networks, and key strategies for strengthening these, could similarly support improved community resilience (Denham & Fairbrother, 2021).
  Evidence: National Disasters and Emergency Management Technical Report, Communities Technical Report, Critical Infrastructure Technical Report

- There are more examples of adaptation focused on Aboriginal and Torres Strait Islander peoples in this system compared with other systems. These adaptation programs include land and sea ranger programs in Queensland and the Northern Territory which promote the protection of the natural environment and therefore the maintenance of ecosystem services, and microgrid programs to build energy resilience in remote Indigenous communities.
Evidence: Insights from the Adaptation Stocktake
- Stakeholder engagement as part of the National Assessment identified that the Communities – urban, regional and remote system is the only system where impacts affect all the other National Assessment systems, with the Primary industries and food system identified as the biggest receiver of impacts (Figure 22). This relationship illustrates the need for cross-system coordination of adaptation efforts. Stakeholders also identified the importance of decisions made in the Defence and national security system and the Infrastructure and built environment system as a driver of risk for communities, and that decisions made in the Economy, trade and finance system – for example, around availability and affordability of insurance – are also important.
Evidence: Governance Technical Report

Common risks across communities include water security and heat-health risk. Adaptation actions are already being taken to address these.

- Cities and large towns are developing lasting water supply solutions to avoid the unacceptable risk of water shortages. However, geographic barriers (e.g. lack of access to desalination plants and suitable aquifers for recharge) and community acceptance of solutions such as recycled water, along with economic and regulatory challenges, may hinder these efforts, potentially adding years or decades to implementation. This situation poses a national security risk, particularly in the event of large-scale shortages and evacuations.
Evidence: Communities Technical Report, Water Security Technical Report
- There are a range of policies and programs across levels of government, industries and community service organisations that aim to reduce heat-health risk (Mason et al., 2022). Examples include heatwave warning systems and interventions addressing public health risks across most jurisdictions, heat-health policies for both customers and employees in businesses (Varghese et al., 2021; Xiang et al., 2015), and adaptation measures to reduce exposure, including changes to building codes and neighbourhood greening.

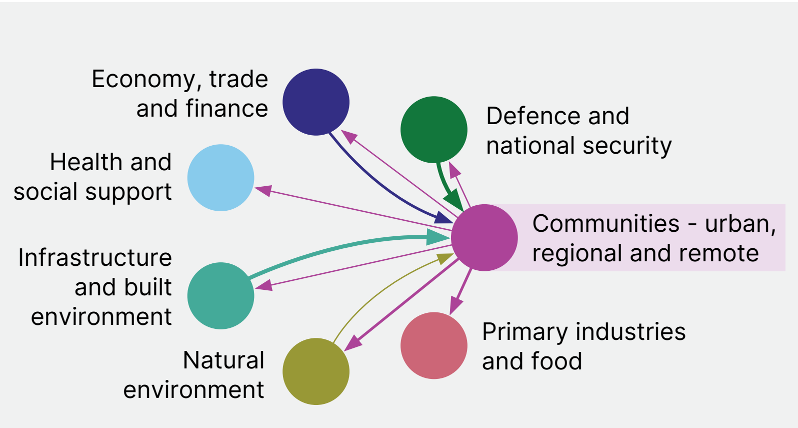


Figure 22: The flow of adverse impacts from decisions between the Communities - urban, regional and remote system and other National Assessment systems. *(Source: Governance Technical Report)* *Each arrow originates at the system where the decision is made and points towards the system that is adversely impacted. The weight of each arrow represents the number of interactions identified. This data reflects stakeholder engagement workshops. The Aboriginal and Torres Strait Islander Peoples system followed a different approach and is not represented in this data.*

- Many of the current responses to heat-health risk do not take into consideration how heatwaves are projected to change in the future or changing vulnerability profiles related to socioeconomic trends (Mavrogianni et al., 2022). There are opportunities to learn from current adaptation activities and further develop options and innovations to respond to these future extreme heat risks.

Existing disadvantage and socioeconomic vulnerabilities exacerbate risk from the changing climate. Addressing these contextual vulnerabilities will reduce climate risk in many communities *(high confidence).*

- The IPCC has identified that climate-resilient development is enabled when actors make inclusive development choices that prioritise risk reduction, equity and justice (IPCC, 2022b).
- Increasing insurance costs driven by climate change will have the greatest impacts on economically challenged households. Modelling analysis indicated that in 2024, 15% of households could be offered insurance premiums worth more than 4 weeks of gross household income, a 25% increase from 2023 (Paddam, et al., 2024), which increases the risk of underinsurance. Financial solutions that support disadvantaged households are likely to increase resilience and the capacity to invest in residential adaptive upgrades.
Evidence: Economy Trade and Finance Technical Report
- Aboriginal and Torres Strait Islander peoples disproportionately experience the effects of climate change, are more likely to live in housing that is not climate adapted and have a higher burden of poor health compared with national averages. Inclusion in decision-making in connection to caring for Country and the development of climate adaptation strategies, as well as supporting community programs to improve health, has been shown to reduce vulnerability to severe hazards and increase resilience.
Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering

- Communities with low economic diversity – in particular, those heavily reliant on climate-sensitive industries such as agriculture – are likely to be at higher risk under climate change. Increasing the diversity of economic opportunities is highly likely to increase the resilience of these communities to climate change.
  Evidence: Communities Technical Report
- There is high contrast in health risk from climate change between locations in close proximity due to local factors. For example, the risk profile from heatwaves can vary significantly depending on urban greening, access to transport, or concentrations of people with low socioeconomic status. The factors that make people vulnerable to tropical cyclones include age, demographics, housing location and status (Parry et al., 2019; Xu et al., 2019). There are also individual factors that may mean people have a diminished capacity to respond to conditions (Parry et al., 2019; Xu et al., 2019). The difference in risk by location can provide indications of adaptation strategies that are likely to be successful, while addressing the underlying sources of disadvantage will reduce all sources of risk from climate change.
  Evidence: Health and Wellbeing Technical Report
- People living with disability face disproportionate risks during emergencies and are among the most disadvantaged during disaster events (National Emergency Management Agency, 2023b); while culturally and linguistically diverse individuals, or individuals who have recently arrived in Australia, have increased vulnerability to severe hazards (Weyrich et al., 2018). Consideration of these disadvantages prior to extreme events will reduce risk to these communities from severe natural hazards.
  Evidence: Health and Wellbeing Technical Report

Case study: Compound estuarine flooding

The kanamaluka/Tamar Estuary is a 70 km-long tidal estuary in northern Tasmania, stretching from the Bass Strait to the confluence of the North and South Esk rivers where Launceston is located.

The tidal range varies from 2.3 m at Low Head (at Bass Strait) to 3.2 m at Seaport (near Launceston) (Palmer et al., 2019).

Launceston is protected from riverine flooding by a levee system (Figure 23) designed to protect against a flood event approximately equal to the magnitude of the 1929 Launceston flood event. A national flood risk assessment ranked Launceston third in the nation for annual averaged loss ratios for flooding for a defended Statistical Area Level 2 (Hewison et al., 2024).

Flood risk in Launceston results from a combination of fluvial flooding from the North and South Esk rivers, with elevated water levels due to the propagation of storm tides upstream along the Tamar River estuary. The joint probability of these 3 events occurring separately or simultaneously must be assessed to determine the flood risk. The Launceston flood risk will increase with climate change (Table 6). The estuary is vulnerable to rising sea levels, which can lead to increased flooding, erosion and potential saltwater intrusion. Climate change may alter precipitation patterns and bring more intense storm events, increase stormwater runoff, and elevate fluvial flooding from the North and South Esk rivers. The risk of increased stormwater runoff also introduces more pollutants, sediments and nutrients into the water, which can degrade water quality, impact biodiversity and affect ecosystems (Palmer et al., 2019). This assessment considers changes in rainfall frequency, sea level rise, and design event flood levels, combining all factors.

Low-lying areas along the estuary, particularly those with built infrastructure, are at greater risk with climate change. In 2050, a 1% Annual Exceedance Probability flood will cause flooding in central Launceston, with water levels generally less than 0.5 m. By 2090, more significant flooding will occur in central Launceston, with large areas submerged by more than 2 m of water. The analysis in this compound flood assessment identifies the need to raise the levee heights to make them more resilient to climate change.

Elements at risk by 2050 and 2100

The heights of extreme coastal water levels will increase approximately in line with increasing mean sea level (McInnes et al., 2013, 2015). This will have consequences for both the frequency and severity of coastal-driven floods. Nuisance floods will become more frequent, but also more severe floods will transition from being compound floods requiring riverine and coastal influences, to being coastal-only floods due to storm surges and tides alone with sufficient sea level rise (McInnes et al., 2013, 2015).

By 2050, an additional 0.14 m of sea level rise is expected *(virtually certain)*. More serious floods will continue to be driven by the compound effects of freshwater and coastal factors, and the role of storm surges will become less important (Hague & Taylor, 2021).

By 2100, at least 0.38 m of sea level rise is expected *(high confidence)*. Under a 0.6 m sea level rise, major floods such as in 2007 will occur several times per year due to coastal influences alone (Hague et al., 2023). Under this scenario, major flooding might be expected to occur more frequently than nuisance flooding does today (Hague et al., 2023).

Defining adaptation thresholds and triggers will be critical in managing the uncertainty of future sea level rise and increases in flood risk (Haasnoot et al., 2013; Stephens et al., 2018). Inundation of the Esplanade for more than 5 days per year was identified as a trigger for adaptation (Barnett et al., 2014). Based on the differences between high tide heights (Hague et al., 2024) and the level associated with inundation of the Esplanade (State Emergency Service, 2012), this trigger is expected to be reached with a 0.5 m sea level rise. However, it could be reached earlier due to year-to-year variability in, interactions between, and future changes in tides and storm surges (Hague & Talke, 2024), as well as future changes in stream flow (Ball et al., 2019).

Discussion

To assess flood risk in Launceston, a joint probability assessment of how river flood events interact with water levels in the estuary is essential, as this interaction can be complex. In the BMT Group Limited, 2019 report, it was assumed that peak flooding in the rivers coincided with high tide levels in Launceston. Geoscience Australia (Maqsood et al., 2016) evaluated how compound floods could change in Launceston under sea level rise. Unlike coastal water levels (e.g. Maqsood et al., 2016), a 0.8 m sea level rise does not lead to a direct 0.8 m increase in the heights of compound flood peaks. This effect is particularly noticeable in extreme flood events: the 50-year return period flood increases by 0.25 m under a 0.8 m sea level rise, while the 200-year return period flood only increases by 0.15 m under the same scenario. This phenomenon arises from the complex relationship between coastal and riverine flood drivers in estuaries (e.g. Khanam et al., 2021). It highlights a general reduction in the difference between tidal floods and compound flood hazards under sea level rise compared to current conditions (Kumbier et al., 2018).

Additionally, sea level in an estuary can be influenced by engineering works. Palmer et al. (2019) modelled the effects of sea level rise combined with sediment infill on high tide heights. They found that high tide levels at Launceston would closely follow increases in mean sea level, although this effect could be reduced by half if sediment filled the estuary to its current deepest point.

Figure 23: Launceston with levee system highlighted in cyan (adapted from Maqsood et al., 2016).

Basemap: Esri "Imagery hybrid". Sources: Esri, Maxar, Earthstar Geographics, TomTom, Garmin, FAO, NOAA, USGS, DESI, DPIPWE

For more information on this case study, see the Communities Technical Report.

Annual exceedance probability (AEP)	Peak flood level (m, Australian Height Datum)		
	Existing conditions	2050 conditions	2090 conditions
5%	3.1	3.5	4.1
2%	3.9	4.4	5.0
1%	4.6	5.1	5.5
1 in 200	5.2	5.6	6.1
1 in 500	6.1	6.5	6.9

Table 6: Comparison of existing peak flood levels at the North Esk River Confluence (Inversek).

At this location, the levee height is approximately 5.1 m Australian Height Datum (Adapted from BMT Group Limited, 2019)

Defence and national security system

Summary

The Defence and national security system refers to the structures and functions dedicated to safeguarding Australia. Australia's domestic disaster response is primarily the responsibility of state and territory governments.

The Australian Government provides support where state and territory capacities are overwhelmed, including through requests for deployment of the Australian Defence Force and other Australian Government capabilities for disaster response and recovery as required.

Priority risk

The National Assessment has undertaken quantitative and qualitative analysis for priority risks. The first pass assessment identified 8 nationally significant climate risks for this system. The analysis focuses on the Australian Government's role in this complex network, although state and territory governments have primary responsibility for responding to crises within their jurisdictions. One priority risk has been analysed as part of the second pass assessment:

- Risks to domestic disaster response and recovery assistance from the competing need to respond to multiple natural hazard events resulting in concurrency pressures and overwhelming the capacity of all levels of government to effectively respond and to do so while reducing reliance on the Australian Defence Force.

Defence and national security

Climate risks are determined by the interaction of risk elements, including hazards, exposures and vulnerabilities. This is a risk summary for the priority risk assessed for this system.

Climate and hazards

- Bushfires
- Compounding and cascading hazard events
- Extreme heat
- Flooding
- Tropical cyclones
- Sea level rise

Exposures

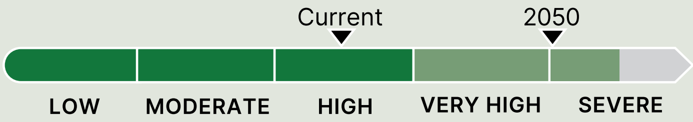
- Remote communities, and people already disproportionately at risk
- Buildings (residential and commercial)
- Critical and essential goods and services
- Critical infrastructure
- Economic drivers (small businesses, agriculture productivity)
- Hazard-prone and remote communities
- Indo-Pacific region

Vulnerabilities

- Declining volunteer workforce
- Community cohesion and resilience
- Rising costs of disaster response and recovery
- Expectation that the Australian Defence Force will respond to domestic disasters
- Legacy infrastructure, just-in-time supply chains, imported fuel

IMPACTS AND RISKS

- Straining of emergency management resources
- Compounding risks across all sectors
- Intensifying pressure on government resources
- Challenges to community cohesion and resilience
- Heightening of health risks from infections
- Physical and mental stress on responders and communities
- Increasing pressure on response organisations including Defence
- Potential for loss of trust in government
- Loss of connection to Country for Aboriginal and Torres Strait Islander peoples
- Slower response and recovery times
- Rising biosecurity threats
- Climate-induced regional changes from migration



Assessment of current risk

The current climate risk to the Defence and national security system is rated as *high (high confidence)*.

The increasing frequency, severity and complexity of extreme weather events is putting pressure on the system's capacity to respond effectively. Compounding and cascading events across sectors such as agriculture, transport, supply chains, human health, energy and water security amplify these challenges, stretching resources and funding.

Additionally, the physical and mental health of emergency management personnel and volunteers is being compromised as events coincide. Increased exposure to extreme heat and other harsh conditions is diminishing their ability to respond effectively. The Australian Defence Force is increasingly being called upon to support domestic disaster response, despite not being structured or appropriately equipped to act as a domestic disaster recovery agency alongside its core function. This is placing pressure on its personnel and capabilities.

Assessment of future risk

By 2050, the climate risk to the Defence and national security system is expected to rise to *very high–severe (medium confidence)*.

The anticipated increase in climate hazards will affect a greater number of communities, with an increase in simultaneous events in different regions.

Disaster response and recovery funding demands are projected to increase significantly, and economic costs of recovery will rise due to the need for more frequent rebuilding efforts. Increased investment in adaptation and resilience will create competing demands for resources across governments.

Safety and security, particularly in rural and regional areas, is likely to be significantly impacted. Disrupted supply chains and the displacement of communities will result in loss of social cohesion and will likely result in migration away from high risk communities, further eroding social capital. Loss of community structures and repeated disasters are likely to further impact volunteer capacity. The perception of inadequate or inequitable response may erode trust in government, which will then further compromise this system. The interconnectedness of climate impacts across various sectors, especially health impacts, will amplify challenges.

The increasing demands and harsher conditions for existing emergency management personnel and volunteers will intensify and may affect their physical and mental wellbeing, as well as the supply chains and resources on which they rely. The capacity to respond to extreme events is likely to be challenged by declining volunteer participation. Mental fatigue arising from more concurrent crises will also further reduce their ability to respond in a timely and effective way.

The expectation that the Australian Defence Force will continue to respond to domestic disasters, combined with an expected increase in regional instability, driven in part by rising sea levels and other climate impacts, will detract from Defence's primary objectives of defending Australia (Commonwealth of Australia, 2023).

Summary of exposures, vulnerabilities, impacts and risks

Compounding and cascading events

Climate change is exerting unprecedented pressure on Australia's structures and functions needed for disaster readiness and response, challenging its capacity to respond effectively to multiple concurrent events. The system faces significant risks due to the compounding impacts of climate change, which cascade across various sectors such as agriculture, transport, supply chains, human health, and energy and water security. This interconnectedness amplifies the challenges for Australia's national security and emergency management response, stretching the system's resources and funding to their limits. One of the most pressing issues is the increased frequency, severity and complexity of extreme weather events. These events are likely to require additional capacity and new approaches to response and recovery, as well as greater investment in risk reduction.

Communities at risk

Communities disproportionately at risk, including Australia's Aboriginal and Torres Strait Islander peoples, face heightened risks from disrupted critical infrastructure, climate-sensitive infections and communicable diseases. Biosecurity risks are also on the rise, further complicating the emergency management landscape. The unique cultural and social dynamics of Aboriginal and Torres Strait Islander peoples' communities require tailored responses that respect their traditions and knowledge systems, adding another layer of complexity to the national disaster response.

Emergency management resources

The additional pressure from increased extreme weather events is challenging the physical and mental health of emergency management personnel and volunteers, who are increasingly exposed to extreme heat and impacts from other hazards. This exposure not only affects their wellbeing but also slows their response and recovery efforts, adding psychological and physical stress that hampers their effectiveness. The system, which includes emergency management services and a dedicated workforce of volunteers, is facing significant risks due to these compounding impacts.

Defence

The growing reliance on the Australian Defence Force for disaster response could be detrimental to public trust if the force is perceived as being overstretched. The public may perceive reliance on the Australian Defence Force for disaster response as stretching them beyond their mission. Conversely, seeking to reduce reliance on the Australian Defence Force may raise concerns if alternatives are not readily available. A careful balance must be achieved. The concurrent risks associated with the geostrategic environment and acceleration of major climate events risks overwhelm the Australian Government's capacity to respond effectively and detract from Defence's primary objective of defending Australia (Commonwealth of Australia, 2023 - *Defence Strategic Review*).

Introduction

This chapter provides a synthesis of the analysis of risks to the Defence and national security system. It draws on a wide range of technical assessments to provide observations that can enable effective adaptation.

It includes:

- System overview
- Priority risk snapshot
- Key climate hazards for the system
- Exposures, vulnerabilities, impacts and risks relevant to the system
- Adaptation observations and considerations
- Case study

The chapter highlights one priority risk and draws on the analysis from across all the priority risk technical assessments. It is important to note for this first National Assessment that all 63 nationally significant risks have not been fully assessed. The chapter provides a useful national understanding of climate risks and information that can support adaptation. Climate risks are not static – this work is a sound foundation that should be built on over time.

System overview

This system refers to the structures and functions dedicated to safeguarding Australia's domestic stability and international interests, including disaster response and recovery.

The priority risk that anchors the analysis is focused on Australia's domestic disaster response; however, a focus on preparedness and community resilience as the climate changes will be important in reducing pressure on disaster response. The National Disaster Risk Reduction Framework is currently the nationally agreed policy in Australia for implementing the United Nations, *Sendai Framework for Disaster Risk Reduction*.

Severe or extreme natural hazard events, such as a flood or bushfire, are not in themselves 'disasters'. Disasters happen when a natural hazard event (or other crisis) results in serious disruption of the functioning of a community or society, leading to human, material, economic and environmental losses and impacts. Thus, a 'disaster' is the consequence of a hazard event interacting with exposure, vulnerability and capacity to cope (United Nations Office for Disaster Risk Reduction, 2025).

Disaster response is primarily the responsibility of state and territory governments within their jurisdictions, relying on emergency management services, a dedicated workforce of volunteers, as well as private and non-governmental organisations in the communities affected. The Australian Government provides support where state and territory governments' capacities are overwhelmed, including through requests for deployment of the Australian Defence Force and other Australian Government capabilities for disaster response and recovery as required.

The purpose of disaster response and recovery efforts is to ensure that individuals and communities are safe and able to recover from disasters. The reliability and security of essential services and infrastructure, such as water, energy, healthcare and transportation, are crucial for maintaining societal functioning during emergencies. Timely and effective management of disasters is important to maintain social cohesion and resilience. Strong social bonds, community networks and local governance structures enable Australians to support each other during crises and to recover effectively. Ineffective or delayed response and protracted displacement as a result of disasters may result in loss of social cohesion and distrust in government.

Climate change is very likely to increase the frequency of concurrent and compound events, such as simultaneous heatwaves, floods or national health emergencies, putting strain on emergency management and recovery operations. The increasing intensity of extreme weather events is placing concurrency pressures on the Australian Defence Force to respond to disasters and achieve its core mission.

Priority risk snapshot: Concurrency pressures in emergency response and recovery

Risks to domestic disaster response and recovery assistance from the competing need to respond to multiple natural hazard events resulting in concurrency pressures and overwhelming the capacity of all levels of government to effectively respond and to do so while reducing reliance on the Australian Defence Force.

This priority risk snapshot focuses on the Australian Government's role in disaster response. The primary roles of state, territory, and local governments, the contribution of other actors and the broader risk context are included in the system analysis. While there is significant overlap between the priority risk and the system analysis, this snapshot is included for completeness.

Rationale

The risk of concurrency pressures in emergency response and recovery is currently rated as **Moderate**, is expected to increase to **High** by 2050, and to become **Very High–Severe** by 2090 (Figure 24). The escalating frequency and severity of disasters, combined with limited resources and concurrent pressures, pose significant challenges. The growing reliance on the Australian Defence Force for disaster response could be detrimental to public trust if the force is perceived as being overstretched. The public may perceive reliance on the Australian Defence Force for disaster response as stretching it beyond its mission. Conversely, seeking to reduce reliance on Defence may raise concerns if alternatives are not readily available. A careful balance must be achieved.

Increasing heat impacts will strain response capabilities and resources. Incremental adaptations are needed and can be implemented and distributed across different sectors and levels of society. Transformational adaptation is also required to reduce dependency on volunteer services, to develop new financial mechanisms and insurance, and to enhance resilience and response effectiveness. Innovation in emergency management is likely to be needed over time to effectively manage the scale of the expected impacts.

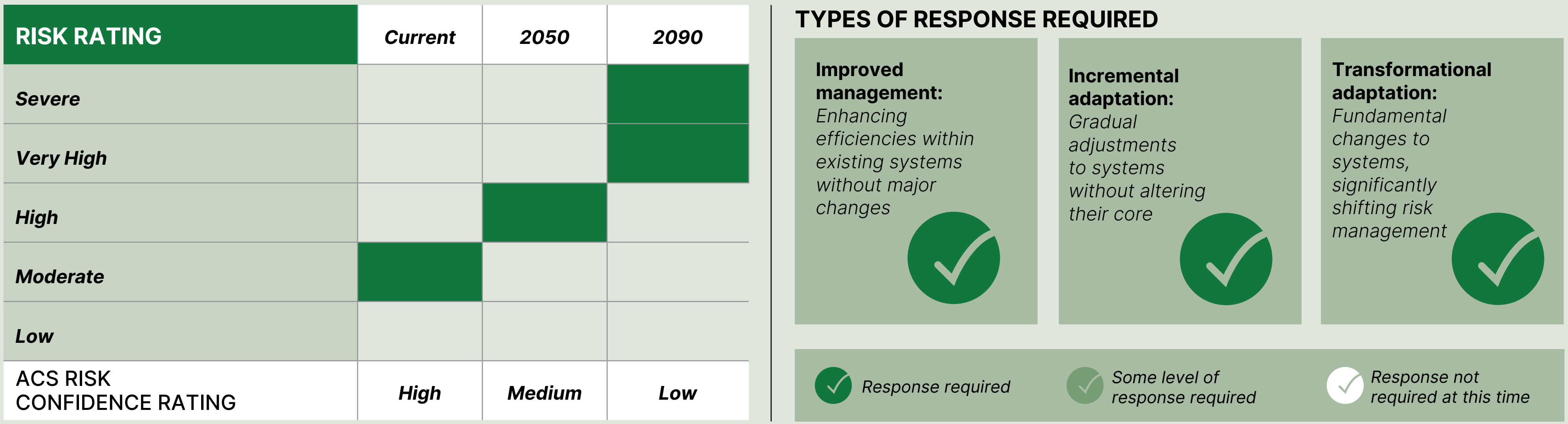


Figure 24: Rating for the Concurrency pressures in emergency response and recovery priority risk for current, 2050 and 2090, and the types of responses required to address the risk. For definitions of risk ratings, please see Figure 9.

Key hazards

- Concurrent and cascading severe events. Extreme risk may result from events which are not in themselves extreme, but which coincide temporally or spatially to increase risk and impacts.
- Extreme hazard events (flood, bushfires, heat and tropical cyclones) especially in northern Australia.
- Sea level rise exacerbating coastal flooding and compromising access to some communities.

Exposure

- Regional and remote communities, and people already disproportionately at risk to hazards.
- Disruption to vital services such as energy, telecommunications, transportation and information technology, and to critical and essential infrastructure and defence assets.

Vulnerability

- Public expectations for the Australian Government to support disaster response and recovery efforts.
- Australian Defence Force capacity and ability to support disaster responses.
- The cost of recovery and the concurrent need for investment in adaptation and disaster risk reduction.
- Supply chains during disasters, noting especially that imported fuel relies on international supply chains, which may be impacted by domestic and regional extreme hazard events.
- Health of emergency services personnel. Extreme heat is likely to reduce the effectiveness of the response and coincident and repeated events will have impacts on mental health and wellbeing of emergency personnel.
- The expectation that the Australian Defence Force will be available and equipped to respond to extreme natural hazard events while maintaining the capability to respond to regional tensions arising from extreme events.
- Recovery and relief expenditure after extreme natural hazard events will increasingly put fiscal pressure on all levels of government. It also adds more pressure to the volunteer workforce.
- Potential for loss of trust in government if response to repeated disasters is perceived as inadequate.

Impacts and risks

- The increasing frequency and severity of climate events risk may overwhelm the government's capacity to respond effectively.
- Potential for loss of social cohesion and loss of trust in governments if its response to repeated disasters is perceived as inadequate or inequitable, with the possibility of national security crises placing additional pressures on the Australian Government to respond.
- Demands on the Australian Defence Force to respond to extreme hazard events may impact their primary function.
- The cost of recovery and the expectation of investment in adaptation and disaster risk reduction will increase demands on government budgets.

Adaptation

- The large scales, increasing costs for recovery and disaster risk reduction, and the likely simultaneous events make effective adaptation challenging and will require more than adjusting existing practices. The system will benefit from innovation in structure or approach.
- New capacity will be needed: engaging new volunteers, especially from diverse communities, and considering alternative capacity will be essential in maintaining a robust emergency workforce capable of meeting the growing demands of climate-related disasters and relieving workforce concurrency pressure.
- Strengthening coordination and collaboration across national, state and local levels, including with non-governmental organisations, may help to address cascading impacts that contribute to pressure on national disaster and emergency management services. These likely impacts include increasing disease risk, reduced water security and impacts on primary production and food security, the natural environment, supply chains and health.
- Technologies such as remote sensing, enhanced personal protective equipment, and improved Earth observation tools can support efficient decision-making and bolster national security against increasing climate-driven risks.
- Australia can build resilience and reduce pressure on disaster response by investing in effective adaptation, including risk-informed planning to reduce exposure, and the development of resilient infrastructure.

Elim Beach near Hope Vale, Queensland.
Photo by: Dominic Jeanmaire. Used with permission.

Key climate hazards for the system

This section describes the changing climate hazards for the Defence and national security system.

In Australia, extreme heat and heavy precipitation are expected to intensify and occur with increased frequency *(high confidence)*.

Compound events such as bushfires, storms and tropical cyclones are also expected to intensify, amplifying their effects on ecosystems, health, emergency management, communities and infrastructure. Dangerous compound events may consist of events that are not extreme in themselves but lead to an extreme event or impact when combined (Seneviratne et al., 2021).

Compounding hazards may also amplify impacts of an individual hazard. For example, humidity itself may not be extreme, but when combined with high temperatures it can cause risks to multiple domains and systems (e.g. health) that support our domestic national security.

Climate change is altering the frequency, intensity and timing of (natural) climate drivers, such as the El Nino Southern Oscillation, and may also change the way in which these interact, triggering unprecedented combinations of natural hazard events. This is highly likely to be compounded by other risks such as national health crises, and these compounding factors will result in cascading effects across systems such as health or primary industry that escalate the impacts of an event, especially in highly exposed or disadvantaged regions.

Exposures, vulnerabilities, impacts and risks

This section provides a summary of impacts and risks associated with the Defence and national security system (Table 7).

These impacts and risks have been identified by understanding the changing climate hazards, as well as the exposures and vulnerabilities that drive them.

Table 7: Specific examples of how climate change can impact domestic disaster response and recovery assistance, now and in the future. *(Source: National Disasters and Emergency Management Technical Report)*

Exposure	Key climate drivers	Impacts	Defence and National Security Implications
Emergency management (EM) response capacity	Extreme bushfires, floods and tropical cyclones, and compounding of these hazards.	Increased occurrences are likely to overwhelm emergency management capacities. Physical and mental health of personnel (distress, grief, social impacts) could reduce the ability to respond to and manage emergencies.	Increased use of Australian Defence Force resulting in increased concurrency pressures.
Critical infrastructure and essential services	Extreme weather events (storms, floods and bushfires) and sea level rise and coastal erosion.	Disruption to vital services such as energy, telecommunications, transportation and information technology, and to critical and essential infrastructure and defence assets. Reduced capacity to respond with impacts on community wellbeing, social cohesion and resilience, and exposure of civilians to extreme events.	Disruptions are likely to reduce response capacity, with implications for domestic and regional security challenges.
Regional and remote communities	Extreme temperature, heatwaves, bushfire, sea level rise, and extreme weather.	Damage to energy grids and water supply, infrastructure, leading to power outages, food insecurity and water scarcity in affected areas. Direct health and wellbeing impacts from event (e.g. physical health impacts from bushfire smoke, mental health impacts from loss of homes or livelihoods) and indirect impacts from loss of cold chain and cold storage for medicines.	Increased health risks and economic impacts, potential loss of social cohesion and ability to cope with extreme events, potential for loss of trust in government.
Economy, supply chains and trade	Extreme climate events.	Potential for unprecedented need for emergency management services, response and recovery. Challenges in scaling emergency response systems and resources to meet the demands of more frequent and severe events. Tangible and intangible costs of disasters to the economy and gross domestic product affecting resource availability and capacity of paid and unpaid emergency management capacity. Disruptions to domestic supply chain routes as a result of ineffective emergency service response due to concurrency pressures will further compound disasters. For example, a disaster will worsen in instances of fatality and impacts to community if medical supplies or emergency food supplies cannot be transported to the necessary areas due to the destruction of major roads and supply routes.	Higher demands for resources and emergency management response capacity, especially with access to imported fuel. Increased resource competition for relief and recovery funding.

Compounding and cascading events

Climate change is increasing the challenge for preparation, response, relief and recovery operations. Compound hazards, and concurrent and cascading impacts across agriculture, transport and supply chains, human health, and energy, food and water security, will compound risks to Australia's national security. These impacts will negatively affect the long-term resilience of communities *(high confidence).*

- Compound events, such as simultaneous drought, heat and fires, or heavy rainfall with high winds and coastal storm surges, are becoming more frequent. Compound hot/dry events were observed during the 2019–20 Black Summer bushfires, resulting from a combination of factors such as persistent drought, heatwaves and dry vegetation, leading to devastating impacts.

  In the future, the frequency of most severe and extreme events is increasing, resulting in new types of compound events in places which may not have experienced these in the past.

  Evidence: National Disasters and Emergency Management Technical Report, Australia's Future Climate and Hazards Report

- Compound hazards have the potential to result in loss of life and economic damage and can result in long-term change to community cohesion and displacement. NSW and Queensland have both experienced a high number of compound events in recent years (Figure 25). Both are experiencing changes to settlement and population distribution, with each subsequent hazard event increasing pressure on emergency response and recovery. The risk to transport infrastructure increases noticeably in rural areas at higher global warming levels, with implications for adequate response to crises as well as risks to food security and health.

  Evidence: National Disasters and Emergency Management Technical Report, Critical Infrastructure Technical Report

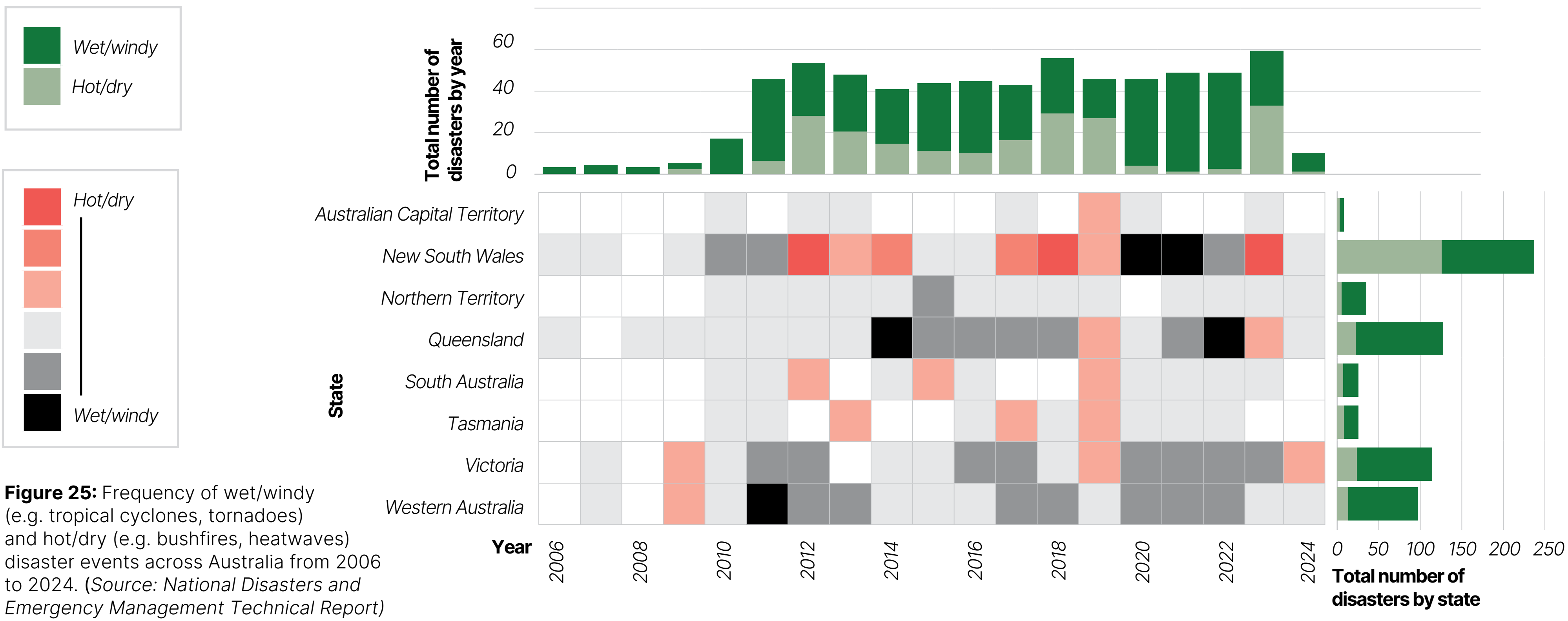


Figure 25: Frequency of wet/windy (e.g. tropical cyclones, tornadoes) and hot/dry (e.g. bushfires, heatwaves) disaster events across Australia from 2006 to 2024. (*Source: National Disasters and Emergency Management Technical Report)*

- A measure of 'hazard proneness' has been assessed, considering floods, bushfires, tropical cyclones and heatwaves, for communities across Australia. Areas that are 'prone to' a specific hazard experience more severe and more frequent occurrences of that hazard than areas that are not. General hazard proneness means that an area is prone to multiple hazards.
- Hazard proneness varies across regions, with a concentration in the north – particularly the north west – and the east coast at higher global warming levels (Figure 26 & Figure 27), and increases as global warming increases (compared with current, GWL +1.2°C), with variabilities across each region (Figure 26). Note: This is a pilot measure that currently excludes risks from sea level rise.
  Evidence: National Disasters and Emergency Management Technical Report
- Different regions are likely to experience changes in extreme and severe events in different ways (Figure 28 and Table 8). Northern Australia will see significant increases, particularly in heatwaves, floods and tropical cyclones. Central Australia will experience increases in heat and heatwaves. Southern and eastern Australia will experience an increase primarily in bushfires. Note – only 4 hazards were included in this analysis: floods, bushfires, tropical cyclones and heatwaves
  Evidence: National Disasters and Emergency Management Technical Report
- Compound or concurrent events in recent years have impacted defence operations and infrastructure, while overwhelming emergency management services, including community volunteers. The consequences of extreme natural hazard events have exceeded state and territory emergency capacities, necessitating Australian Government assistance (Commonwealth of Australia, 2023).
  Evidence: National Disasters and Emergency Management Technical Report

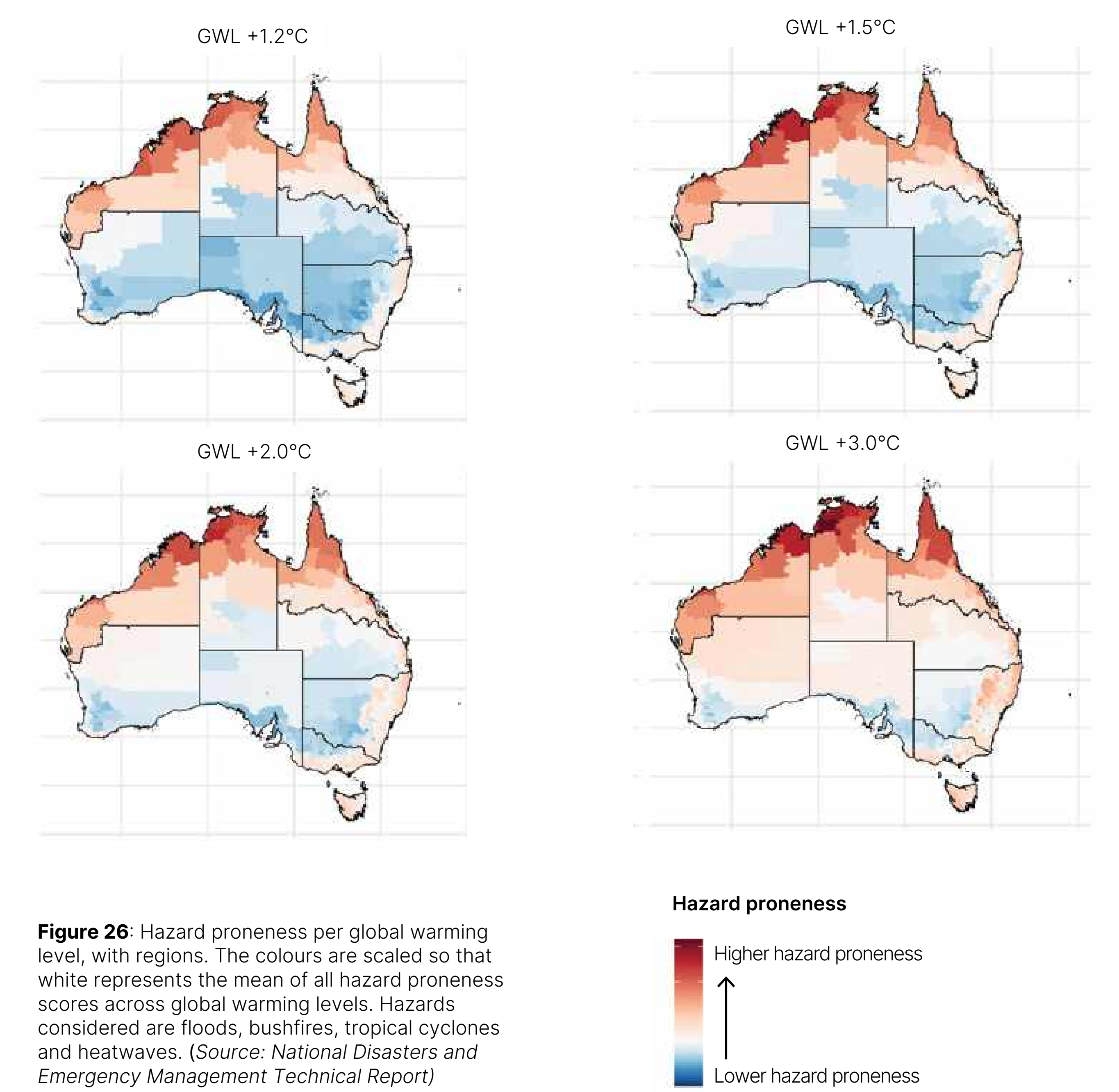


Figure 26: Hazard proneness per global warming level, with regions. The colours are scaled so that white represents the mean of all hazard proneness scores across global warming levels. Hazards considered are floods, bushfires, tropical cyclones and heatwaves. (*Source: National Disasters and Emergency Management Technical Report)*

- The costs associated with disaster response, recovery and reconstruction are likely to escalate. Increasing climate-driven hazards have put pressure on Australian, state and territory government budgets, leading to higher expenditure on emergency services, infrastructure repairs and community recovery efforts. For example, between 1 June 2018 and 30 June 2022, the Australian Government's Disaster Recovery Funding Arrangements (DRFA) provided $3.1 billion in funding to states and territories for disaster response. As part of the 2023 Intergenerational Report, The Treasury modelled the expected change in future Australian Government DRFA expenditure, relative to historic average DRFA expenditure. The analysis, which projects DRFA expenditure due to bushfires, tropical cyclones, floods and storms, shows the fiscal costs to government of recovering from severe and extreme natural hazards could increase exponentially over time.

  In 2050, Australian Government DRFA expenditure is projected to increase on average by 1.1 times under an equivalent +2.0°C warming scenario or by 1.5 times under a +3.0°C warming scenario above 2023–24 levels. In 2090, it is expected to increase by 5 times under an equivalent +2.0°C warming scenario and by 6 times under a sub +3.0°C warming scenario (Treasury modelling for the National Assessment).

  Evidence: National Disasters and Emergency Management Technical Report

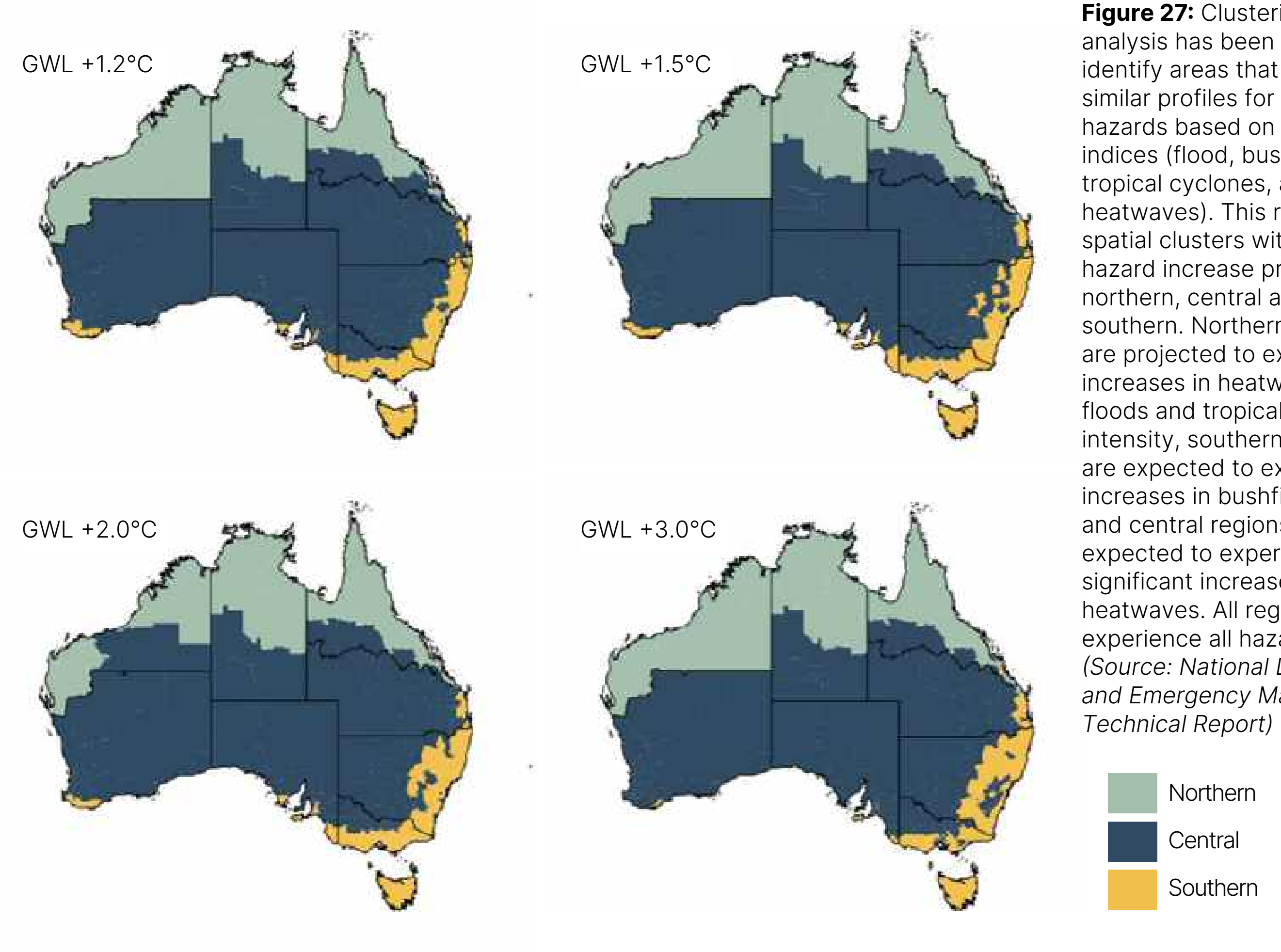


Figure 27: Clustering analysis has been used to identify areas that have similar profiles for changing hazards based on 4 hazard indices (flood, bushfire, tropical cyclones, and heatwaves). This results in 3 spatial clusters with similar hazard increase profiles: northern, central and southern. Northern regions are projected to experience increases in heatwaves, floods and tropical cyclone intensity, southern regions are expected to experience increases in bushfires, and central regions are expected to experience significant increases in heatwaves. All regions can experience all hazards. *(Source: National Disasters and Emergency Management Technical Report)*

	Heatwave	Flood	Tropical cyclone	Bushfire
Northern	above average	above average	significantly above average	average
Central	above average	below average	average	significantly below average
Southern	below average	average	below average	above average

Table 8: National hazard index cluster analysis results by cluster region and hazard. All regions will experience all hazards. *(Source: National Disasters and Emergency Management Technical Report)*

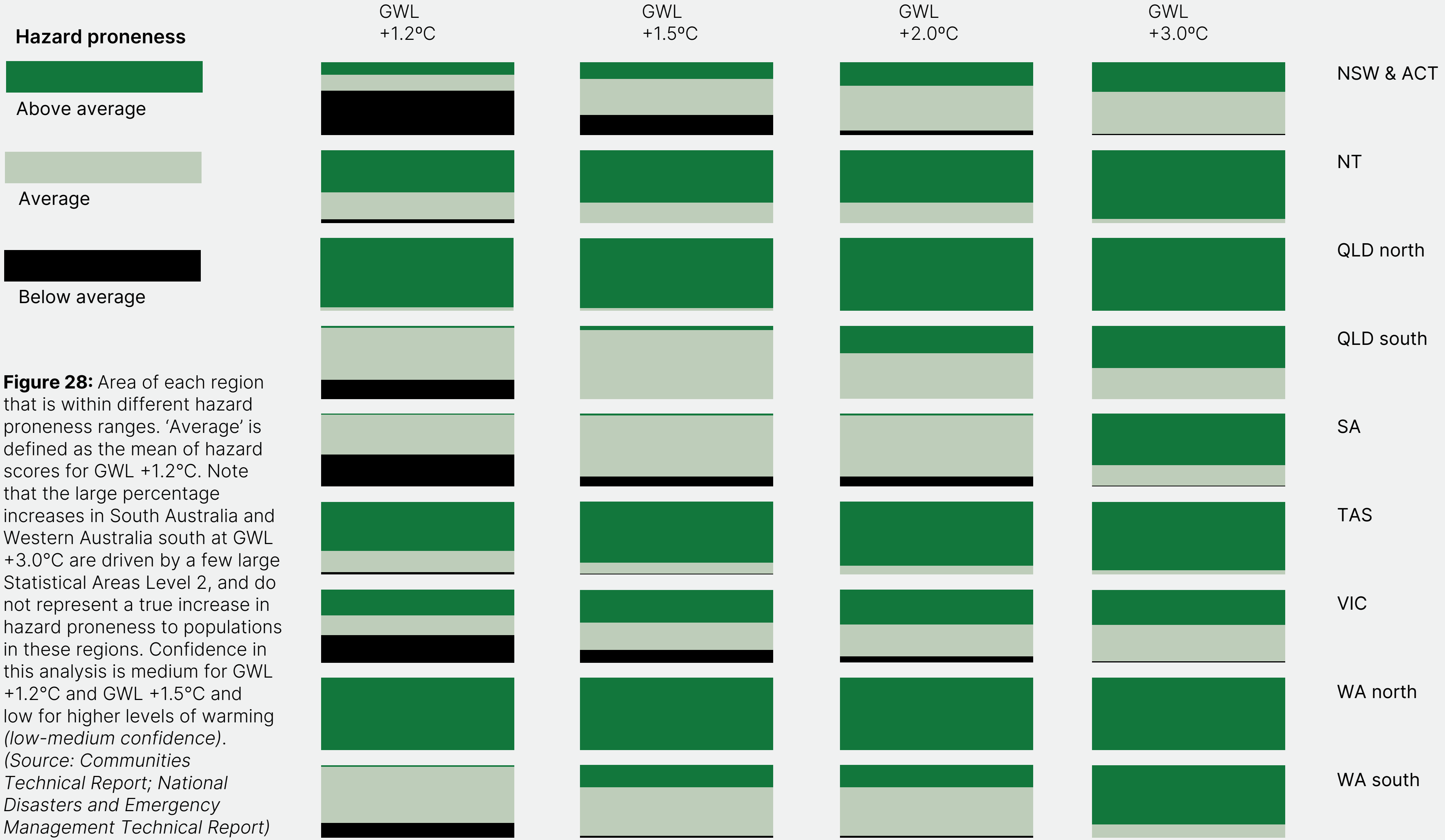


Figure 28: Area of each region that is within different hazard proneness ranges. 'Average' is defined as the mean of hazard scores for GWL +1.2°C. Note that the large percentage increases in South Australia and Western Australia south at GWL +3.0°C are driven by a few large Statistical Areas Level 2, and do not represent a true increase in hazard proneness to populations in these regions. Confidence in this analysis is medium for GWL +1.2°C and GWL +1.5°C and low for higher levels of warming *(low-medium confidence)*. *(Source: Communities Technical Report; National Disasters and Emergency Management Technical Report)*

Increased frequency, severity and complexity of extreme weather and the following climate impacts will cascade, increasing the need for additional capacity in response and recovery operations and risk-reduction investment *(high confidence).*

- Cascading risks occur when an initial climate event triggers subsequent disruptions, such as the social and health impacts caused by disruptions in food supply chains by flood, fires and subsequent impacts (e.g. bridge collapse or landslide), which can ripple across multiple sectors and regions. An increased frequency of extreme hazards under all future global warming levels is likely to result in shorter recovery periods for at-risk communities and may reduce resilience.
Evidence: National Disasters and Emergency Management Technical Report, Australia's Future Climate and Hazards Report, Primary Industries Technical Report, Communities Technical Report
- The changing climate will not only increase the likelihood of compound severe and extreme hazard events; it will also increase biosecurity and novel health risks. Changing environments for disease vectors are highly likely to exacerbate consequences for other systems such as health, water security, primary production and food, and the natural environment. These cascading impacts are likely to require increased coordination among Australian, state, territory and local governments, along with non-governmental organisations, to enhance support for disaster risk reduction and climate adaptation.
Evidence: Australia's Future Climate and Hazards Report, Climate and Communicable Disease Discussion Paper, Primary Industries Technical Report
- Disruptions to interconnected systems such as critical infrastructure and supply networks, personnel and resources, and communications infrastructure will compound the severity of disasters and in parallel, will almost certainly affect equipment and assets and are likely to reduce the ability for emergency management to respond effectively. Concurrent increases in extreme heat across northern Australia are highly likely to impact the effectiveness of assets operated by emergency management personnel, volunteers and Australian Defence Force members (see Case study - Northern Rivers in the *Communities Technical Report*).
Evidence: National Disasters and Emergency Management Technical Report
- Impacts in the Defence and national security system have the potential to cascade through to increase risk in other systems due to interdependencies across systems that may occur in unpredictable ways. For example, community disruption and displacement would increase the risk to primary industries and food production and has direct impacts on local economies with the potential for indirect impacts on the national economy. There is also the potential for disruption to broader government services as resources are diverted to managing disasters. Conversely, the Defence and national security system can be disrupted by impacts elsewhere. Disruptive and cumulative impacts from geopolitical tensions are likely to increase domestic risks (Department of Climate Change, Energy, the Environment and Water, 2024) and reduce the ability of the Australian Defence Force to respond (Commonwealth of Australia, 2023). Understanding the various interconnected pathways of climate impacts and their effects on domestic disaster response and recovery assistance is essential for informing risk-based interventions.
Evidence: Real Economy Technical Report, Communities Technical Report, Governance Technical Report

Communities at risk

Communities face increasing risks from climate-driven events, with many already residing in areas exposed to floods, storms and bushfires. The Northern Territory, Queensland north and Western Australia north are particularly exposed, with significant percentages of their populations in high-risk areas.

- Populations in the Northern Territory, Queensland north and Western Australia north are generally at higher risk of natural hazards today than other parts of the country. In the Northern Territory, 67,000 people (26.5%) currently reside in high-risk areas, while 110,000 (43.7%) live in very high-risk areas. This suggests a substantial exposure to climate impacts, especially given the region's small population size. Western Australia north has 94,000 people (85.4%) living in very high-risk areas, making it significantly exposed to climate hazards.
  Evidence: Communities Technical Report
- Compound hazards result in loss of life and economic damage. Both NSW and Queensland are experiencing changes to settlement and population growth, and so an upward trend of disasters increasing pressure on emergency response during subsequent hazards. The main factors corresponding with increasing exposure in these locations include: a rise in the number and value of homes, businesses, infrastructure and other assets at risk, due to population growth in at-risk areas; and an increase in the number of settlements and populations in areas susceptible to severe and extreme natural hazard events as the climate changes, such as coastal regions and urban fringes. The risk to transport infrastructure particularly increases in inland Queensland between the current and future climate for higher global warming levels.
  Evidence: National Disasters and Emergency Management Technical Report, Critical Infrastructure Technical Report
- People living with disability face disproportionate risks during emergencies and are among the most disadvantaged during disaster events, with particularly restricted access to social networks and other sources of support (National Emergency Management Agency, 2023b). The United Nations' *Global Assessment Report on Disaster Risk Reduction* emphasises that persons with disabilities often experience heightened vulnerability due to physical, informational and systemic barriers. According to the ABS, disability prevalence has increased between 2018 and 2022 for all age groups below 70 years of age, at the same time as the extreme natural hazard events are increasing (Australian Bureau of Statistics, 2022).

Regional and remote communities are increasingly at risk from changes in extreme natural hazard patterns. Aboriginal and Torres Strait Islander peoples experience some unique or disproportionate risks *(high confidence).*

- The geographic location of many remote communities means that the response time to natural hazards as they occur, is likely to be slower than national average, at the same time as critical infrastructure is highly likely to be compromised and, especially in northern and central Australia, where extreme heatwaves will increase in frequency and duration. If existing emergency response capabilities are already under strain, response time may further extend and adequacy of response will be further stretched, resulting in disproportionate risks to these communities.
  Evidence: National Disasters and Emergency Management Technical Report, Communities Technical Report, Primary Industries Technical Report, Governance Technical Report
- If increasingly severe and frequent disasters in these communities are not able to be managed in a timely and effective way, this increases the risk of displacement. Protracted situations of displacement may result in social cohesion tensions, distrust in government, food and water insecurity, and increased risk of health issues.
  Evidence: National Disasters and Emergency Management Technical Report, Governance Technical Report
- The values and perspectives of Aboriginal and Torres Strait Islander peoples, including the importance of connection to Country, are at risk when there may be a perceived need to relocate people and communities in response to supply chain and critical infrastructure disruption and extreme hazard events. Displacement has impacts on the ability to care for Country and to practise and transmit Lore and Culture.
  Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering
- Aboriginal and Torres Strait Islander consultations highlighted that Aboriginal and Torres Strait Islander women play a pivotal role in their communities' wellbeing, cohesion and cultural preservation. However, they are particularly at risk during community displacement, where increased climate extremes and the response to extreme natural hazard events can threaten their ability to fulfil these pivotal roles. Additionally, instances of family violence increase at these times (Mahendran et al., 2021), further compounding the challenges faced by women and others in these communities.
  Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering
- Changing climate conditions are likely to strongly aggravate disease or health conditions that affect Aboriginal and Torres Strait Islander' peoples at a higher rate than the general population, in particular where there is inadequate housing or energy supply. This includes the increased transmission of diseases, reduced effectiveness of medication, as well as impacts from poor air quality or extreme heat that are likely to exacerbate existing respiratory or cardiovascular disease.
  Evidence: Climate and Communicable Disease Discussion Paper

Increases in climate-sensitive infections and communicable diseases are likely to heighten health risks to people exposed to extreme events, such as emergency management personnel and volunteers. Biosecurity risks may also increase *(low confidence).*

- Personnel deployed to response, relief and recovery operations in disaster-impacted areas, as well as the resident populations, are likely to be at greater risk of communicable disease under future global warming. Common communicable diseases such as influenza and salmonellosis, as well as novel communicable diseases such as avian influenza, dengue fever, Japanese encephalitis and melioidosis, are highly sensitive to changes in the climate. A 1°C increase in mean temperature is associated with an increase of up to 15% in incidences of salmonellosis.
Evidence: Climate and Communicable Disease Discussion Paper
- Recent global surges of avian influenza pandemics in bird populations have occurred after patterns of climate events that are likely to become more frequent in the future. In Australia, wild waterbirds – the natural reservoir for avian influenza – move according to drought and rain cycles and transmit the virus to domesticated birds in the industrialised poultry sector. This was seen in 2024 when poultry outbreaks of non-H5N1 avian influenza surged after periods of high rainfall in southeastern Australia (the Murray–Darling Basin and southern Queensland).
Evidence: Climate and Communicable Disease Discussion Paper
- Emergency responses to climate hazards (e.g. emergency shipping of livestock feed) can present a pathway for biosecurity threats. Feed from Queensland entering NSW in 2018–20 for drought relief introduced parthenium weed (30 infestations).
Evidence: Primary Industries Technical Report

Emergency management resources

Australia already faces significant challenges in natural hazard preparation, response, relief and recovery operations due to its size and reliance on volunteers *(medium confidence).*

- Australia's vast geographical size means that several regions are situated more than 100 km away from emergency management facilities. These areas are considered to have a higher potential for challenges in responding to hazards due to the distance. For example, in extreme fire danger conditions, being located closer to emergency management facilities can enhance the immediacy of response and help reduce the risk to human lives and property.
  Evidence: National Disasters and Emergency Management Technical Report
- Australia does not appear to have water storage plans or capabilities that match its fire risk. Water security is under pressure for many rural and regional communities across Australia, with multiple towns at risk of reaching, or already having reached, 'Day Zero' conditions. Water is a potent weapon in fighting fires and is essential for the survival of people caught in fire events or trying to survive after them. Crises in water supply have clear national security implications over the medium and long term with the potential for resource competition and loss of infrastructure increasing impacts on communities.
  Evidence: Water Security Technical Report
- Australia's emergency service capability relies on volunteers for effective and proportionate response to natural hazards impacting the continent. In recent decades, Australia's overall volunteer numbers have decreased, particularly through recent COVID-19 disruptions, and are yet to recover to pre-pandemic rates (Volunteering Australia, 2024). Australia has an average volunteer rate of 18.7% of people per LGA, which covers all forms of volunteering, not just emergency response, with levels in capital city fringes and inner remote regions tending below this

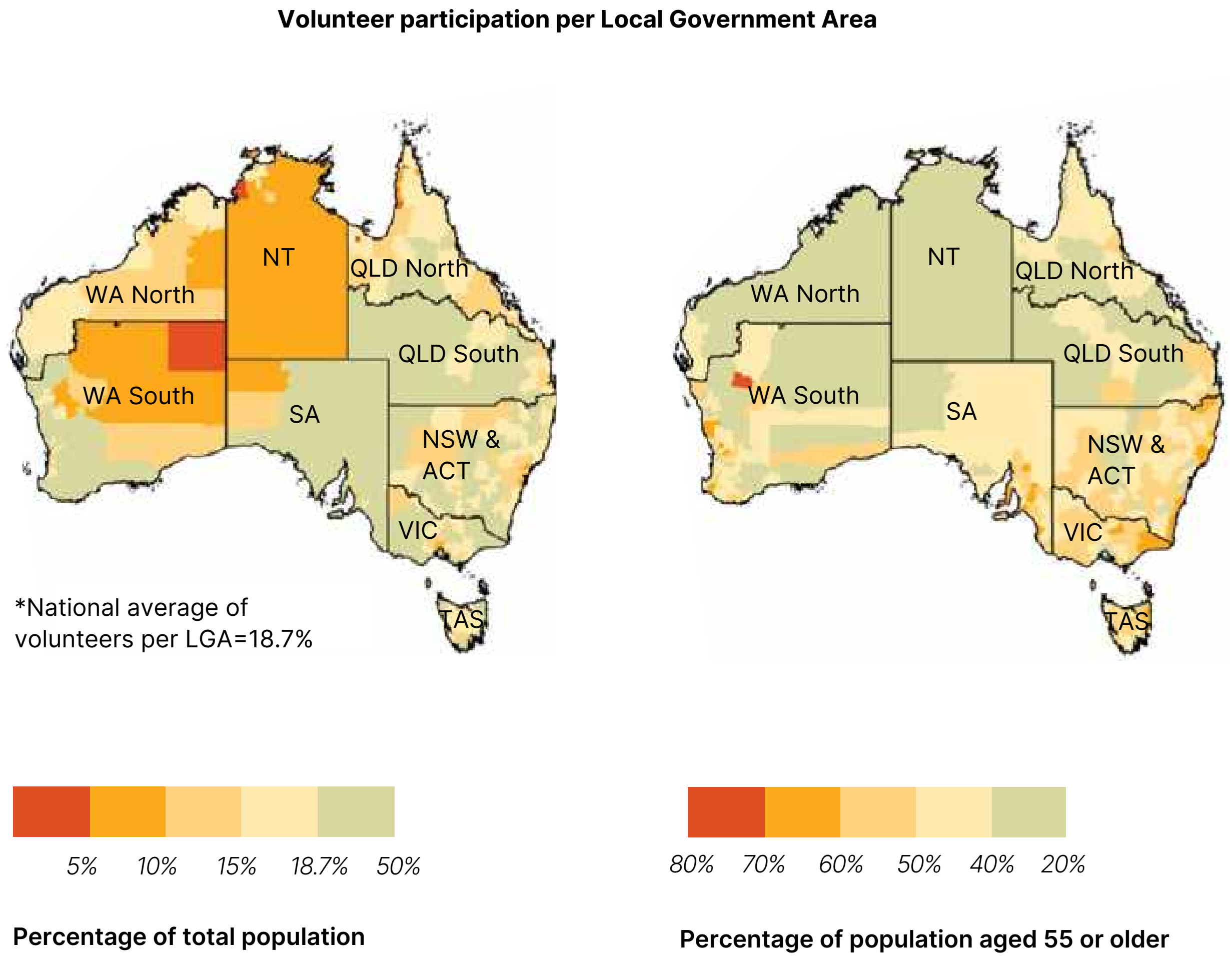


Figure 29: Percentage of population who participate in organised volunteer duties per Local Government Area, noting that this covers all forms of volunteering, not just emergency response. Percentage of total volunteer population aged 55 or older per Local Government Area. *(Source: National Disasters and Emergency Management Technical Report)*

average, potentially reducing the ability to respond to concurrent natural hazard events (Figure 29).
Evidence: National Disasters and Emergency Management Technical Report

- Australia's general volunteer population is ageing, with an average of 42% of all volunteers aged 55 years or older per LGA. This is a shift from 35% of volunteers aged 55 years or older per LGA in 2011, and from 36% in 2016 (Australian Bureau of Statistics, 2011, 2016, 2021) (Figure 29). Older volunteers bring valuable experience and leadership to communities and are an asset. All volunteers play a crucial role in communities and can influence disaster relief and recovery. However, with general volunteer numbers ageing, there is an emerging risk that must be addressed. As older volunteer cohorts retire in rural and remote regions, challenges in recruiting and training new volunteers are highly likely to lead to gaps in service delivery.
Evidence: National Disasters and Emergency Management Technical Report

The increasing frequency and severity of climate events is negatively impacting emergency response personnel and volunteers, physical, psychological and mental health *(high confidence).*

- The recent increase in severity and frequency of climate hazard extremes such as heatwaves, bushfires, tropical cyclones and floods has significant impacts on the wellbeing of response and recovery workers, with impacts on physical and mental health, fatigue and working conditions. Severe or extreme heatwave days are projected to increase significantly (Figure 30) across much of Australia *(high confidence)* so it is almost certain to become increasingly challenging for emergency response personnel with negative impacts on their capacity to respond.
Evidence: National Disasters and Emergency Management Technical Report, Health and Wellbeing Technical Report
- Health services and supporting infrastructure are severely stretched in capacity during hazard/climate emergencies. This may compound physical, mental health and safety impacts among communities, volunteers and emergency services personnel, particularly with a significant increase in frequent and compounding events.
Evidence: National Disasters and Emergency Management Technical Report, Australia's Future Climate and Hazards Report

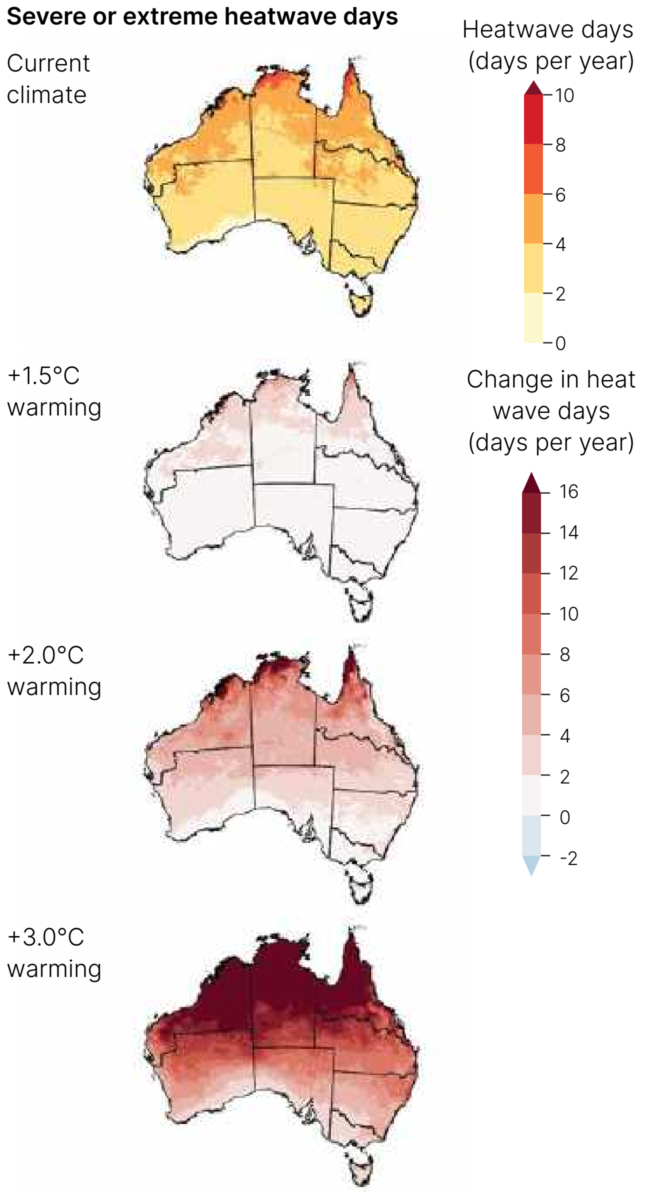


Figure 30: Median number of days per year experiencing severe or extreme heatwave conditions for the current climate (+1.2°C above the preindustrial average) and the change at each future global warming level (+1.5°C, +2.0°C and +3.0°C) compared with the current climate. *(Source: Australia's Future and Climate Hazards Report)*

Defence

The increasing frequency and severity of natural hazard events, and the related escalating demands on the Australian Defence Force to respond to national disasters, is placing concurrency pressures on the Australian Defence Force to respond to disasters and achieve its core mission *(medium confidence).*

- In 2022 alone, 70% of Australians lived in disaster-declared regions, with many communities facing multiple, coincident or closely following disasters (National Emergency Management Agency, 2024a). During the 2019–20 Black Summer bushfires, the Australian Defence Force were called in to support multiple simultaneous crises such as floods, tropical cyclones and bushfires. Increased requests to the Australian Defence Force to respond to disasters could impact force preparedness, readiness and combat effectiveness (evidence from stakeholder consultations; Butler & Hurst, 2022; Commonwealth of Australia, 2023; Norman & Davis, 2023).
  Evidence: National Disasters and Emergency Management Technical Report
- Australia's Department of Defence land and property holdings comprise more than 3 million hectares of land and 25,000 buildings, with a replacement value of over $32 billion; it also has large training areas and bases close to the coastline. Even without climate change, Australia's highly variable climate means that these Defence lands and facilities are prone to bushfire, flooding, multi-year dry and extreme heat. With more chronic climate-related impacts expected from sea level rise, hotter days and increasing water scarcity, the Department of Defence is likely going to have to invest in mitigating the impact of climate change on their operations and facilities.
  Evidence: Water Security Technical Report
- Extreme weather events are highly likely to have impacts on military operations, infrastructure and readiness (Brangwin & Watt, 2022). These events can disrupt training, damage facilities and challenge logistical support. Climate-induced disruptions at depots and to supply chains and transportation networks can hinder the timely deployment and resupply of defence forces to at-risk locations, affecting overall national security readiness.
  Evidence: National Disasters and Emergency Management Technical Report
- The Defence Strategic Review 2023 stated that the 'Defence Force is not structured or appropriately equipped to act as a domestic disaster recovery agency concurrently with its core function, in any sustainable way' and expects to be the force of last resort for domestic aid to the civil community. However, since 2019 over 50% of members have been assigned to domestic disaster relief tasks (Commonwealth of Australia, 2023).
  Evidence: National Disasters and Emergency Management Technical Report

Future climate change is expected to increase the frequency and intensity of extreme events across the region, with impacts on Australia's neighbours in the Indo-Pacific, and with possible impacts on Australia's emergency response capacity. Domestically, climate impacts could contribute to community unrest, highlighting the need for preparedness. The U.S. Department of Defense's 2014 Climate Change Adaptation Roadmap notes that climate change acts as a 'threat multiplier', amplifying instability and risks (US Department of Defense, 2014) *(low confidence).*

- Geopolitical tensions and increasing environmental risks in the Indo-Pacific region, such as sea level rise, drought, and food and water insecurity, could lead to mass migration and intrastate and interstate conflict (Commonwealth of Australia, 2023). These tensions and increasing risks are highly likely to result in increased calls on the Australian Defence Force (Department of Climate Change, Energy, the Environment and Water, 2024). Requirements could include humanitarian aid and disaster relief operations, as well as the possibility of large-scale non-combatant evacuation operations requiring significant resources.
  Evidence: National Disasters and Emergency Management Technical Report
- The impact of climate change on Australian communities could lead to social instability and population displacement with resultant loss of social cohesion (Ghosh and Orchiston, 2022).
  Evidence: National Disasters and Emergency Management Technical Report
- Climate change pressures in the region 'could lead to mass migration, increased demands for peacekeeping and peace enforcement, and intrastate and interstate conflict' (Commonwealth of Australia, 2023, p.41) and could exacerbate domestic social pressures.
- Climate change may create new security risks related to the supply of essential goods, including fuel, and services to Australia. The Defence Strategic Review states that the 'acceleration of major climate events risks overwhelming the Government's capacity to respond effectively and detracting from Defence's primary objective of defending Australia' (Commonwealth of Australia, 2023).
  Evidence: National Disasters and Emergency Management Technical Report

Adaptation observations and considerations

This section provides information that can support adaptation planning and approaches.

Strengthening coordination and collaboration across federal, state, territory and local levels, and increasing capacity, is needed as emergency response evolves *(medium confidence).*

- The uncertain, urgent, dynamic and long-term nature of climate change risks is likely to require increased coordination among federal, state and local agencies, and with non-governmental organisations, during disasters for effective and equitable relief. Increased disease risk, impacts on primary production and food security, the natural environment, supply chains and on health, as well as reduced water security will also require increased coordination. The experiences of agencies such as Emergency Management Victoria and the National Emergency Management Agency (and its predecessors) highlight the value of coordinated and integrated approaches in addressing increasing climate-driven risks.
  Evidence: Governance Technical Report
- Existing adaptation efforts by states and non-governmental organisations could be further expanded and enhanced; for example, the Australian Building Codes Board is investigating climate resilience for buildings (Department of Industry, Science and Resources, 2024), and at the local level the Heat Smart Western Sydney project looks at ways to reduce heat-health impacts (Western Sydney Regional Organisation of Councils, 2021).
- Engaging new volunteers, especially from diverse communities, will be essential in maintaining a robust emergency workforce capable of meeting the growing demands of climate-related disasters and relieving workforce concurrency pressure. Alternative capabilities for crisis response are likely to be needed to reduce the reliance on the Australian Defence Force and to ensure the capacity to respond to emerging national crises is maintained.
  Evidence: National Disasters and Emergency Management Technical Report
- The *Sendai Framework for Disaster Risk Reduction* 2015–30 underscores the role of inclusivity in disaster risk management, emphasising that empowering people with disabilities to participate in decision-making processes is essential for building resilient communities (United Nations Office for Disaster Risk Reduction, 2025). It highlights how incorporating the perspectives of people with disabilities can significantly enhance the design and implementation of adaptive strategies. By integrating these insights, governments and organisations can develop more inclusive policies and practices that address the needs of people with disabilities. This approach not only strengthens the effectiveness of disaster risk reduction but also creates opportunities for co-designed solutions that benefit the broader community.

Involving Aboriginal and Torres Strait Islander peoples in decisions before, during and after disasters is crucial for effective community empowerment and preparedness and for mitigating the risk of displacement. This engagement considers cultural context, leverages existing community capacities, and helps reduce the risk of displacement *(high confidence).*

- Aboriginal and Torres Strait Islander consultations highlighted that community empowerment and the involvement of Aboriginal and Torres Strait Islander Elders and community leaders in decision-making before, during and in response to extreme natural hazard events is key to mitigating the risk of displacement from traditional lands. While engaging Aboriginal and Torres Strait Islander peoples in decision-making can help to reduce displacement, the current climate trajectory suggests that, for some communities, displacement may ultimately become unavoidable.
  Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering
- Aboriginal and Torres Strait Islander consultations highlighted that culturally nuanced support networks and internal diversity (i.e. ensuring Aboriginal and Torres Strait Islander peoples are consulted or employed by non-Aboriginal organisations) will enable more efficient and effective disaster responses. This includes ensuring that emergency messages are communicated in appropriate languages to remote communities, that place-based communication networks and warning systems function properly, and that messages are culturally appropriate.
  Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering

Advancing research, risk assessments, planning, innovation and technology that target climate risk management will support effective adaptation *(high confidence).*

- Australia can build resilience and reduce pressure on disaster response by integrating future climate change projections into risk assessment frameworks. The *National Emergency Risk Assessment Guidelines* handbook has been developed to provide a nationally consistent approach to risk assessments and prioritisation. The National Bushfire Intelligence Capability provides information on locations and infrastructure most at risk from bushfires. Most jurisdictions have also developed frameworks and localised risk assessments to better understand key climate-driven risks, vulnerabilities and exposures. For example, the NSW Government has an Emergency Risk Assessment Framework and conducted a State Level Emergency Risk Assessment in 2017.
  Evidence: National Disasters and Emergency Management Technical Report

- Our scientific understanding of compound events is increasing, although it is still not sufficient to assess the probability and location of compound events. However, existing science can support risk analyses by contributing to compound climate event storylines, narratives and scenarios. These can be based on the frequency of individual hazards, their sequencing and spatial footprint, and by using historical compound events and cross-system risk assessments to explore compounding and cascading risks (e.g. see Sillmann et al., 2021). Scenarios should consider response capability – for example, the capacity to respond without the Australian Defence Force.
  Evidence: National Disasters and Emergency Management Technical Report
- Shifting resources towards disaster risk reduction and resilience will reduce the strain on recovery resources following hazard events. National, state and territory initiatives, such as the Australian Institute for Disaster Resilience and South Australia's Bushfire Management Plan, focus on building resilience in high-risk areas. The development of the forthcoming National Resilience Framework will outline the government's role, focus and approach to achieving better cohesion and linkages across policy for enhancing Australia's resilience to all hazards.
  Evidence: National Disasters and Emergency Management Technical Report
- Advanced technologies such as remote sensing, enhanced personal protective equipment and improved Earth observation tools can support decision-making in preparation for and during disasters. Initiatives such as Queensland's Emergency Management Sector Adaptation Plan and the Bushfire Technology Pilots Program are examples of using advanced technology for disaster response.
  Evidence: National Disasters and Emergency Management Technical Report
- Opportunities for transformational adaptation include the application of artificial intelligence, autonomous systems, robotics, augmented reality and brain – computer interfaces to help people to train and respond to events (Natural Hazards Research Australia, 2024).

Tools for reducing disaster risk to reduce exposure are valuable. Public infrastructure that protects communities, land-use planning and building codes are key tools for areas at risk from extreme natural hazards, and proactive relocation of high-risk communities should be considered *(high confidence).* **This is covered in more depth in the Communities - urban, regional and remote system chapter.**

- Land-use planning that integrates projections for rising sea levels, extreme weather events and coastal hazards to prevent development in high-risk areas and ensure infrastructure resilience will reduce risk. Public infrastructure to reduce exposure includes solutions such as sea walls, but also the preservation and restoration of natural buffers such as mangroves and wetlands, which provide essential protection against coastal hazards as well as improved carbon sequestration and habitat for wildlife (Natural Hazards Research Australia and Suncorp, 2024).
  Evidence: Communities Technical Report, Insights from the Australian Adaptation Stocktake, Natural Ecosystems Technical Report
- Sea level rise is highly likely to result in managed retreat of some communities (Barnett et al., 2013; Sipe & Vella, 2014; Suncorp Group & Natural Hazards Research Australia, 2023). The Grantham case study in the 'Governance and adaption' chapter provides an example of successful managed retreat post-disaster; however, proactive assisted relocation should also be considered in high-risk areas to give time for holistic solutions that include considered and broad engagement to build community support.
  Evidence: Communities Technical Report, Governance Technical Report
- In cities the value of developments in high-risk areas significantly increases exposure; therefore, the cost of long-term risk may not be reflected in current valuation (Fuerst & Warren-Myers, 2021; Natural Hazards Research Australia, 2023). Risk-based land-use planning, building codes, and infrastructure standards and regulation have the potential to reduce future risks (Norman et al., 2021).
  Evidence: Communities Technical Report

Case study: Northern Rivers flooding and the future under climate change

This case study explores the potential future impact of climate change on concurrency pressures during disaster response, particularly regarding the Northern Rivers region in north eastern NSW.

The Northern Rivers region has experienced severe climate-related disasters over 7 of the last 8 years. The 2022 floods were the costliest disaster in Australia's history and second costliest globally in 2022. These extreme costs reflect the highly exposed location of some of the region's main settlements and existing vulnerabilities, including socioeconomic disadvantage, housing stress and environmental degradation. The long-lasting impacts illustrate the dangers of cascading and compounding climate change impacts. Some examples include the challenges of emergency services' and governments' ability to assist with overlapping and large-scale disaster response and recovery efforts, the reliance on the Australian Defence Force, and far-reaching infrastructure, primary industries and supply chain disruption.

The climate in NSW has already changed, with land temperatures increasing on average 1.4–1.6°C since the pre-industrial period. Climate change has also changed the frequency and severity of extreme events. Storm events and king tides have combined with sea level rise in Byron Bay to cause serious coastal erosion of its iconic beaches, requiring restoration works by the shire council and conversations about managed retreat. Over the last 7 years, the Northern Rivers region has experienced multiple, large-scale events, notably the 2017 and 2021 floods, 2019–20 drought and bushfires, multiple 2022 floods and landslips, and more fires in 2023. In 2023 the region was over-represented among the 20 LGAs that have suffered 65% of average annual disaster losses in NSW, and between 2006–07 and 2023–24 the Clarence Valley Council sought and received assistance from National Disaster Recovery Arrangements 34 times.

The catastrophic floods of February–March 2022 in the region, particularly in Ballina and Lismore, were unprecedented. In Lismore, the floods reached a height of 14.4 m, surpassing the 1974 record by over 2 m. Because of the unprecedented scale of the event, community members had to fill the gap and support governments' response, coordinating rescues via social media and using their own boats despite significant safety risks. A survey of 43 local volunteers showed they contributed over 500 hours, rescuing around 1,079 people. Shortfalls in formal assistance persisted post-rescue, with many residents cut off from external aid for days or weeks. Community-organised efforts provided essential supplies and meals.

In Lismore, 1,399 homes were badly damaged, leaving 2,000 people homeless (Figure 31). Many were relocated to temporary accommodations such as caravan parks, motels and tents, though some caravan parks were also flooded. Disaster support agencies struggled to find accommodation for their staff. Some flood victims had to leave temporary housing for holiday tourists, and tourism operators had to discourage visitors, leading to a downturn

Figure 31: Northern Rivers flood impacts 2022. (*Source: Northern Rivers Case Study*)

in the sector. Those displaced experienced severe mental health deterioration. A survey in 2023–24 found housing, homelessness, mental health and economic impacts were the most pressing issues.

The existing shortage of affordable housing worsened the situation. Internal migration during the COVID-19 pandemic increased rents significantly, and the 2022 floods added pressure. Across NSW, 4,055 homes were deemed uninhabitable, pushing lower-income residents into precarious situations. Government recovery funding was significant but uneven and slow, causing stress for many. The Resilient Homes program had over 6,500 applications, most of which were rejected after long waits. Landslip-affected residents struggled to get assistance.

Insurance issues compounded problems, with many people non-insured or underinsured. Difficulties with claims processes deepened mental health and financial impacts. Physical impacts on public infrastructure had far-reaching effects, with damaged schools and sewage treatment plants, and disrupted utilities. Communities had to step in to address infrastructural barriers.

Climate change will raise temperatures, increase heatwaves and intensify extreme rainfall, leading to higher flood risks. Sea level rise, coastal inundation, bushfires and more intense storms will also become more common. Rising seas and extreme rainfall will worsen coastal and riverine flooding. By 2060, under a high-emissions scenario, 4 Northern Rivers LGAs could remain among the top 20 in NSW for disaster-related losses, with damage rising from $445 million in 2023 to an estimated $1.646 billion of the state's $9.1 billion annual total.

These environmental threats will strain disaster response and recovery, worsening existing social vulnerabilities. Populations disproportionately at risk and already facing challenges such as housing insecurity and economic instability will be hit hardest. Communities recovering from past disasters may struggle with new disasters while still rebuilding. Reliance on volunteer labour for recovery will likely reach its limit unless community efforts, care work and equity are better supported.

The Northern Rivers experience highlights the challenges of recurring and compounding extreme events, which exacerbate issues such as housing shortages and cost-of-living pressures. It shows how climate events overwhelm standard response processes, shifting risks to communities. Despite the devastation, the community's resilience demonstrates the potential for self-organisation. The key challenge is to foster community-driven adaptation within broader government efforts that better address interdependencies and escalating climate risks.

For more information on this case study, see the National Disasters and Emergency Management Technical Report.

Economy, trade and finance system

Summary

The Economy, trade and finance system is about how we access and use resources and how we work. It encompasses Australia's interconnected insurance and investment markets, import and export markets, the labour market, the production, distribution and consumption of goods and services, and the institutional arrangements governing economic activities and trade networks across all scales.

Priority risks

The National Assessment has undertaken quantitative and qualitative analysis for priority risks. The first pass assessment identified 5 nationally significant climate risks for this system. One priority risk has been analysed as part of the second pass assessment:

- Risks to the real economy from acute and chronic climate change impacts, including from climate-related financial system shocks or volatility.

Economy, trade and finance

Climate risks are determined by the interaction of risk elements, including hazards, exposures and vulnerabilities. This is a risk summary for the Economy, trade and finance system.

Climate and hazards

- Bushfires
- Tropical cyclones
- Changes in temperature including extremes
- Coastal and estuarine flooding
- Coastal erosion and shoreline change
- Drought
- Riverine and flash flooding

Exposures

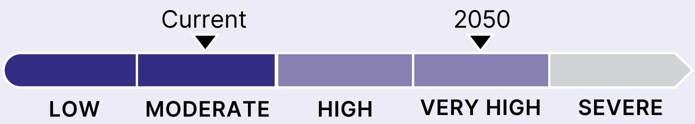
- Agriculture, mining, construction and tourism
- Businesses and supply chains
- Coastal housing stock and infrastructure
- Finance and markets
- Government resources for recovery
- International trade and finance
- Outdoor workers
- People and households

Vulnerabilities

- Ageing or unadapted infrastructure
- High household debt
- Interconnectedness and volatility of financial markets
- Land-use planning that has not considered climate change
- Unaffordable or inaccessible insurance
- Reliance on climate-sensitive industries
- Resource limited communities
- Reliance on global markets

IMPACTS AND RISKS

- Withdrawal of investment
- Damaged and devalued assets
- Health and social costs
- Higher insurance premiums and increasing non-insurance and under-insurance
- Higher recovery costs and insurance payouts
- Reduced wealth and rising cost of living
- Increasingly limited access to loans and mortgages
- Reduction in productivity and real wages growth
- Financial impacts cascading across the economy and increasing other risks



Assessment of current risk

The current climate risk to the Economy, trade and finance system is rated as *moderate (medium confidence)*.

Extreme weather events, such as heatwaves, floods and bushfires, are becoming more frequent and severe, leading to direct economic impacts and localised disruptions for some communities and households.

Compounding impacts are already felt across a few local regions which have experienced multiple large-scale events in recent years. These extreme weather events are resulting in increasing insurance costs in some areas, financial impacts on businesses, reduced asset values for households and increased need for disaster relief funding. Labour and productivity challenges are emerging for sectors such as tourism, and across the supply and value chains in agriculture, fisheries and mining.

Physical risks to infrastructure and critical assets, especially in coastal regions, are expected to increase, leading to financial losses and reduced productivity. Public health impacts have also been observed due to the stress and trauma associated with climate-related disasters with consequences for labour productivity and longer-term economic costs.

Novel financing opportunities and solutions for investing in adaptation may emerge through sustainable finance initiatives such as the Network for Greening the Financial System (NGFS) or CSIRO's Enabling Resilience Investment project.

Assessment of future risk

By 2050, the climate risk to the Economy, trade and finance system is projected to increase to *very high (low-medium confidence)*.

Physical risks to infrastructure and critical assets, especially in coastal regions, are expected to increase, leading to financial losses and reduced productivity. Impacts are likely to cascade from this system into others. The impacts on insurance and the cost of recovery efforts will become more pronounced, with the costs to households also expected to rise, potentially leading to disruption of livelihoods and risks to community cohesion.

Impacts on sustainability and prosperity are also possible, with risks of resource depletion, high economic costs from supply disruptions, and the potential for long-term disruption to community stability and cohesion.

In the absence of effective investment in adaptation and resilience for households and the financial system, acute and chronic extreme events in the future are likely to create financial shocks that may manifest as strong market corrections, leading to broader economic impacts. These impacts are likely to be felt most acutely by demographics and regions that already experience disadvantage.

Summary of exposures, vulnerabilities, impacts and risks

People and households

Extreme weather events, such as heatwaves, floods and bushfires, are becoming more frequent and severe, directly affecting homes and communities. Such events can lead to property damage, increased insurance costs and even loss of homes, particularly in coastal areas vulnerable to sea level rise and erosion. These events may also reduce asset values, especially in high-risk areas. These impacts, as well as disruptions in supply chains and increased prices for essential goods, will contribute to the cost of living, placing further strains on household budgets. These pressures may also threaten the cohesion of some coastal communities and those reliant on climate-sensitive industries.

Government and governance

All levels of government are exposed through revenue (erosion of tax base) and fiscal (disaster and welfare spending) channels. Governance vulnerabilities include adequate and equitable resource allocation for adaptation and recovery, outdated regulation and role ambiguity in addressing climate risks and inadequate information.

Businesses and supply chains

Physical risks to infrastructure and critical assets, especially in coastal regions, are expected to increase. Extreme heat is likely to reduce productivity of outdoor workers. Extreme weather events can damage facilities, disrupt operations, and lead to financial losses. Supply chains, particularly those dependent on agriculture, fisheries and mining, are vulnerable to climate impacts both domestically and globally. Disruptions in global supply chains caused by extreme weather in key trading regions compound these risks, affecting the availability and cost of raw materials and products. This can reduce food security and productivity and challenge the viability of some businesses, especially those in primary industries and construction.

Finance and markets

The affordability and availability of insurance for at-risk communities are likely to worsen, with flow-on impacts on related sectors. Loans and private and public equity markets are climate-exposed through asset investments. Climate change poses long-term risks to the Australian economy that are difficult to quantify and often sit beyond the planning horizons of financial institutions. Novel risks and rare high-impact low-likelihood or 'Black Swan' events represent significant threats to the financial system, with potential cascading effects on the broader economy. Large companies in the energy, insurance and banking sectors have the resources to conduct climate risk assessments on their own portfolios and to invest in resilience, but they remain vulnerable to cascading risks.

Cascades

Impacts on one sector can quickly spread to others, creating a complex web of interdependencies. Disruptions in supply chains can lead to shortages of essential goods, affecting businesses and households. Increased insurance costs can strain household budgets, reducing disposable income, consumer spending and economic growth. Financial system shocks or volatility can be triggered by asset write-downs or loan defaults across a region, with potential ripple effects for households and businesses by reducing access to finance, the value of investments or superannuation. Novel risks and high-impact low-likelihood or 'Black Swan' events can destabilise financial markets, leading to broader economic consequences. The system also carries significant governance risk, as dynamic and urgent financial decisions have the potential to drive maladaptation.

International trade and finance

While the assessment of international risk is out of scope, it is noted here for completeness. Disruptions in global supply chains due to extreme weather events in key trading regions can affect Australia's import and export markets. Additionally, climate-related financial system shocks or volatility in international markets can have ripple effects on the Australian economy. Significant risks and opportunities are likely to be driven by climate change–related impacts outside Australia's borders, as our biggest trading partners and nearest neighbours experience the impacts of climate change. Global reinsurance pricing is increasing domestic home and building insurance premiums against perils.

Introduction

This chapter provides a synthesis of the risks to the Economy, trade and finance system. It draws on a wide range of technical assessments to provide observations that can enable effective adaptation.

It includes:

- System overview
- Priority risk snapshot
- Key climate hazards for the system
- Exposures, vulnerabilities, impacts and risks relevant to the system
- Adaptation observations and considerations
- Case study

This chapter highlights one priority risk snapshot and draws on the analysis from across all the priority risk technical assessments. It is important to note for this first National Assessment that all 63 nationally significant risks have not been fully assessed. Climate risks are not static – this work is a sound foundation that should be built on over time.

System overview

The Economy, trade and finance system in Australia is a complex network that governs how resources are accessed and utilised, and how work is conducted.

It includes interconnected insurance and investment markets, import and export markets, the labour market, and the production, distribution and consumption of goods and services (Figure 32). This system is underpinned by institutional arrangements that guide economic activities and trade networks at all levels.

The economy includes the production, distribution and consumption of goods and services. It includes essential services and infrastructure such as transportation, utilities and communication networks, which are vital for daily economic activities. Supply chains ensure the efficient flow of raw materials, goods and services from producers to consumers. Government finances and capacities provide foundational support for public services and infrastructure, directly influencing economic conditions. Individual and household budgets play a key role in driving demand within the economy, influencing production and service delivery.

Trade drives economic growth by facilitating the exchange of goods and services with other countries. International trade networks ensure that raw materials and finished products flow efficiently across borders, supporting the overall economy. The impacts of climate change on our trading partners, and the potential for transboundary risks, are out of scope for this first National Assessment. These impacts change the magnitude of risk to Australian trade, as well as presenting new opportunities.

Finance includes the interconnected insurance and investment markets, domestic financial institutions and international financial systems. Domestic financial institutions and markets, such as banks, credit unions, insurers and investment funds (including superannuation funds), facilitate investment and savings, ensuring liquidity and financial stability. While this system includes a wide range of insurance products, this chapter largely focuses on building and home and contents insurance against weather-related perils. International financial systems link Australia to the global market, enabling cross-border trade and investment.

Effective governance, including regulation and reporting requirements, ensures transparency and stability in financial transactions, maintaining economic integrity.

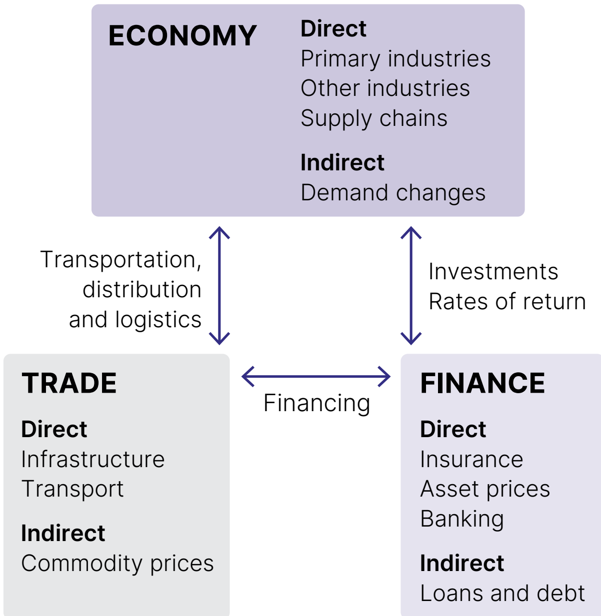


Figure 32: Relationships among the groups of economic activities. *(Source: Real Economy Technical Report)*

Priority risk snapshot: Real economy

Risks to the real economy from acute and chronic climate change impacts, including from climate-related financial system shocks or volatility.

The real economy is the part of a country's economy that produces and uses goods and services, rather than the part that consists of financial services such as banks and stock markets (Figure 34). This priority risk is assessed and evaluated around the plausible worst-case scenario depicted in the risk statement and focuses on the observed and anticipated impacts and consequences to the real economy from direct or indirect economic impacts for at-risk communities.

Rationale

The current risk to the real economy from climate change is rated as **Moderate**; direct impacts to households and businesses from climate change are being experienced in some communities with cascading impacts on insurance costs and asset values. The risk is expected to increase to **High–Very High** by 2050 as direct financial impacts will increase and there is a significant potential for cascading impacts, including financial transmission of international impacts, to trigger climate-driven economic crises (Figure 33). Compounding economic impacts across multiple systems, as well as significant disaster costs and insurance challenges, mean that the risk is rated as **Severe** for 2090. While the vulnerability of the real economy is low, adaptive capacity is also low. As such, improved management and incremental adaptation – through improved regulation, for example – are required and can be effective, although the distributed nature of the risk, and global factors, are likely to influence the success of potential interventions.

Key hazards

- Heatwaves, tropical cyclones, bushfires and severe floods have direct impacts on homes, businesses and infrastructure. These events will become more frequent and severe *(high confidence)* leading to property damage, increased insurance costs, and loss of income.
- Chronic climate change impacts will also drive risk, especially rising temperatures *(very high confidence)* and rising sea levels *(very high confidence)*. Coastal erosion and sea level rise pose significant risks to coastal communities and infrastructure, and significant current exclusions for insurance cover mean that repair and recovery costs remain with households and businesses or may be transferred to governments.

RISK RATING	*Current*	*2050*	*2090*
Severe			■
Very High		■	
High		■	
Moderate	■		
Low			
ACS RISK CONFIDENCE RATING	***Medium***	***Medium***	***Medium***

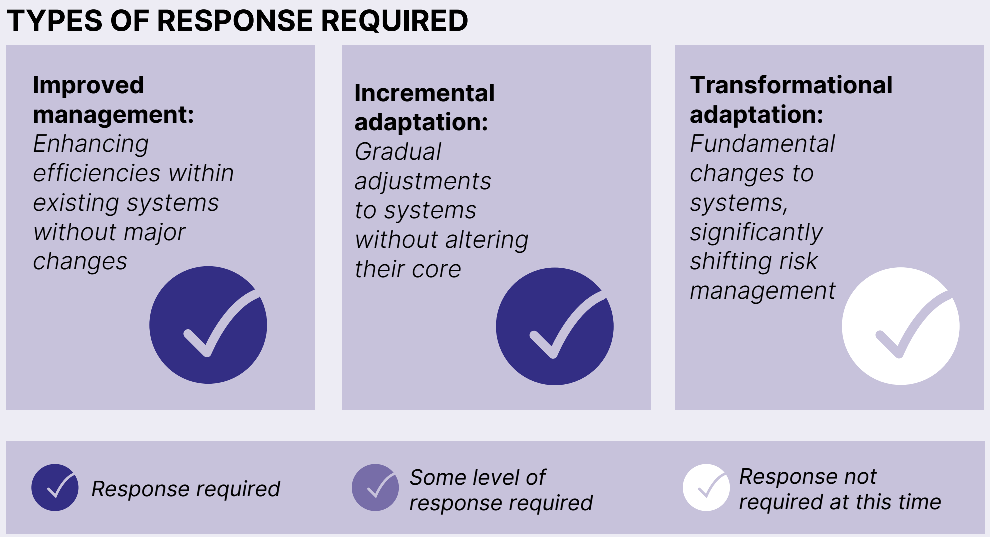


Figure 33: Rating for the Real economy priority risk for current, 2050 and 2090, and the types of responses required to address the risk. For definitions of risk ratings, please see Figure 9.

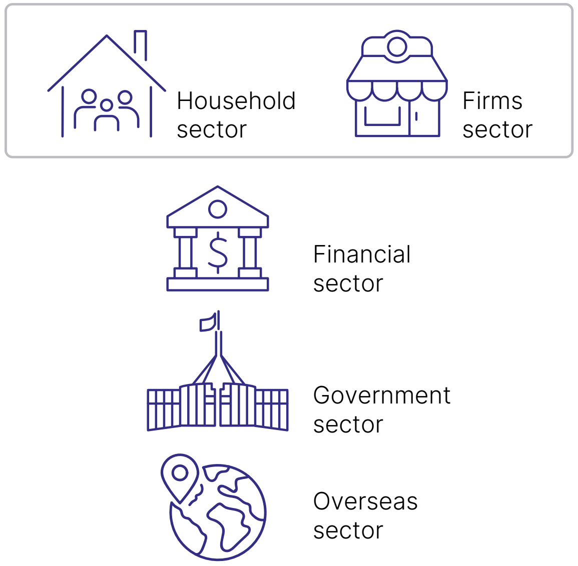


Figure 34: Reserve Bank of Australia view of the economy, with the 'real economy' outlined in grey.

Exposure

- **People and households:** are increasingly directly (e.g. loss and damage of real estate and infrastructure) and indirectly exposed to the economic impacts of extreme weather events. Indirect exposure occurs through supply chains and macroeconomic channels such as inflation.
- **Businesses and supply chains:** are exposed to extreme weather events which can damage facilities, disrupt operations, and lead to financial losses or rapid withdrawal of capital (divestment). Indirect costs will include extreme heat resulting in reduced workforce productivity, and increased costs of inputs or transport due to disrupted supply chains.
- **Finance and markets:** are climate exposed through insurance, loans, and private and public equity markets. This results in indirect exposure of householders via mortgages and superannuation schemes, and businesses are exposed through loans (including mortgages) and investments.
- **Governance**: All levels of government are exposed through revenue (erosion of tax base) and fiscal (disaster and welfare spending) channels.
- **International trade and finance:** The Australian domestic economy is indirectly exposed to global extreme events through disruptions in global supply chains in key trading regions and the need to access global reinsurance.

Vulnerability

- **Affordability of and access to insurance:** Rising costs and reduced availability of insurance can lead to underinsurance or non-insurance. This transfers the cost of disaster recovery back to householders and governments. Lack of insurance also reduces the financial capacity to support loans and mortgages and reduces the value of assets.
- **Resource-limited communities:** High household debt and limited access to affordable insurance make these communities particularly vulnerable to climate impacts, due to a lack of financial agency to take on adaptation measures.
- **Whole-of-system resilience:** Banks and investment funds are vulnerable to cascading risks from climate impacts to infrastructure and economic activities. Asset-level resilience is limited if whole-of-system resilience is lacking.
- **Global dependencies:** Reliance on international supply chains and financial markets makes Australia vulnerable to global climate impacts. Disruptions in global supply chains and financial market volatility can have significant ripple effects on the Australian economy.
- **Governance vulnerabilities:** include the speed at which response is needed with the potential for inadequate and inequitable resource allocation for adaptation and recovery. Role ambiguity and regulation not fit for purpose in a changing climate and inadequate information are also vulnerabilities.

Impacts and risks

- **Economic costs:** The Colvin Review (2024) projected disaster costs across each state and territory for flood, bushfire, storm, cyclone and hailstorm for a moderate emissions scenario may total an annual cost of approximately $40.3 billion by 2049–50 (median value). This modelling included both financial and social costs.
- **Insured losses:** from declared insurance catastrophes have grown historically from 0.2% of Gross Domestic Product (GDP) (or $2.1 billion) in 1995–2000 to 0.7% of GDP (or $4.5 billion) in 2020–24, with floods, expanding development and urbanisation driving the losses.
- **Disaster funding:** Average Australian Government expenditure under the Disaster Recovery Funding Arrangements (DRFA) could increase by 2090, on average, by 5 times at an equivalent +2.0°C global warming scenario or by 6 times under a sub +3.0°C global warming scenario (The Treasury, 2023a).
- **Insurance market:** Households exposed to natural hazards are highly likely to face increases in insurance premiums in the future, decreasing affordability of full insurance cover to households and leading to underinsurance or a 'protection gap'.
- **The construction industry:** A perceived risk in the medium to long term is unaffordable or financially unsustainable insurance due to pricing to a higher level of risk and the cost of rebuilds (housing and infrastructure) after extreme events. Experts rated this as a higher risk to revenue than reduced productivity from increasing heat for outdoor workers.

Adaptation

- The financial sector can build in resilience to climate change impacts through pricing or, in extreme cases, insurance withdrawal or capital flight. Such measures transfer costs and risks back to householders and businesses. Adaptation pathways need to consider actions that build the resilience of both the financial sector and the communities it services.
- Stakeholders and literature note innovative and new approaches to insurance and reinsurance (e.g. parametric insurance) to manage risk tolerances and place downward pressure on insurance premiums. These solutions are expected to be most effective and to avoid maladaptive outcomes if tied to adaptation measures which address underlying exposure and vulnerability. The most enduring and effective solutions to insurance affordability pressures are expected to be investing in risk management and risk reduction.
- Businesses require data and formal guidance to assess their physical climate risk. Long-term economic risks posed by climate change are difficult to quantify and often sit beyond the planning horizons of financial institutions. Quality, consistent climate information and sustainable finance taxonomies and corporate risk disclosure regimes are emerging to fill this gap.

Key climate hazards for the system

This section describes the changing climate hazards and how these influence the Economy, trade and finance system.

Climate change and related hazards already affect Australia's Economy, trade and finance system through multiple channels. While climate risks and hazards are often localised, with pronounced impacts on regional economies, climate-related shocks can also more broadly impact the Australian Economy, trade and finance system *(high confidence)*.

- Insurance Council of Australia data on insured losses over the past 40 years shows a steady increase in disaster-related payouts as a result of severe natural hazard events, particularly since the turn of the century (Figure 35). This is in addition to other significant costs to the community, including health, social and environmental impacts, and the unpaid labour typically deployed to support affected communities (The Treasury, 2023a).
- The total economic cost of climate-related disasters was $38 billion per year on average, representing 2% of GDP in 2020, and by 2060 this cost could rise to at least $73 billion, or 4% of Australia's GDP (Deloitte, 2021).

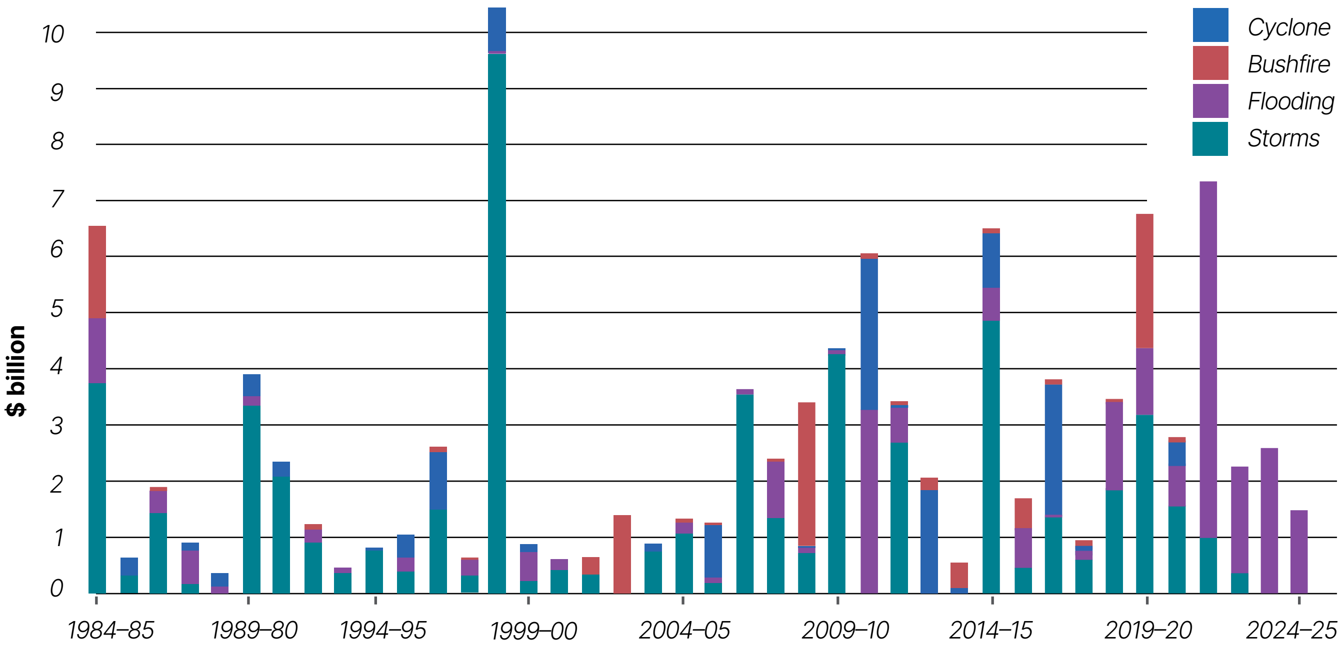


Figure 35: Normalised value of insured losses caused by natural disasters, 1982–83 to 2024–25. Impacts from non-climate-driven disasters, such as earthquakes and gas disruption, are excluded. *(Source: Insurance Council of Australia, 2025)*

- The impact of extreme weather on the Australian economy has more than tripled over the past 3 decades, with the rate of growth of the financial impact of extreme weather outpacing the rate of economic growth. Insured losses from declared insurance catastrophes have grown historically from 0.2% of GDP (or $2.1 billion) in 1995–2000 to 0.7% of GDP (or $4.5 billion) in 2020–24, with floods, expanding development and urbanisation being the main drivers of losses (Figure 36) (Insurance Council of Australia, 2024).

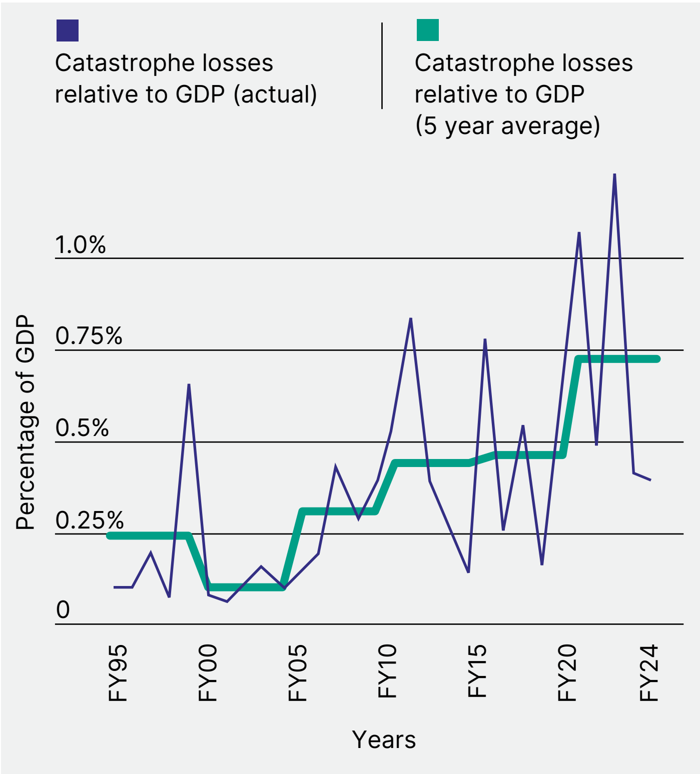
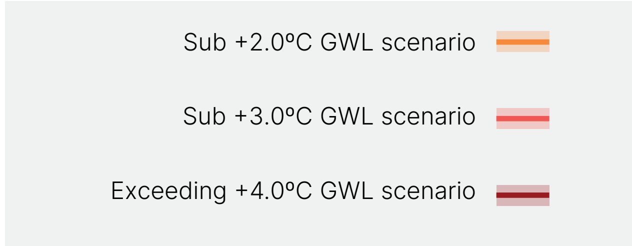


Figure 36: Catastrophe losses relative to Australian Gross Domestic Product (GDP) and 5-year averages (adapted from ICA, 2024).

- In the immediate aftermath of the 2019–20 bushfires, an estimated 80,000 tourists cancelled or postponed activities. International tourist bookings reduced by an estimated 10 to 20%, which cost the tourism industry approximately $4.5 billion (Carruthers, 2020).
- The east coast flood events in $9.6 billion in economic losses (Munich, 2023). Insured losses were estimated to be $5.5 billion from approximately 234,000 claims (Insurance Council of Australia, 2022).



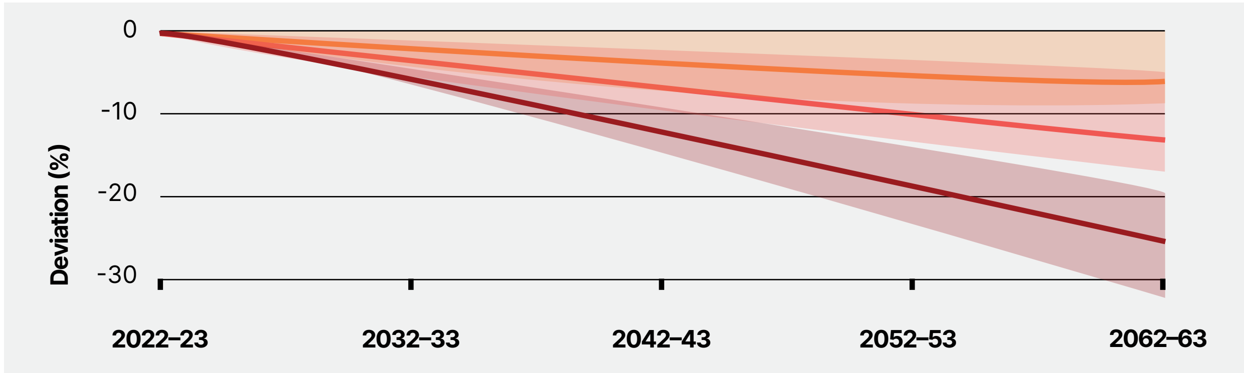


Figure 37: Potential change in projected international tourism arrivals due to direct impacts of temperature rises across climate scenarios, 2023 to 2063 (adapted from The Treasury, 2023a).

Note: Treasury modelling used representative concentration pathways rather than global warming levels, so equivalence to global warming levels is shown.

Heat-related and other extreme weather events, coastal erosion and sea level rise are increasing risks to the finance system and the real economy. Increased frequency, intensity and duration of extreme events and rising sea levels with associated chronic and acute coastal impacts will add to the challenges for coastal communities, finance and trade, with the potential for cascading impacts in the rest of the economy *(medium confidence).*

- Climate models project an increase in the intensity, frequency and area exposed to extreme weather events, including more spatially and temporally compounding events, and events *(high confidence)* that are highly likely to have different characteristics from historical events.
  Evidence: Australia's Future Climate and Hazards Report
- The number of days when a severe or extreme heatwave is experienced is projected to increase, with the greatest increases in the northern parts of Australia. Heatwaves will be more extensive, last longer and be more severe, leading to an increase in deaths, heat-related illness and pressure on health services. At +3.0°C of global warming, heat-related mortality is projected to increase by 444% in Sydney, 259% in Melbourne, 335% in Townsville, 312% in Perth, 146% in Launceston and 423% in Darwin compared to current conditions (note that the population demographics do not change in these mortality calculations). Heat-related mortality and morbidity has direct and indirect impacts on the economy, particularly through labour productivity.
  Evidence: Health and Wellbeing Technical Report
- Cumulative wealth loss in Australia from reduced agricultural and labour productivity from climate change could exceed $19 billion by 2030, $211 billion by 2050, and $4.2 trillion by 2100 (Steffen et al., 2019).
- The potential reduction in projected tourism arrivals in the medium term (2063) due to the direct impacts of rising temperatures making Australia less attractive as a tourist destination, has been estimated at approximately 7% (GWL +2.0°C), 14% (GWL +3.0°C) and 25% (GWL +4.0°C) from 2023 levels (Figure 37). This analysis did not consider additional impacts from extreme weather events: degradation of tourism attractions, changes in tourist behaviour, structural changes in the tourism market, or changes in the costs of travel from net zero transformation (The Treasury, 2023a).

Exposures, vulnerabilities, impacts and risks

This section provides a summary of impacts and risks associated with the Economy, trade and finance system (Table 9).

These impacts and risks have been identified by understanding the changing climate hazards, as well as exposures and vulnerabilities, that drive them.

Impacts from the changing climate are not limited to the direct effects of physical damage to infrastructure or production but also extend to systemic economic disruptions, changes in market dynamics and cascading financial risks.

Table 9: Key impacts in the Economy, trade and finance system. Results that are sourced directly from the literature are referenced in the table. New results from the National Assessment are not assigned references in the table. All sources are referenced throughout the chapter.

Climate impacts	Current	Future		
	GWL +1.2°C	GWL +1.5°C	GWL +2.0°C	GWL +3.0°C
Insured losses	Insured losses from declared insurance catastrophes have grown historically from 0.2% of GDP (or $2.1 billion) in 1995–2000 to 0.7% of GDP (or $4.5 billion) in 2020–24 (Insurance Council of Australia, 2024).	Increasing floods and expanding development and urbanisation will continue to drive losses.	Increasing floods and expanding development and urbanisation will continue to drive losses.	Damage-related loss in value is expected to rise to $571 billion by 2030, $611 billion by 2050 and $770 billion by 2100 at GWL +3.0°C (Steffen et al., 2019).
Total economic loss	The total economic cost of climate-related disasters was $38 billion per year on average, representing 2% of GDP in 2020 (Deloitte, 2021).	Cumulative wealth loss in Australia from reduced agricultural and labour productivity from climate change could exceed $19 billion by 2030 (Steffen et al., 2019). Total economic cost projected for flood, bushfire, storm, cyclone and hailstorm for 2049–50 moderate emissions scenario is approximately $40.3 billion annually (median value). This modelling included both financial and social costs (Colvin, 2024).	Cumulative wealth loss in Australia from reduced agricultural and labour productivity from climate change could exceed $211 billion by 2050 (Steffen et al., 2019).	Cumulative wealth loss in Australia from reduced agricultural and labour productivity from climate change could exceed $4.2 trillion by 2100 at GWL +3.0°C (Steffen et al., 2019).

Climate impacts	Current	Future		
	GWL +1.2°C	GWL +1.5°C	GWL +2.0°C	GWL +3.0°C
Commonwealth Disaster Recovery Funding Arrangements (DRFA) payments to states and territories	$3.1 billion provided to states and territories from 2018–19 to 2021–22 (Australian National Audit Office, 2023). $6.4 billion estimated for 2022–23 to 2025–26 (Australian National Audit Office, 2023).		DRFA payments* could increase, on average, by up to 200% by 2050 (The Treasury, 2024, supplied to the National Assessment). *Commonwealth costs only.	DRFA payments* could increase, on average, by up to approximately 600% (GWL +3.0°C) by 2090 (The Treasury, 2024, supplied to the National Assessment). *Commonwealth costs only.
Economic impacts – international tourism arrivals	International tourist bookings reduced by approximately 10-20% in 2019–20 due to bushfires. The cost to the tourism industry was approximately $4.5 billion (Carruthers, 2020; The Treasury, 2023a).		International tourist bookings may reduce by 7% from 2022 levels (The Treasury, 2023a).	International tourist bookings may reduce by 14% from 2022 levels (The Treasury, 2023a).
Workforce and labour productivity **– Heat-related impacts on labour productivity**	Heatwaves are estimated to reduce annual productivity by $616 per worker, $5.8 billion, or 0.33–0.47% of GDP. Number of days per year manual labour dangerous to perform: - People acclimatised to local conditions: 1 day per year. - People not acclimatised (e.g. out of state): 4–6 days per year. (Y. Zhang et al., 2018)			By 2061, between 700,000 (GWL +3.0°C) and 2.7 million (>GWL +3.0°C) additional days of work are projected to be lost each year in agriculture, construction, manufacturing and mining (NSW Treasury, 2021). Labour productivity decrease of 0.2% at GWL +3.0°C–0.8% at GWL +4.0°C by 2063 (The Treasury, 2023a). Number of days per year manual labour dangerous to perform: - People acclimatised to local conditions: 5–14 days per year. - People not acclimatised (e.g. out of state): 33–45 days per year. (Y. Zhang et al., 2018)
Agricultural productivity **– Crop yields**				Production-weighted crop yields are estimated to be approximately 1% lower by 2063 for GWL +3.0°C (The Treasury, 2023a). Production-weighted crop yields are estimated to be approximately 3.5% lower for >GWL +4.0°C (The Treasury, 2023a).

People and communities

Physical risks to infrastructure and critical assets are expected to increase, leading to property damage, increased insurance costs and even loss of homes, particularly in coastal areas vulnerable to sea level rise and erosion *(high confidence).* **Direct and indirect economic impacts may be a particular burden on coastal communities or those reliant on climate-sensitive industries.**

- In 2019, approximately 120 ports, 5 power stations, 75 hospitals, 44 water and waste facilities, and 258 police, fire and ambulance stations across Australia were found to be located within 200 m of the coast; if disrupted, they could have significant negative impacts on local communities (Steffen et al., 2019).
- Australian Climate Service analysis of multiple hazards indicates that currently, approximately 6% of residential buildings nationally are in high-risk areas and 7.5% in very high-risk areas, increasing to 9.1% (an additional 139,000 buildings) in very high-risk areas by 2030. Nationally, the number of residential buildings in very high-risk areas is projected to increase from 829,000 (9%) at +1.5°C of global warming to 1,040,000 (11%) at +3.0°C of global warming assuming current population distribution.
Evidence: Communities Technical Report
- Losses in Australian property values could be $571.0 billion in value by 2030, $611.0 billion by 2050 and $770.0 billion by 2100, at a high emissions scenario (RCP8.5). Projected impacts to housing are linked to contractions of industrial activity, reductions in employment, commodity price impacts and critical infrastructure (Steffen et al., 2019).
- One quarter of those impacted by the 2019 Townsville floods did not have insurance (Australian Competition and Consumer Commission, 2020). There is increased risk of insurers withdrawing from highly exposed markets, which may increase this number, particularly for people who are already the most at risk from climate-related disasters. Loss of insurance could lead to loss of access to finance, with flow-on impacts to house prices and, ultimately, household financial wealth and wellbeing.
Evidence: Real Economy Technical Report
- The economic resilience of communities, particularly remote and rural regions heavily reliant on climate-sensitive industries, is likely to be at higher risk under climate change. For example, the Cassowary Coast, a major banana producer in Queensland, faces increased physical and socioeconomic impacts from future extreme events such as (historical) Tropical Cyclones Larry (2006) and Yasi (2011). Changes in temperature, rainfall patterns and extreme weather conditions in future could adversely affect crop yields and livestock productivity, leading to significant productivity losses impacting agriculturally reliant communities.
Evidence: Communities Technical Report

Pressures on the affordability and availability of insurance cover for at-risk communities is likely to worsen, with flow-on impacts on other related sectors *(high confidence).*

- While home and contents insurance cover in Australia has generally been available for most major hazards, not all hazards or their impacts are insurable or insurable everywhere. Notably, actions of the sea, erosion, subsidence and flooding may be excluded from standard policies, excluded for certain types of events, offered as an opt-out or not be covered at all. More frequent and severe hazards are likely to lead to increased impacts that may be opted out of (e.g. optional flood cover) or not currently covered (e.g. sea level rise) in standard building insurance (The Treasury, 2024). This could result in very high uninsured costs after an extreme event.
- Households are likely to face further increases in insurance premiums in the future, decreasing affordability of full insurance cover to households (Australian Competition and Consumer Commission, 2020; Vij et al., 2022) and leading to underinsurance or a 'protection gap'. Swiss Re estimates the protection gap in Australia for natural catastrophe losses for the decade 2014–23 at US$12 billion, which is 33% of the estimated US$37 billion cost of natural catastrophes over that period (Swiss Re Group, 2024). Modelling analysis indicated that in 2024, 15% of households had insurance premiums worth more than 4 weeks of gross household income, a 25% increase from 2023, with Queensland (24%), the Northern Territory (19%) and NSW (17%) facing the highest proportions of households under affordability stress (Paddam et al., 2024). Increased costs in 2024 were primarily driven by increased 2023 reinsurance costs, suggesting that global climate-hazard impacts are adding to domestic insurance affordability pressures.
- There is pronounced regional variation in the rate of non-insurance across Australia. While exact figures are unknown, it is estimated that the rate of home building non-insurance across northern Australia stands at about 20%, compared to about 11% for the rest of Australia (Australian Competition and Consumer Commission, 2020).
- Temporary refusal of insurance cover after multiple and costly floods has already been felt in some areas such as Roma, in Queensland (Suncorp Group, 2014), and more recently in Lismore, NSW. This is driven by the difficulty insurance companies have in pricing risks in a changing environment and their requirements to hold minimum levels of capital to provide a measure of financial resilience to withstand heavy or unexpected losses. Without new models of insurance or reasonable adaptation measures, there is a risk of lower insurance coverage for some hazards in some regions in the future.
Evidence: Real Economy Technical Report

Risks to Aboriginal and Torres Strait Islander economic activities are generally not identified in analyses of the economic impacts of climate change *(medium confidence).*

- Aboriginal and Torres Strait Islander communities have disproportionately limited access to the financial system (Weier et al., 2019).
- There is a risk of continuing economic participation constraints and of not providing opportunities to increase Aboriginal and Torres Strait Islander peoples' participation beyond caring for Country through, for example, the nature repair market and the Australian Carbon Credit Units (ACCUs) scheme as well as agriculture, trading and aquaculture.
Evidence: Aboriginal and Torres Strait Islander Peoples Technical Report
- Aboriginal and Torres Strait Islander consultations highlighted that Aboriginal and Torres Strait Islander peoples and communities' economic activities such as partnerships, local activities, and Caring for Country practices are not well identified or documented and need to be included in assessments of economic participation.
Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering
- Aboriginal and Torres Strait Islander consultations point to compounding constraints faced by Aboriginal and Torres Strait Islander peoples posing a significant risk to their economic participation and their ability to benefit from future market opportunities. Climate change could exacerbate this exclusion as opportunities for Aboriginal and Torres Strait Islander peoples to access employment on Country diminishes.
Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering

Government resources for adaptation and recovery

In addition to direct effects on economic activity, there are direct and indirect fiscal impacts. Climate-related disasters will add fiscal pressure to government budgets *(high confidence).*

- The Australian Government provides direct support to states and territory governments following disasters when state and territory capacity is exceeded. The Australian Government administered expenditure over the period 2018–19 to 2022–23 was $15.9 billion, with the 2 largest programs that account for the Australian Government's disaster recovery expenditure being the Disaster Recovery Funding Arrangements (DRFA) and the Australian Government Disaster Recovery Payment (AGDRP). A large proportion of current funding is weighted towards the built and economic domains (Colvin Review, 2024).
- The Australian Government paid $3.1 billion to state and territory governments through the DRFA from 2018–19 to 2021–22 (Australian National Audit Office, 2023). In 2022–23, $3.2 billion worth of DRFA requests for assistance were assessed, with the Australian Government contributing $1.6 billion and a further $1.9 billion in direct personal benefit payments (National Emergency Management Agency, 2023a).
- In 2022–23 alone, the Australian Government provided over $6.5 billion of disaster funding, with the majority of that funding directed towards responding to significant disaster events which occurred during this period, such as the NSW floods of July 2022 and the southeast Queensland floods of February 2022. This resulted in a $2.4 billion, or 57%, increase on the previous year (Colvin, 2024).
- As compound and extreme weather events become more frequent and severe due to climate change, the costs associated with disaster response, recovery and reconstruction are escalating. DRFA payments could increase, on average, by up to 200% in the medium term (2050) equivalent to +2.0°C. In the long term (2090), this escalates to approximately 600% under a sub +3.0°C scenario respectively (Figure 38). This only covers Australian Government contributions and does not include contributions from states and territories or private costs. Projections show that the increased cost of government DRFA funding over the next 40 years could equate to a cumulative $130 billion in today's dollars (The Treasury, 2023a). The estimated cost of future disasters is likely to be an underestimate because the increasing frequency of extreme events is likely to compound costs of recovery.
Evidence: National Disasters and Emergency Management Technical Report

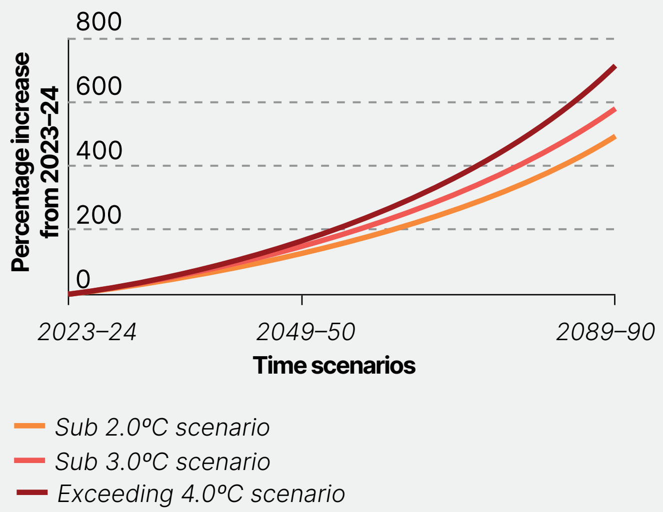
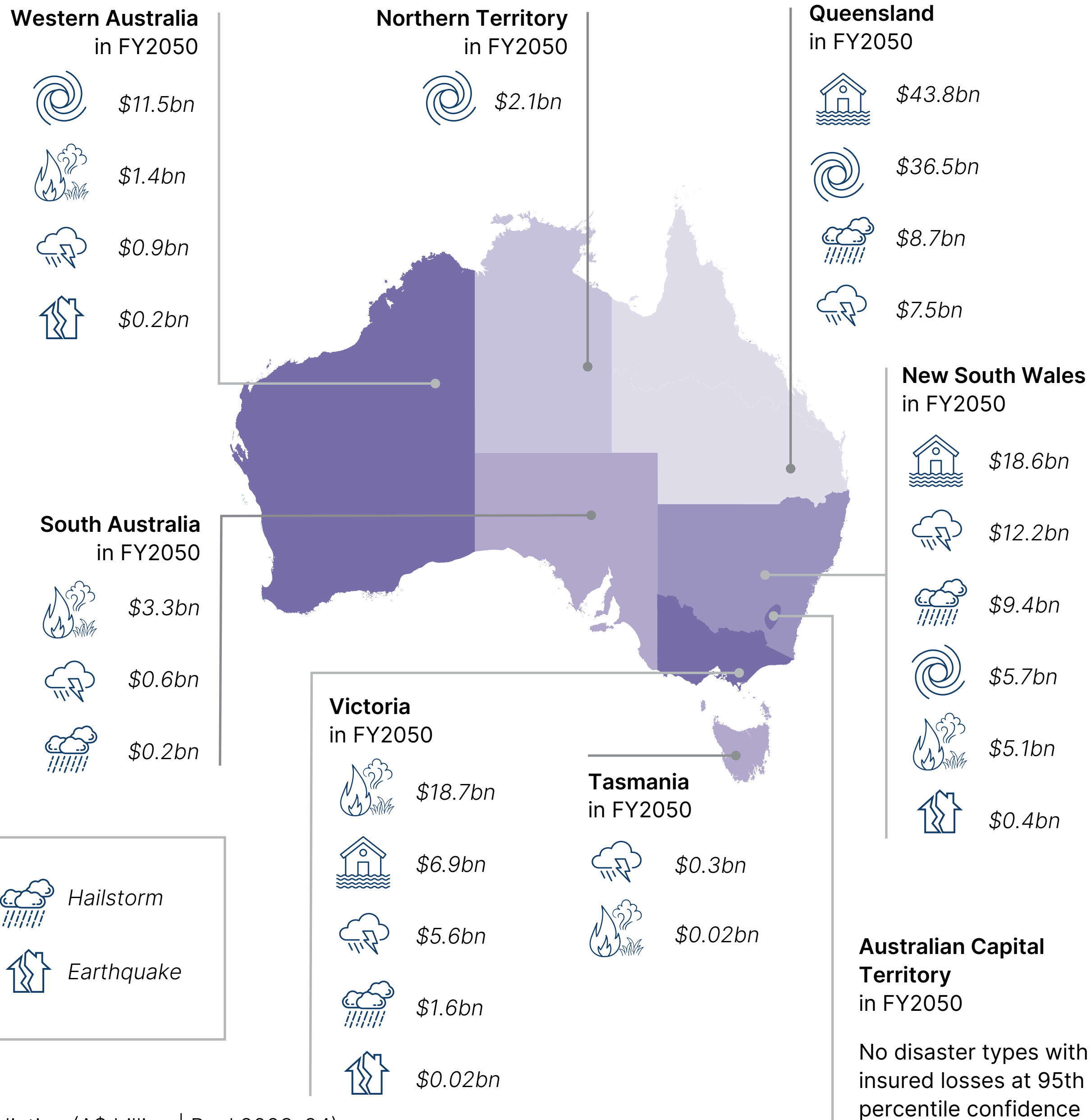


Figure 38: Modelled increase in costs of disaster relief funding (modelled by The Treasury, 2024, supplied to the National Assessment). This only covers Australian Government contributions and does not include contributions from states and territories or private costs.

Note: Treasury modelling used representative concentration pathways rather than global warming levels, so equivalence to global warming levels is shown.

- The Colvin Review (2024) undertook financial and economic modelling to consider how a changing climate may contribute to higher disaster costs across each state and territory for flood, bushfire, storm surge and tropical cyclones across a moderate-emissions scenario and a high emissions scenario to 2049–50. Their estimates are presented in Figure 39.
- Complexities of industrial operations and dependence on production of other industries compound risks beyond current levels. This means that evaluations of physical risks to large public assets may be far behind the actual risk exposure and there may be long lead times to action due to the scale of projects and investment, undermining resilience.
  Evidence: Real Economy Technical Report
- Climate-related disasters and extreme weather events trigger cascading impacts and direct and indirect costs to government through lost incomes and company profits, health and wellbeing issues, and climate migration and conflict (Gao, 2024). This can reduce the ability of governments to provide public services if funds are diverted towards infrastructure recovery and are not available for other government priorities (Steffen et al., 2019).
  Evidence: Real Economy Technical Report



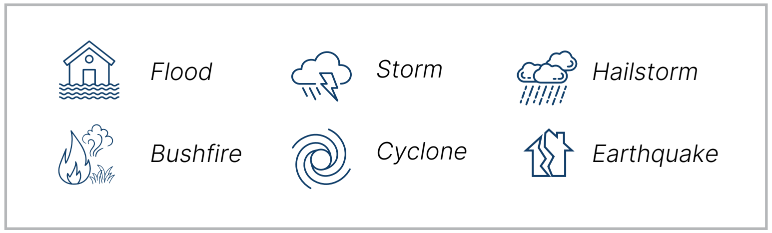


Figure 39: Modelled total annual economic cost by hazard by jurisdiction (A$ billion | Real 2023–24).

95th percentile estimates, including the impact of climate change under a moderate emissions scenario for 2049-50 (adapted from Colvin Review, 2024, from ICA Historical Catastrophe dataset, 2023. ACT has only 2 events with associated insured losses recorded in the ICA dataset).

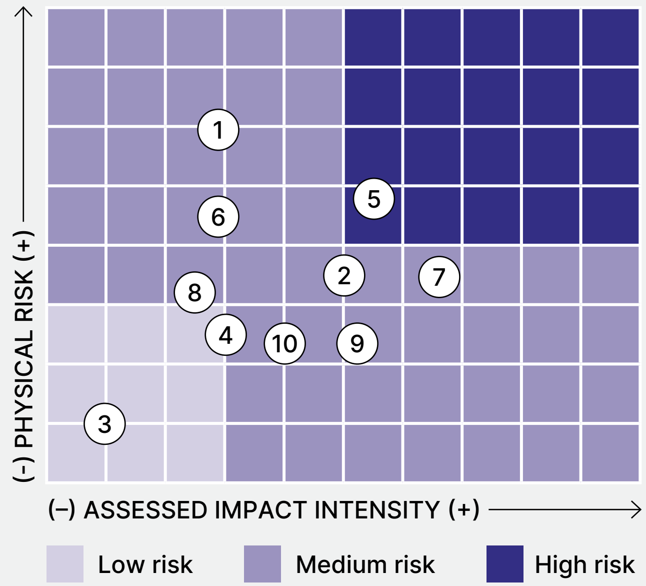
Businesses and domestic supply chains

Businesses are exposed both to direct impacts of extreme climate hazards and indirect impacts from disruptions to supply chains and other critical infrastructure *(high confidence).*

- In 2011, the estimated number and value of coastal assets at risk from the combined impact of inundation and shoreline recession was:
  - 5,800 to 8,600 commercial buildings worth $58.0 billion to $81.0 billion
  - 3,700 and 6,200 light industrial buildings worth $4.2 billion to $6.7 billion
  - 27,000 to 35,000 km of roads and rail worth $51.0 billion to $67.0 billion at 2008 replacement values (Steffen et al., 2019).
- A perceived risk to the construction industry revenue in the medium to long term is financially unsustainable insurance due to pricing to a high level of risk. The cost of rebuilds (housing and infrastructure) after extreme events is also assessed as a high risk.
  Evidence: Real Economy Technical Report

Primary industries (such as agriculture and mining) and construction are already susceptible to climate impacts due to exposure of their activities dependent on natural resources and their outdoor workers. This is likely to reduce productivity and may challenge the viability of some commodities and communities *(medium confidence).*

- Climate risks to the agriculture sector reduce the viability of rural communities and negatively affect social structures in the regions (van Dijk et al., 2013). In rural communities, impacts from hazards on key sectors such as agriculture or nature-based businesses are reducing employment opportunities for residents and impacting mental health (Hanigan & Chaston, 2022; Nicholls et al., 2006; Steffen et al., 2019). Job loss estimates indicate 6,000 jobs lost at the Millennium Drought peak and approximately 7,000 lost due to the 2019–20 Black Summer bushfires (Bowman et al., 2020). Unpleasant working conditions may also push workers into other industries or to leave communities and regions, creating labour and skills shortages and the shutdown of businesses.
  Evidence: Primary Industries Technical Report, Real Economy Technical Report, National Disasters and Emergency Management Technical Report
- Two key vulnerabilities identified by agricultural firms are co-dependence on regional communities and land management practices (Figure 40). Gradual net migration of populations into cities has resulted in a shrinking and ageing of the agricultural workforce in many regional communities. Another vulnerability identified by agricultural stakeholders is cost pressure on inputs from disrupted supply chains, rainfall uncertainty and water irrigation issues, noting that irrigated agriculture, while covering less than 1% of agricultural land, contributes over 25% of total agricultural value and consumes more than 60% of Australia's water resources.
  Evidence: Real Economy Technical Report, Water Security Technical Report
- Increasing heat is likely to lead to significant risks to the future of agriculture and construction industries, with outdoor working conditions increasingly likely to exceed safe thresholds when considering heat-humidity metrics (Figure 41). Currently, heatwaves are estimated to reduce annual productivity by $616 per worker, equating to $5.8 billion, or 0.33% to 0.47% of GDP (Zhang et al., 2011).
- Occupations that are labour-intensive, where outdoor daytime work is common and which rely heavily on physical effort, such as construction, agriculture, tourism and recreation, are already exposed to climate risks (The Treasury, 2023a) and this exposure will increase in the medium to long term. Daytime temperatures are projected to increase in all parts of Australia *(high confidence)* exposing outdoor workers to more heat extremes.
  Evidence: National Disasters and Emergency Management Technical Report, Australia's Future Climate and Hazards Report



1. Significant variations in rainfall
2. Water irrigation issues
3. Subsidies, drought preparedness and disaster recovery assistance
4. Technological change to increase efficiencies in adapting to climate changes
5. Co-dependence on regional communities and land management practices
6. Dynamic changes to land use
7. Pressures on input costs
8. Lead time to rebuilding herds and crop productions
9. Increasing variability of available exports
10. Commodity price variations impacting food prices

Figure 40: Agriculture industry relative risk map based on expert interviews. *(Source: Real Economy Technical Report)*

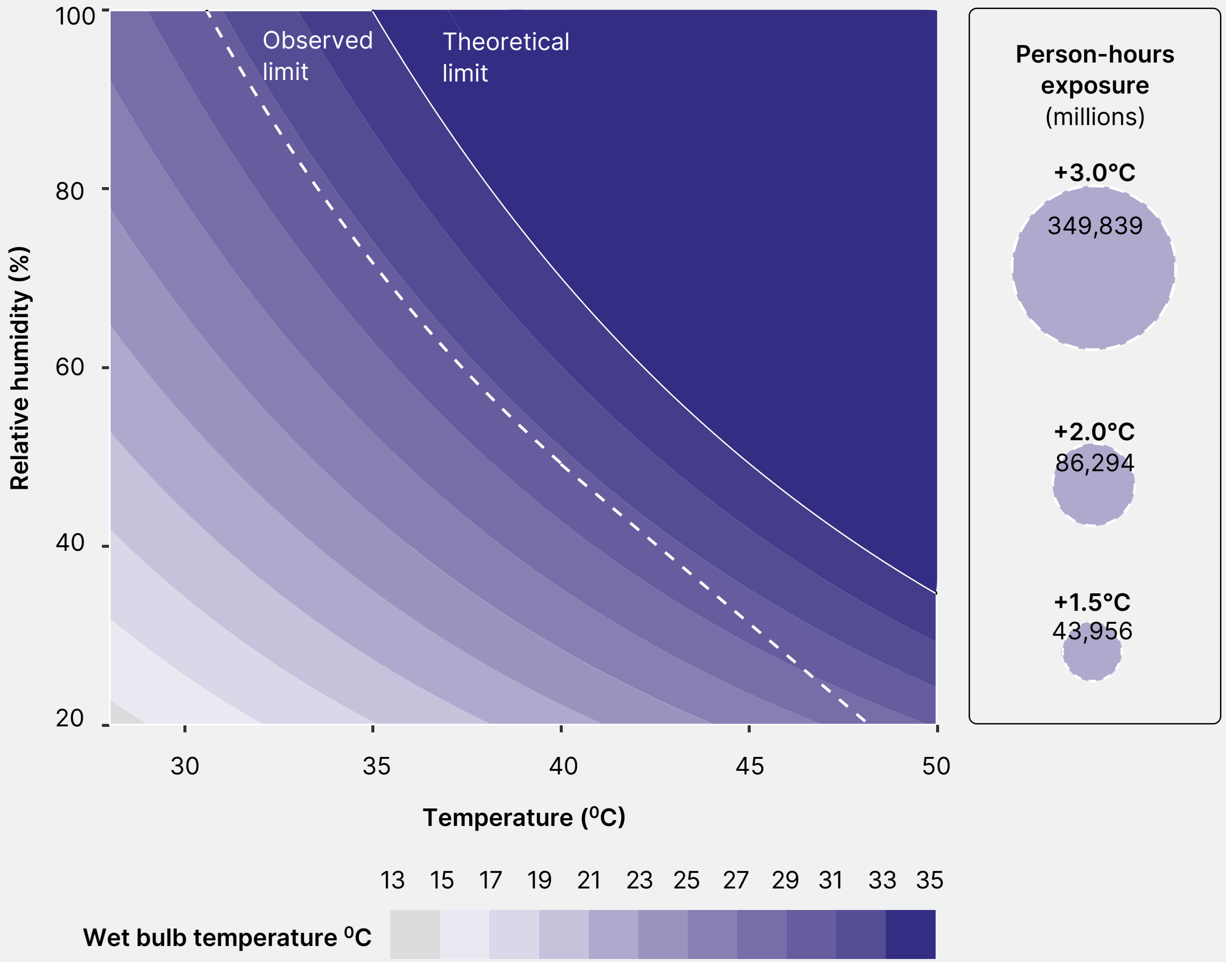


Figure 41: As the humidity rises, it becomes harder for people to cool themselves and maintain a stable core temperature (thermoregulate). Wet bulb temperatures (colour intensity) is a combination of relative humidity (*y* axis) and temperature (*x* axis). The inability to thermoregulate can result in significant health issues; limits to the ability to thermoregulate are indicated theoretically (solid line) and based on observations (dashed line). The number of days of dangerous exposure to wet-bulb temperatures increase significantly from +1.5°C of global warming to +3.0°C of global warming, indicated by circles. (Adapted from Sherwood & Ramsey, 2023).

- In the medium term (by 2061), between 700,000 (GWL +3.0°C) and 2.7 million (>GWL +3.0°C) additional days of work are projected to be lost every year in NSW due to the higher frequency and intensity of heatwaves in agriculture, construction, manufacturing and mining (NSW Treasury, 2021). It is estimated that labour productivity could decrease by 0.2% to 0.8% (GWL +3.0°C–GWL +4.0°C) by 2063, which would reduce economic output by $135.0 billion to $423.0 billion. Labour productivity is generally viewed as a key driver of real wages and national income growth (The Treasury, 2023a).

- Projections indicate that in the long term (by 2070), manual labour in Perth will be dangerous to perform 15 to 26 days per year for agricultural or labour-based work, reducing productivity and employment opportunities (Zhang et al., 2018).
Evidence: Real Economy Technical Report

- Water scarcity threatens the productivity and viability of agriculture. During the Millenium Drought (1997–2009), the agriculture industry's contribution to GDP decreased by approximately 16%, and approximately 6,000 jobs were lost (van Dijk et al., 2013).

- In the medium term, advances in agricultural output driven by innovation may be outpaced by the impact of more frequent and severe natural hazard events, with broadacre cropping farms (on average) facing heightened risk compared to livestock and mixed farms. While individual crop species may respond differently, production-weighted crop yields are estimated to be approximately 1% and 3.5% lower by 2063 at +3.0°C or over +4.0°C of global warming by the end of the century, respectively (The Treasury, 2023a).
Evidence: Real Economy Technical Report

Supply chains face increasing disruptions from climate change, with cascading impacts on primary sectors that depend on them such as agriculture, fisheries and mining. Disruptions in global supply chains caused by extreme weather in key trading regions further compound these risks *(high confidence).*

- The biggest perceived risk to trade is the reliance on transport infrastructure (Figure 42). Coastal assets such as ports, roads and rail connecting to export hubs are particularly vulnerable to many hazards.
  Evidence: Real Economy Technical Report
- The exposure and vulnerability of critical road, rail and port infrastructure to physical climate risks could have an impact on domestic and international trade (Gao, 2024) as well as labour mobility. Disruptions to supply chains have cascading consequences across the economy. Substantial damage to supply chains or increased demand for materials to rebuild after disasters can drive costs and inflation. Impacts include reduced productivity and economic growth, higher food prices and increased cost-of-living pressures (Gao, 2024; Kompas et al., 2018; Lepore & Fernando, 2023).
- Case studies using historical events to assess future impacts show that an extreme event such as the October 2022 eastern Australia floods impacts all sectors across a geographically dispersed area, with the value of blocked freight rising from $4.9 billion in the current climate to $9.3 billion in 2090. Health-related freight (e.g. medicines), although not the largest impacted sector in terms of tonnes, has the largest percentage increase in both required rerouting of freight and value of freight blocked, in both 2050 and 2090.
  Evidence: Supply Chains Technical Report

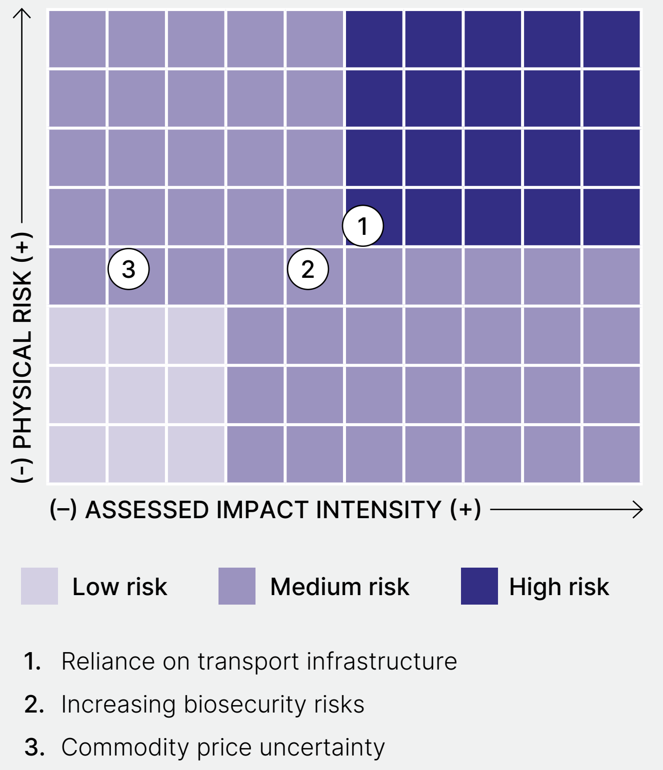


Figure 42: Trade relative risk map based on expert interviews. *(Source: Real Economy Technical Report)*

Extreme heat is anticipated to affect a wide range of infrastructure, with consequential impacts to economic activity. Electricity assets and therefore services are at risk from extreme heat and bushfires *(high confidence).*

- Australia's electricity system assets were built to withstand the weather and temperature extremes of a past climate. These assets are now increasingly likely to be exposed to extreme heat events that are beyond the engineered operating limits, which increases the risk of system outages. Zurich-Mandala (2023) report that more than 25% of Australia's current energy generation assets are in the 3 highest climate risk categories based on the Zurich-Mandala Climate Risk Index. This proportion is expected to increase to 35% of generation capacity by 2050 and approximately 40% of generation assets will experience increased climate risk over this period (SSP2-4.5, GWL +3.0°C).
Evidence: NCRA Phase 0 Electricity and Heat Case Study
- Exposure of power lines and transformers to prolonged extreme heat can cause de-rating (i.e. lowering the rated capability of power systems) and shorten the lifetime of components, requiring more frequent maintenance and increasing the risk of abrupt failure (Dumas, Kc & Cunliff, 2019). Coal- and gas-fired power plants and solar and wind farms, are vulnerable to extreme heat, with potential disruption to generator output and system reliability (Figure 43 and Figure 44). Extreme heat is also a major driver of customer demand, and outages during high-demand periods can potentially leave businesses and consumers vulnerable and incur large economic impacts (e.g. Huang et al., 2020).
Evidence: National Assessment Phase 0 Electricity and Heat Case Study Report, Electricity Sector Climate Information (ESCI) Case Study
- Bushfire risk will increase across most of the National Electricity Market *(high confidence)* and heatwaves will add pressure to the grid (Australian Energy Market Operator, 2020; Zhang et al., 2011). This is very likely to increase power outages, potentially causing further impacts to exposed businesses.

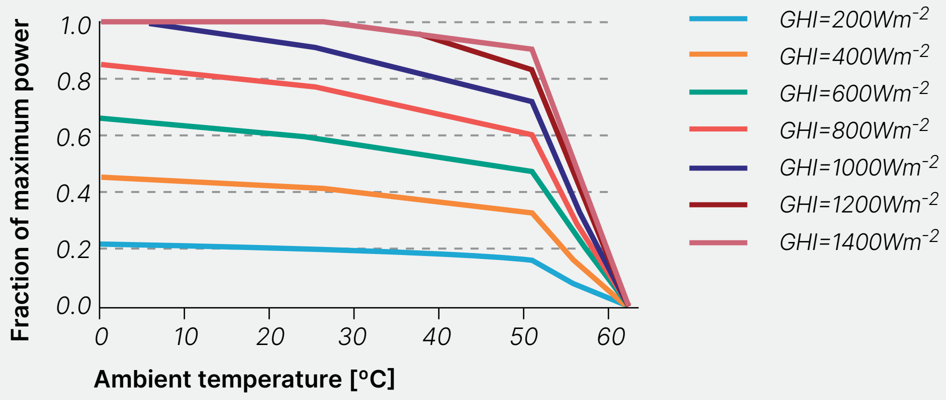


Figure 43: Solar panel output generally increases as the amount of incident sunlight increases (measured as Global Horizontal Irradiance, or GHI). However, modelled power output declines with ambient temperature, falling off significantly for temperatures over 50ºC (adapted from Huang et al., 2020).

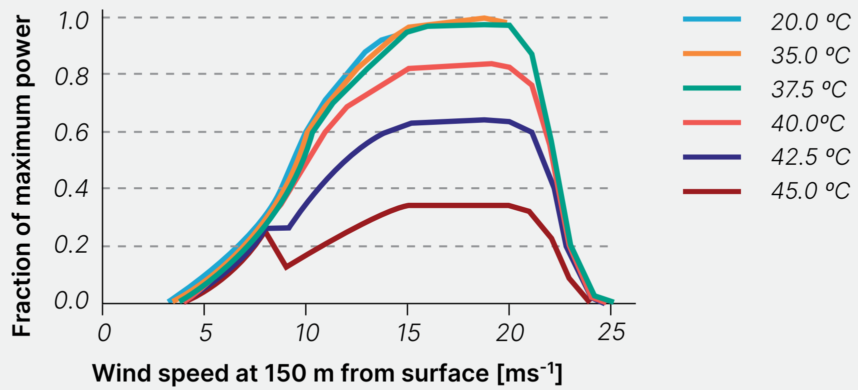


Figure 44: Wind farm output generally increases with wind speed. However, as temperatures rise (shown with different coloured lines) power output declines sharply (adapted from Huang et al., 2020).

Finance and markets

Direct and indirect climate impacts represent a very high risk to the financial system with flow-on consequences to the rest of the economy *(medium confidence).*

- Propagation of climate risk through transmission linkages from the real economy and trade and financial sector were identified by finance stakeholders as a very high risk to the finance system. Shocks to business revenues such as through damage to key economic infrastructure (e.g. electricity, water, transport) transmit into the financial system via declines in cashflows and breaches of loan covenants, or forced assets sales. These relationships are not well understood or widely evaluated.
Evidence: Real Economy Technical Report
- Insurance is a common way to transfer risk that has not or cannot be treated to minimise financial losses and fund recovery. Finance stakeholders identified the critical role of availability and affordability of insurance products as the highest risk to the finance system from physical climate change.
Evidence: Real Economy Technical Report
- Banks and investment funds (including superannuation funds) invest a large proportion of their capital in long-term infrastructure assets and equity markets. If these assets do not generate expected cashflows (due to reduced or disrupted use), attract additional recovery or maintenance costs and suffer impacts to their capital values due to climate risk, these additional risks may lead to significantly lower returns than anticipated, with consequences for the real economy. Similarly, risk assets such as equities are sensitive to climate change, with global analysis suggesting that projected cumulative returns on a 60/40 (equity/bonds) global investment portfolio would be 10% (GWL +1.5°C) to 25% (GWL +3.0°C) lower versus a climate uninformed baseline over the 40-year horizon (Teo & Verdegaal, 2023). The flow-on impacts to superannuation returns would impact working Australians and retirees.
Evidence: Real Economy Technical Report
- Another related potential pathway for flow-on consequences of untreated climate risk is the sustainability of government budgets or debt, with potentially increasing expenditures and decreasing revenues as a result of direct and indirect climate change impacts.
Evidence: Real Economy Technical Report

The well-understood aspects of even moderate scenarios of further climate change have implications for the long-term performance of the Australian economy that are unaccounted for, difficult to quantify and/or often sit beyond the operational planning and decision time horizons in finance and trade. Additionally, high-impact climate change scenarios and events, including tipping points and abrupt changes, hold additional potential risks that are poorly accounted for. Consequently, economic estimates of climate change impacts are widely acknowledged to be highly conservative *(high confidence).*

- Estimates of economic costs in projections are generally based on a limited set of damage functions (a way of relating hazard intensity to costs) and may not consider non-market value losses (Investor Group on Climate Change, 2024; Steffen et al., 2019). These could include impacts on cultural or heritage value or impacts of ecological changes such as reduction in natural pollinators.
- Current productivity measures often provide an incomplete picture, such as of the care and support sector's performance, due to the challenges in fully capturing the value of these services to those benefiting from them (The Treasury, 2023a).
- The full dynamic response of the Australian economy to national and global climate change impacts is poorly understood, even for low or moderate scenarios of future change. There are several ways in which the risks could be much higher, including various 'tail risks'. First, scenarios of high global emissions remain plausible even if unlikely. Second, the global warming response to emissions is often described by the median or likely (>66% chance) confidence interval of achieving a certain temperature outcome, meaning that risks from tails (e.g. <5% or >95% confidence interval) may be left unexplored. Third, the response to a given warming level could be at the high end of the plausible range in terms of change to extreme events (including unprecedented or 'record-shattering' Grey and Black Swan events), climate tipping points and abrupt changes.
  Evidence: Real Economy Technical Report
- High-impact, low-likelihood events and outcomes are difficult to quantify due to few historical observations and smaller sample sizes in projections. Therefore, they are difficult to include in modelled impacts or quantitative projections, meaning these 'tail risks' may actually be increasing. In the absence of large samples of quantifiable projections, these are best considered through plausible worst-case scenarios and storylines of extreme events.
  Evidence: Real Economy Technical Report
- The World Economic Forum (WEF) estimates that roughly half of the world's total GDP relies on the natural world (World Economic Forum, 2020). However the pressures on these resources from human activity and climate change are increasing the risk of terrestrial ecosystem tipping points which are not typically captured in economic impact assessments of climate risks.
  Evidence: Natural Ecosystems Technical Report
- Johnson et al. (2021) estimated that by 2030 the collapse of 3 ecosystem services – wild pollinators, aquaculture and forestry – could reduce global GDP permanently by 2.3% annually. This is expected to be an underestimate as it does not consider potential ecological tipping points and the analysis did not model further interactions between ecosystem services.
  Evidence: Real Economy Technical Report
- Non-market values of coastal ecosystems, including regulating local temperature and humidity as well as providing flood control and protection against coastal erosion, are generally not included in estimates of potential economic losses from climate change. Kompas, Che and Grafton (2024) estimated the non-market value losses from sea level rise in the Kimberley's coastal ecosystem and wetlands to be $4.3 billion by 2050 and $15.8 billion by 2100 at a high-emissions scenario (RCP8.5). Estimates of the physical and economic impacts of coastal sea level rise and storm surge across Victoria are from $9.44 billion per year to 2040, $14.77 billion per year to 2070 and $23.66 billion per year to 2100 (Kompas et al., 2022).
  Evidence: Real Economy Technical Report
- Quantitative methods for including ecosystem tipping points tend to be biased towards underestimation and their assessments need to be improved to include measures of financial, environmental and social costs. Emerging approaches that look at linking financial flows to ecosystem drivers include the Taskforce on Nature-related Financial Disclosures.
  Evidence: Real Economy Technical Report
- More work needs to be done to improve economic modelling of physical risks to capture economy-wide effects such as the inclusion of additional economic impacts that may arise from sea level rise, water stress, health impacts and biodiversity loss. This requires the availability of suitable data, including more disaggregated geographic, sectoral and temporal data to calibrate existing damage functions.
  Evidence: Network for Greening the Financial System, 2024; Expert consultation

Cascades

Impacts on one sector can quickly spread to others through a complex web of interdependencies. Disruptions in supply chains can lead to shortages of essential goods, affecting businesses and households. Novel risks and high-impact, low-likelihood events can destabilise financial markets, leading to broader economic consequences *(high confidence).*

- A wide range of climate impacts and consequences from other systems would flow into the Economy, trade and finance system, especially from the Health and social support system. For example, the health impacts of the Black Summer bushfires of 2019–20, including respiratory issues and other medical conditions, led to significant healthcare expenses. Smoke haze caused daily economic disruptions, costing Sydney alone an estimated $12 million to $50 million per day in reduced productivity and absenteeism (Hughes et al., 2020).
Evidence: Health and Wellbeing Technical Report
- Experts note that that while some analysis aims to quantify flow-on impacts (Figure 45), these reported figures likely do not adequately capture indirect fiscal impacts and the true cost of ongoing associated health, social and community impacts from such events.
Evidence: Real Economy Technical Report

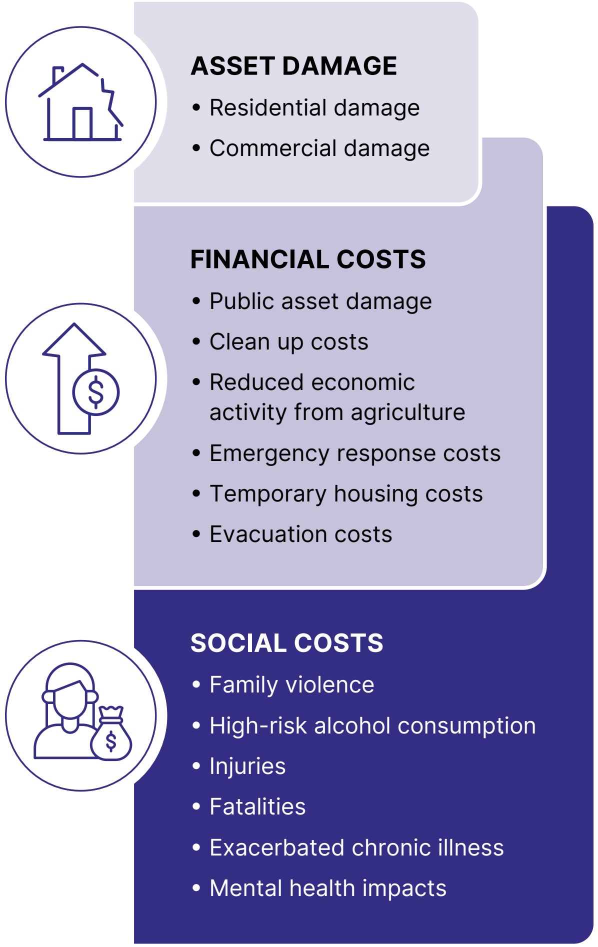


Figure 45: Components covered in the estimates of total economic costs of disasters. (adapted from Colvin Review, 2024).

- Some impacts to the Economy, trade and finance system are likely to originate from unexpected sources, such as disease and pests, as the Australian environment is very susceptible to biosecurity risks. Impacts from multifactor and concurrent risks across industries remain mostly unexplored.
Evidence: Real Economy Technical Report
- The Economy, trade and finance system carries significant governance risk with decisions made in this system being a driver of risks for other systems. The uncertain, urgent, dynamic and long-term nature of climate change risks can strain normal planning approaches, extending beyond typical governance cycles, falling between established roles and responsibilities, and introducing the need for more dynamic, pathways-based planning approaches. Further, the shared or cross-system nature of climate change risks challenges governance structures, processes and relationships.
Evidence: Governance Technical Report
- Stakeholder engagement as part of the National Assessment identified that impacts to and decisions in the Economy, trade and finance system are most likely to compound risks in the Health and social support, Infrastructure and the built environment and Primary industries and food systems (Figure 46).
Evidence: Governance Technical Report

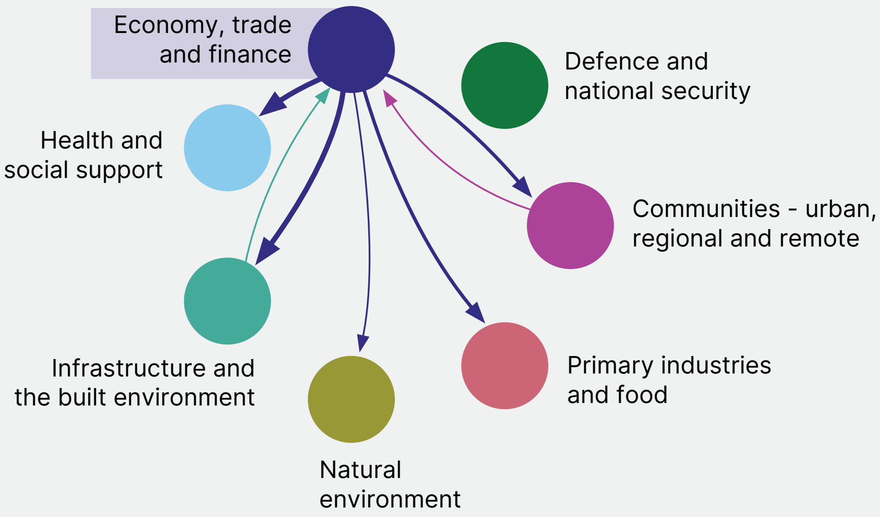
International trade and finance

The Australian economy is affected not only by the impact of climate change on its businesses, infrastructure and resources, but also indirectly through international trade with the rest of the world. This is outside the scope of the current assessment but is noted here for completeness.

- Disruptions in global supply chains due to extreme weather events in key trading regions can lead to increased costs and reduced availability of goods. Additionally, climate-related financial system shocks or volatility in international markets can have flow-on effects on the Australian economy. Increases in global reinsurance pricing is increasing domestic home and building insurance premiums against perils.
  Evidence: Real Economy Technical Report

Figure 46: The flow of adverse impacts from decisions between the Economy, trade and finance system and other National Assessment systems. *(Source: Governance Technical Report)*

Each arrow originates at the system where the decision is made and points towards the system that is adversely impacted. The weight of each arrow represents the number of interactions identified. This data reflects stakeholder engagement workshops. The Aboriginal and Torres Strait Islander Peoples system followed a different approach and is not represented in this data.



Adaptation observations and considerations

This section provides information that can support adaptation planning and approaches.

Investment in resilience is needed across the economy. Currently, most investment related to climate hazards and extreme events comes as a reaction to disasters.

- Experts noted that most investment related to extreme events comes as a reaction to a disaster (Figure 47). Households may find themselves simultaneously subjected to the compounding inflationary impacts from hazard damage, rising insurance premiums and adaptation spending (e.g. 'build back better'). However, in the long term, effective and transformative adaptation measures could provide the resilience required to overcome such financial shocks.
  Evidence: Real Economy Technical Report
- The Investor Group on Climate Change (2024) recommends building a shared understanding of physical risk and resilience, establishing regulations and incentives to support private investment in adaptation, and facilitating innovation in resilience. The Insurance Council of Australia (2024) recommends a 10-year rolling program for disaster resilience, buy-back schemes and prevention of new development in high-risk locations where there is no viable way to reduce risk, tax and levy reform to keep insurance products affordable, and the implementation of formalised recovery arrangements for greater coordination and collaboration between governments and the insurance industry.

Coordinated insurance solutions distribute risk more evenly. While there are some examples of success in this area in reducing premiums, more needs to be done.

- Insurers and banks are most likely to adapt by reducing exposure to climate risks (Australian Prudential Regulation Authority, 2022). Experts note that while this would protect the financial soundness of those institutions, it could transfer risks back to households and businesses (e.g. loss of access to insurance) and thereby degrade access to finance (loans and mortgages generally require an asset to be insured). Adaptation pathways need to consider actions that build the resilience of both the financial sector and the communities it services.
- Some positive economics outcomes have been observed from adaptation actions in the finance system. The $26.5 million Roma flood mitigation project in Queensland commenced in 2019 and consists of a 5.2 km earthen levee. The project has given protection to over 500 homes in Roma. Insurance cover was reinstated by Suncorp following construction of flood protection works and led to a drop in property premiums in the town by an average of 45% by 2021–22 (Queensland Reconstruction Authority, 2022).
- The average tropical cyclone premium has reduced significantly following the introduction of the Cyclone Reinsurance Pool in 2022, an arrangement between insurers and the Australian Government via the Australian Reinsurance Pool Corporation. The gap between affordability stressed and non-stressed households for cyclone insurance in Queensland, the Northern Territory and Western Australia reduced by 19%, 26% and 67%, respectively, in 2024 from the previous year (Australian Competition and Consumer Commission, 2023; Paddam et al., 2024).

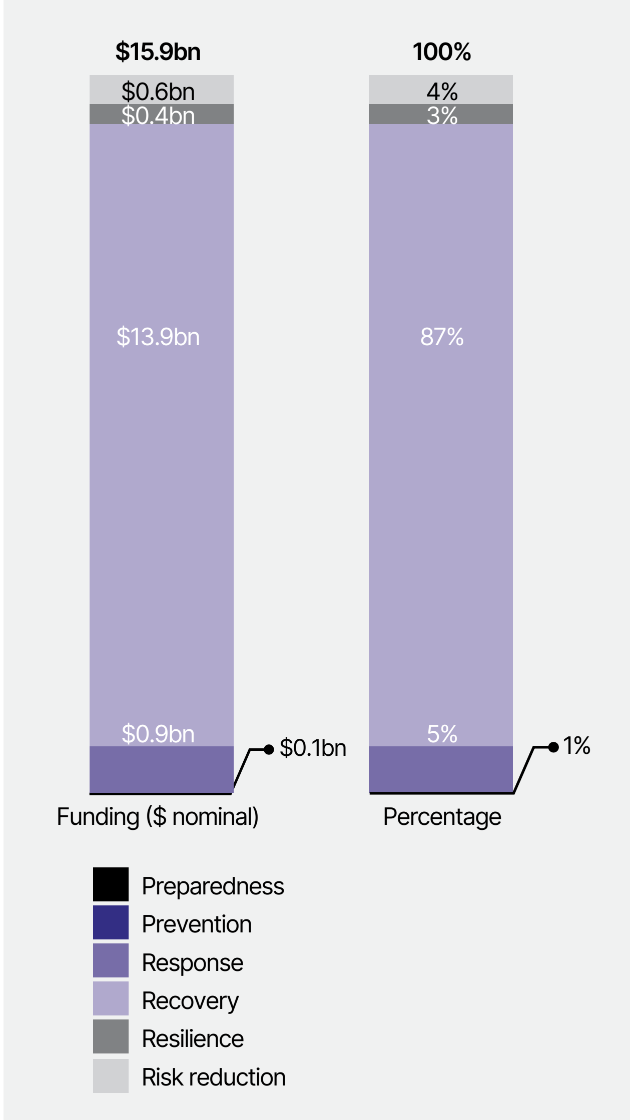


Figure 47: Total Australian Government administered disaster funding across the disaster continuum (Preparedness, Prevention, Response, Recovery, Resilience and Risk Reduction) 2018-19 to 2022-23 (adapted from Colvin Review, 2024). Prevention is not visible.

Governance, regulation and better information provision, including through disclosure regimes, will help adaptation. However, more guidance is also needed on whether risk assessments and better monitoring of proposed solutions are resulting in improved preparedness and reduced impacts.

- The Economy, trade and finance system is responsible for 8% of total policies, plans and laws, and for 5% of total adaptation programs, projects and actions identified in the *Australian Adaptation Stocktake*. Most of these connect to adaptation in the Infrastructure and the built environment system. As with other systems, there appears to be little monitoring or evaluation to understand the long-term effectiveness of adaptation in the system.
Evidence: Insights from the Adaptation Stocktake
- Businesses benefit from data and formal guidance to assess their physical climate risk. Sustainable finance taxonomies and corporate risk disclosure regimes are emerging to fill this gap. The Australian Government is working with the Australian Sustainable Finance Institute to develop a sustainable finance taxonomy, and the *Corporations Act 2001 (Cth)* was amended in September 2024 to introduce new mandatory climate-related disclosure requirements. Improving climate disclosure supports regulators to assess and manage systemic risks to the financial system as a result of climate change (Investor Group on Climate Change, 2024).
- Critical infrastructure assets are regulated by the Cyber and Infrastructure Security Centre (Department of Home Affairs) which provides related businesses with guidance on ensuring continuous operation even when facing disruptions related to climate risk. This has the potential to increase the opportunities for consistency in assessing climate impacts.
Evidence: Real Economy Technical Report

Significant adaptation is already happening in different sectors. Engagement, including with Aboriginal and Torres Strait Islander peoples, is likely to be beneficial in developing solutions that work for specific communities.

- The energy sector (electricity generation, gas production and network), insurance and banking are dominated by large companies that have sufficient resources to conduct climate risk assessments and to invest in resilience activities. However, they are vulnerable to cascading risks and these have flow on effects to other systems.
Evidence: Real Economy Technical Report
- Agricultural firms actively adapt to climate and weather changes in their daily operations and also manage production volatility such as failed seasons, crop losses and water availability. These industries have a large number of relatively small family businesses, with 25% of family workers in Australia reported to be working in agriculture, forestry and fishing (Australian Small Business and Family Enterprise Ombudsman, 2024). They can operate on very thin profit margins and often lack the resources to implement large changes in their operations.
Evidence: Real Economy Technical Report
- Aboriginal and Torres Strait Islander consultations highlighted that Aboriginal and Torres Strait Islander peoples require increased, sustainable and ongoing resourcing to implement Caring for Country plans and effectively mitigate and adapt to the effects of climate change. This could include resourcing Aboriginal and Torres Strait Islander communities and organisations to lead, co-design and deliver training on Caring for Country practices in a changing climate.
Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering
- Aboriginal and Torres Strait Islander consultations highlighted that Aboriginal and Torres Strait Islander peoples can benefit from future market opportunities – for example, increased trade with Papua New Guinea facilitated by the Torres Strait Treaty of 1985. There are opportunities for partnerships with local Aboriginal Land Councils, universities, the Indigenous Rangers program and the Nature Repair Market.
Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering

Case study: Economic impact of Black Summer bushfires of 2019–20 – tourism

Bushfire and associated air pollution can cause loss of life, threaten human health, damage property and infrastructure, and cause widespread environmental impacts, including the destruction of ecosystems and long-lasting impacts to soil and water quality.

This case study provides an example of the resulting social and economic impacts that can last for many years. In the coming decades, there is projected to be a continued increase in the number of dangerous fire weather days *(high confidence)* and an extended fire season across southern and eastern Australia *(medium confidence)*.

The bushfire season in 2019–20 lasted for 8 months between July 2019 and March 2020, with around 240 consecutive days of burning. Fires were burning in northern and central NSW and Queensland. These fires overlapped with fires in the ACT and Victoria. There were simultaneous fires occurring in South Australia and Western Australia, stretching disaster response and recovery resources across the country.

Approximately 7,000 jobs were lost due to the 2019–20 bushfires (Bowman et al., 2020). Tragically, 33 people lost their lives, while thousands more were affected by smoke inhalation and other impacts, increasing health costs. By season's end, bushfires had burned a record 19 million hectares, destroyed more than 3,000 homes, displaced tens of thousands of people, and were estimated to have killed billions of animals.

Costs to governments through financial aid to support disaster recovery at a national and state level were substantial but also injected much-needed economic stimulus. At the national level, the Australian Government delivered its $2.2 billion National Bushfire Recovery Fund which included, among other measures, the Black Summer Bushfire Recovery (BSBR) Grants Program (Australian National Audit Office, 2021). The Victorian Government invested $250 million by establishing programs to help affected communities (Wittwer et al., 2021).

Tourism, including education-related travel, is not only one of Australia's top exports but also generates substantial economic stimulus from domestic travel. Tourism spend in the year prior to Black Summer was more than $120 billion, and tourism employed 5% of Australians overall and 8.1% in rural areas (Tourism Research Australia, 2020). In the immediate aftermath of the 2019–20 bushfires, an estimated 80,000 tourists cancelled or postponed activities (The Treasury, 2023a).

Reiner et al. (2024) quantified the cost of the short-term shock from tourism losses during Black Summer across the entire supply chain, disaggregating the direct fire damages in different tourism sectors.

The study found that tourism shutdown resulting from the bushfires led to a direct loss of $1.7 billion (tourism expenditure and depreciated infrastructure) and to indirect impacts along supply chains of $2.8 billion in total output losses and $1.6 billion in reduced consumption. Aviation suffered the most losses in both consumption and wages/salaries, but while accommodation suffered the most employment losses. The hospitality and transport industries were worst hit, followed by recreational and education sectors (Figure 48). A number of the BSBR grants were received by applicants for use on tourism programs (National Emergency Management Agency, 2024b). To support the tourism industry, the Australian Government provided a $76 million Rebuilding Australian Tourism package and launched a successful domestic travel campaign. However, international and domestic tourism was impacted by COVID-19 travel restrictions following on from Black Summer, making it challenging to assess the long-term effectiveness of the program.

For more information on this case study, see the Real Economy Technical Report.

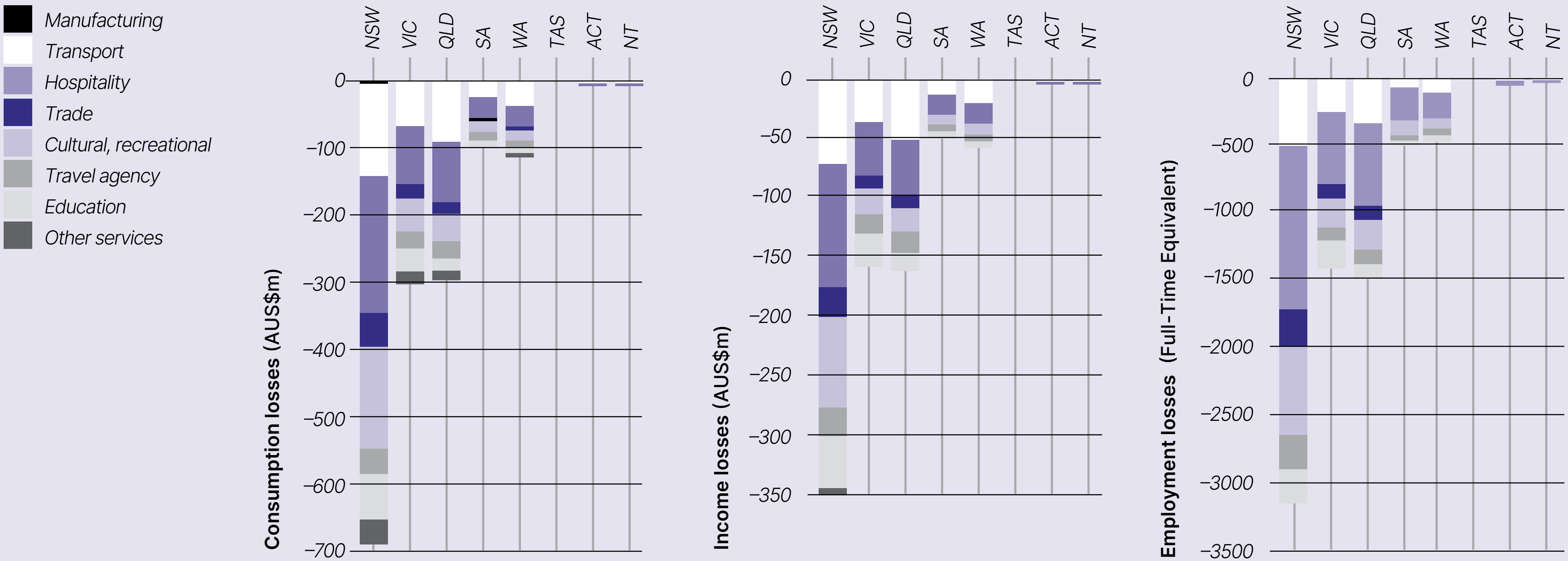


Figure 48: Losses in consumption, income and employment across states and territories due to the tourism shutdown from the 2019-2020 Black Summer bushfires and disaggregated by broad sector groupings (adapted from Reiner et al., 2024).

Health and social support system

Summary

The Health and social support system refers to population health and wellbeing, as well as the provision, availability, and access to health, wellbeing and social support. This system includes services that encompass healthcare, public and preventative health, aged care, disability services, housing support, employment and financial wellbeing and their supporting infrastructure.

Priority risks

The National Assessment has undertaken quantitative and qualitative analysis for priority risks. The first pass assessment identified 9 nationally significant climate risks for this system. One priority risk has been analysed as part of the second pass assessment:

- Risks to health and wellbeing from slow onset and extreme climate impacts.

Health and social support

Climate risks are determined by the interaction of risk elements, including hazards, exposures and vulnerabilities. This is a risk summary for the Health and social support system.

Climate and hazards

- Bushfires
- Droughts
- Changes in temperature, including extreme heat
- Flooding
- Tropical cyclones

Exposures

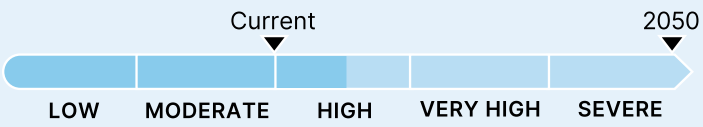
- People and communities particularly in rural and remote areas, including Aboriginal and Torres Strait Islander communities
- People and services in multi-hazard-prone locations
- Ecosystem services that underpin population health (e.g. clean air, water)
- Health system infrastructure, and other critical infrastructure that supports the health system
- Health system supply chains
- Health workforce and service delivery

Vulnerabilities

- Poor socio-economic and/or environmental conditions
- Poor social and community connection
- Limited access to, or quality of, health and social services
- Pre-existing health conditions, including mental ill health
- Extremes of age (i.e. older or very young people)

IMPACTS AND RISKS

- Greater morbidity and mortality
- Increasing heat-related illnesses
- Exacerbations of chronic health conditions, including respiratory and cardiovascular disease
- Higher risk of communicable diseases, including vector-borne diseases
- Rising mental ill health
- Increasing transport costs and reduced access to medicines
- Exacerbation of health inequalities
- Overburdening of health services and infrastructure
- Increasing biosecurity risks
- Reduction in productivity and economic impacts



Assessment of current risk

The current climate risk to the Health and social support system is rated as *moderate–high (medium confidence)*, with noticeable impacts on communities living with disadvantage, people with existing health risk factors, and outdoor workers, emergency services and volunteers.

This system is already experiencing significant pressures due to climate change. Key hazards such as heatwaves, floods, bushfires, droughts and tropical cyclones are becoming more severe, leading to increased mortality and morbidity, particularly from heatwaves and bushfire smoke. The increasing potential for the spread of communicable diseases poses new challenges for the healthcare system.

For groups such as the elderly, those in rural and remote areas, outdoor workers and some Aboriginal and Torres Strait Islander peoples climate change will exacerbate existing health and social disparities and increase pressure on the healthcare system as it attempts to manage the rising demands. Infrastructure supporting population health and health services (such as water infrastructure) is also at risk, while disruptions to supply chains may result in increased costs for transporting essential goods.

Mental health impacts are already being felt by people impacted by hazards and extreme events, including emergency personnel and volunteers, as well as those experiencing solastalgia or climate anxiety as a result of climate change.

Assessment of future risk

By 2050, the climate risk in to the Health and social support system is expected to increase to *severe (medium confidence)*.

The projected rise in frequency and severity of some climate hazards will exacerbate existing health vulnerabilities and disadvantage, and climate impacts will affect a larger proportion of the population and have a broader geographic reach.

Public health risks, including mental health impacts, will become more pronounced, with a significant potential for loss of life from direct and indirect impacts, such as increased communicable disease transmission. The mental and physical wellbeing of coastal, regional and remote communities is at risk, especially among those already disadvantaged. Aboriginal and Torres Strait Islander peoples will face heightened risks due to the disproportionate experience of impacts from climate change, alongside changes to Country and the potential for loss of connection to Country. Certain groups, such as outdoor workers, will face increased health risks due to rising temperatures.

The health system will be further challenged by disruptions to supply chains, particularly for health resources. Climate impacts on transport, infrastructure and other critical systems may also severely affect access to healthcare.

The Health and social support system is likely to become increasingly challenged, as existing systems and services will be less able to cope with changing patterns of surges in demand. Under current conditions and resources, the social services sector is unlikely to be able to deal with the increasing severity of future climate risks without transformational adaptation.

Summary of exposures, vulnerabilities, impacts and risks

Heat, bushfires and health

Australia is already feeling the effects of climate change on human health, with hazards such as heatwaves, floods, bushfires, droughts and tropical cyclones becoming more severe. Heat and bushfires with associated air pollution in particular can have large impacts on population health due to their broad geographic area of impact. These hazards cause a range of health issues, including increased mortality and morbidity. The healthcare system is under growing pressure as it deals with these increasing demands.

Communicable diseases

Communicable disease transmission is a growing concern as many disease pathogens and vectors (such as mosquitoes and ticks) are sensitive to increasing temperatures, altered rainfall patterns, and flooding. Vector-borne diseases such as dengue fever and Japanese encephalitis are particularly climate-sensitive, so risks from these diseases are likely to increase. The Australian healthcare system has less experience managing some of these diseases, which may pose challenges for preparedness and response. There is also evidence that pathogens such as influenza viruses and Staphylococcus bacteria are climate-sensitive, meaning there may be an increasing risk of diseases caused by these pathogens in a changing climate. Preliminary evidence suggests that climate change may also cause mutations in diseases such as influenza and Japanese encephalitis, further increasing health risks.

Risk factors for climate impacts on health

The risks and impacts of climate change on health vary widely depending on factors such as individual health status, geographic region, socioeconomic status and access to support. Neighbouring areas can experience very different levels of risk and impact, and the risk factors can change depending on the hazard. For example, older people are vulnerable to heatwaves as they tend to have poorer thermoregulation, but they may also be vulnerable to tropical cyclones and flooding, as reduced mobility may mean they are unable to evacuate as quickly. Other groups particularly susceptible to the health impacts of climate change include people in rural and remote areas, those working outdoors, women, volunteers, and emergency responders.

Aboriginal and Torres Strait Islander peoples' health

Aboriginal and Torres Strait Islander peoples have a holistic understanding of health and social and emotional wellbeing. Aboriginal and Torres Strait Islander peoples are already experiencing the adverse impacts of climate change, which exacerbate existing health and social disparities. Displacement from Country due to climate change can have severe health and wellbeing consequences, including increased homelessness and weakening of family and social connections, identity, and belonging. Other climate risks to the health and wellbeing of Aboriginal and Torres Strait Islander peoples are due to reduced air quality, extreme heat, flooding, interrupted health services, and energy insecurity.

Infrastructure including supply chains and water security

Climate change is also disrupting the Health and social support system by disrupting critical infrastructure and supply chains, which can reduce access to health services and, as a result, increase morbidity and mortality. For example, the transport of medicines and other essential products is becoming more costly due to climate impacts on road and rail infrastructure. Some extreme events could increase costs up to 25% by 2050 and could double transport costs by 2090.

Introduction

This chapter provides a synthesis of the Health and social support system. It draws on a wide range of technical assessments to provide observations that can enable effective adaptation.

It includes:

- System overview
- Priority risk snapshot
- Key climate hazards for the system
- Exposures, vulnerabilities, impacts and risks relevant to the system
- Adaptation observations and considerations
- Case study

The chapter highlights one priority risk snapshot and draws on the analysis from across all the priority risk technical assessments. It is important to note for this first National Assessment that all 63 nationally significant risks have not been fully assessed. The chapter provides a useful national understanding of climate risks and information that can support adaptation. Climate risks are not static – this work is a sound foundation that should be built on over time.

System overview

Australia's Health and social support system refers to population health and wellbeing, as well as the provision, availability, and access to health, wellbeing and social support.

This system includes primary, secondary and tertiary healthcare, public and preventative health programs, aged care, disability services, housing support, employment in the sector and financial wellbeing, and supporting infrastructure.

The overall health of Australians is considered good, with a high life expectancy at birth when compared with similar countries (Australian Institute of Health and Welfare, 2024a). Over the last 100 years, deaths from infectious diseases have declined, while deaths from chronic conditions, such as cancers and dementia, have increased. Today, chronic conditions are an ongoing cause of substantial ill health, disability and premature death in Australia.

Primary healthcare is provided by general practitioners, community health services, Aboriginal Community Controlled Health Services and allied health professionals. Public and private hospitals offer secondary and tertiary acute, emergency and specialist care, while public health programs focus on disease prevention and health promotion.

Aged care includes both residential facilities for those who can no longer live independently at home, and home care services that help older Australians stay in their homes. Disability services provide essential programs and funding to improve accessibility and inclusion.

Housing support initiatives aim to provide safe and affordable options for low-income families, vital for health and wellbeing, while homelessness services offer emergency shelters and long-term solutions. Employment and financial wellbeing are addressed through job support programs and government benefits that assist those in financial need.

The system’s infrastructure includes hospitals, clinics and other healthcare facilities equipped with the necessary technology and resources. A well-trained workforce of doctors, nurses and allied health professionals is crucial for the system’s functioning. Reliable supply chains ensure the availability of medical supplies and medications.

The Health and social support system is underpinned by the wider determinants – also known as building blocks – of health and wellbeing. These wider determinants include socioeconomic, cultural and environmental conditions, living and working conditions, and social and community networks. Although they are critical to health and wellbeing, many of these wider determinants sit outside the Health and social support system, so addressing them effectively requires a collaborative cross-system approach.

Governance in this system involves collaboration across federal, state and territory, and local levels to develop policies and allocate resources effectively. Regulatory bodies maintain standards and quality assurance in healthcare and social services.

Community health programs and volunteer services play a crucial role in promoting health and wellbeing. Volunteers enhance the system’s capacity and reach, as well as supporting response to disasters, forming a robust network that strives to ensure the resilience of Australia’s population, especially in the face of climate change challenges.

Priority risk snapshot: Health and wellbeing

Risks to health and wellbeing from slow onset and extreme climate impacts.

Rationale

The risk to health and wellbeing from slow-onset and extreme climate impacts is currently rated as **Moderate**. This risk is expected to increase to **Severe** by 2050 and to remain **Severe** through 2090 (Figure 50). Key factors include heatwaves, mental health challenges, and impacts on social cohesion, many of which require both technological and cultural innovations to address. While the health sector has long-established capacity to manage emergencies and implement incremental adaptation, there is a high need for transformational adaptation to address the social aspects of this risk, including social disadvantage. There are significant possibilities for reducing exposure and mitigating risks through transformational adaptations, particularly in the social sector.

Key hazards

- Australia is already experiencing adverse impacts to human health and the Health and social support system from climate change, from both acute hazards such as heatwaves, floods, bushfires and tropical cyclones, and slow onset hazards such as droughts. These hazards are generally becoming more frequent and more intense and can all damage physical and mental health on both short and long timescales.

Exposure and vulnerability

- Factors that increase vulnerability to health impacts include underlying health status, socioeconomic status, housing composition, housing conditions, and access to health and social support services. It also includes the ability to make use of health support and to respond to hazard warnings; for example, people with limited English or limited transport have increased vulnerability.
- Exposure factors include the quality of critical infrastructure, the built environment and how it affects the microclimate, and the proportion of outdoor workers in a region. It also encompasses hazard footprints and how these interact with topology – for example, catchment profiles and floods.

Impacts and risks

- Health risks and outcomes for heatwaves vary considerably spatially and across society (Figure 49).
- We can expect increases in hazard-related morbidity and mortality associated with heatwaves and bushfires in the future. Quantitative modelling of the expected mortality for heat-attributed deaths across Australia demonstrates that in many

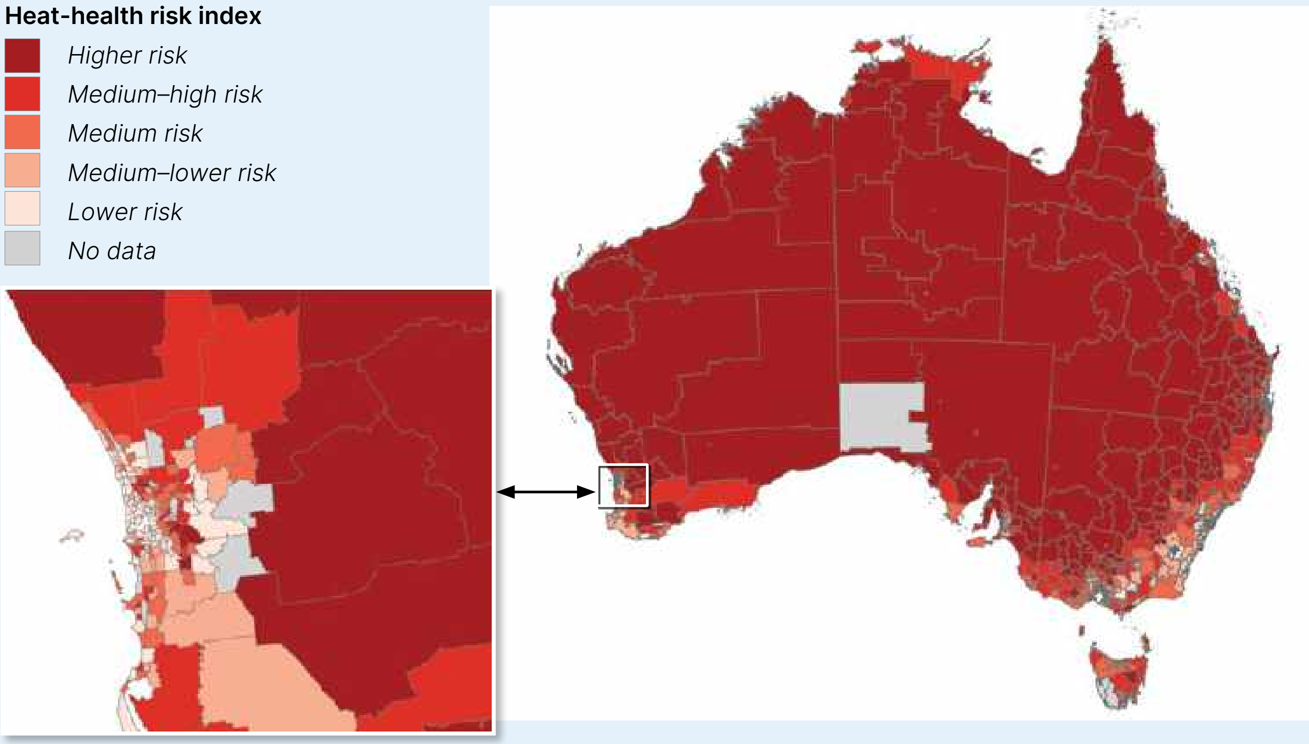


Figure 49: Heat-health risk index has been calculated for Australia by the 2021 Statistical Area Level 2 regions. A close-up view of Perth is shown to demonstrate how overall risk can change. Examples of high risk factors include low socio-economic index and high built environment exposure due to low urban greening (adapted from the Australian Climate Service, 2024).

RISK RATING	Current	2050	2090
Severe			
Very High			
High			
Moderate			
Low			
ACS RISK CONFIDENCE RATING	*High*	*High*	*Medium*

TYPES OF RESPONSE REQUIRED

Improved management: *Enhancing efficiencies within existing systems without major changes*

Incremental adaptation: *Gradual adjustments to systems without altering their core*

Transformational adaptation: *Fundamental changes to systems, significantly shifting risk management*

Response required *Some level of response required* *Response not required at this time*

Figure 50: Rating for the Health and wellbeing priority risk for current, 2050 and 2090 and the types of responses required to address the risk. For definitions of risk ratings, please see Figure 9.

locations there is a very significant increase in projected heat-related deaths at global warming level +3.0°C compared with the current climate.

- Health and social support services may not keep up with more frequent, severe and longer duration events, particularly where the events also compromise critical infrastructure.
- Bushfires and associated poor air quality are a significant and increasing driver of poor health outcomes, particularly those associated with cardiovascular disease and respiratory disease.
- Future climate-related health impacts are closely linked to other systems at risk, such as supply chains or local economic impacts, such as impacts on agriculture in communities that are centred on these industries.

Adaptation

- Effective adaptation strategies in the Health and social support system must consider and address a wide variety of risk factors to the health impacts of climate change. Key factors that may determine an individual's or population's vulnerability to these impacts include access to resources, knowledge, technology, and social networks for individuals and communities, which enable effective adaptation and resilience. For example, individual responses to health risks are influenced by factors such as health service access and social connectedness, while community-level responses depend on infrastructure and collective social networks.
- Adaptation options should focus both on the regional geography of risk (areas where hazards will significantly increase) and interventions appropriate for different places and segments of society. Places that share similar hazard profiles but different risk profiles can provide insights.
- Remote communities, including Aboriginal and Torres Strait Islander communities, face heightened health risks from climate-related water security challenges. Effective adaptation to these challenges may include making sufficient plans to monitor, maintain and repair remote water assets, particularly during emergency events.
- Improving ventilation or filtration in areas susceptible to higher temperatures, storms, extreme winds and tropical cyclones may mitigate the indirect increase in the spread of airborne diseases due to increased congregation of people inside, poor ventilation and increased air-conditioning use.
- Complex relationships between risk factors suggest that addressing single risk factors is not likely to be effective and risks maladaptation.

Key climate hazards for the system

This section describes the changing climate hazards that most affect the Health and social support system.

Australia is already experiencing adverse impacts on human health and the Health and social support system from climate change, especially from hazards such as heatwaves, floods, bushfires and tropical cyclones. These hazards are generally becoming more frequent and more intense, and can damage physical and mental health on both short and long timescales *(high confidence)*.

Table 10: Hazard types ranked by fatalities caused, all time periods (ranked by the 1967–2022 period). Data from Risk Frontiers' PerilAUS data. *(Source: Risk Frontiers, 2023)*

Note: Heatwave statistics represent lower-bound best estimate.

Rank	Hazard	1967–2022		1990–2022	
		Deaths	%	Deaths	%
1	Heatwave	1,202	34.9	909	38.4
2	Flood	636	18.5	399	16.9
3	Bushfire	568	16.5	311	13.2
4	Gust	564	16.4	509	21.5
5	Cyclone	231	6.7	62	2.6
6	Lightning	111	3.2	59	2.5
7	Landslide	70	2.0	68	2.9
8	Earthquake	14	0.4	14	0.6
9	Tornado	13	0.4	3	0.1
10	Rain	33	1.0	30	1.3
11	Hail	1	0.0	1	0.0
	All hazards	3,443	100.0	2,365	100.0

- The top 11 deadliest natural hazard types in Australia are listed by rank in Table 10. Two periods of interest are depicted: 1967–2022 and 1990–2022. The hazard types have been ranked according to the 1967–2022 period.
- Heatwaves are an enduring feature of Australia's climate, and have significant social, health (physical and mental) and economic impacts (Lawrence et al., 2022). Extreme heat leads to more deaths and hospital admissions than any other hazard in Australia (Coates et al., 2014, 2022). Currently, Australia experiences 4 days per year at the severe or extreme level (the levels at which the Bureau of Meteorology issues warnings; Nairn & Fawcett, 2014). The number of days when heatwaves are experienced is projected to increase, with the highest increases expected across northern Australia *(high confidence)*. The impacts of extreme temperatures can be compounded if they occur with other factors such as high humidity (Sherwood & Huber, 2010) or arid conditions (Hao et al., 2022).
Evidence: Australia's Future Climate and Hazards Report
- Susceptibility to fire across southern and eastern Australia is projected to grow due to increases in temperatures and the frequency of heatwave conditions, along with more time spent in drought *(high confidence)*. There is very likely to be an increase in the number of dangerous fire weather days and a longer fire season, with the potential for more megafires *(high confidence)*. The degree to which vegetation changes over the 21st century will alter overall fire risk in some locations. At high warming levels, megafires may become less likely due to the reduction in forested areas (with trees replaced by greater areas of grassland/scrubland) *(medium confidence)*. These changes are likely to have adverse effects on health and wellbeing as bushfires and the associated poor air quality are significant drivers of poor health outcomes.
Evidence: Australia's Future Climate and Hazards Report
- Tropical cyclones pose a significant threat to human health and lives as they expose people to numerous related hazards, including extreme winds, storm surge, flooding and landslides (Do & Kuleshov, 2023). Tropical cyclone frequency is projected to decrease *(medium confidence)*. However, in recent decades there have been more high-intensity tropical cyclones. Projections indicate that, globally, a greater proportion of tropical cyclones will be of high intensity, with greater rainfall and higher storm surges due to rising sea levels *(high confidence)*.
Evidence: Australia's Future Climate and Hazards Report
- Riverine and flash flooding affects both physical and mental health through displacement, potential drownings, and trauma from exposure to the event including through loss of possessions and income. In parts of the east coast and tropics, an increase in annual severe run-off is projected, with a potentially greater risk of flooding. More intense short-duration, heavy rainfall events are projected, even in regions where the average rainfall decreases or stays the same *(high confidence)*. This could lead to flash flooding.
Evidence: Australia's Future Climate and Hazards Report
- Drought affects people's physical and mental health when they are required to move to more secure water sources or the livelihood of their communities is compromised. Time spent in meteorological drought is projected to increase across large areas of the country, particularly in southern and eastern areas *(low to medium confidence)*. Aridity is projected to increase in the southwest of Western Australia and across parts of the southern mainland *(high confidence)*.
Evidence: Australia's Future Climate and Hazards Report

Exposures, vulnerabilities, impacts and risks

This section provides a summary of impacts and risks associated with the Health and social support system (Table 11).

These have been identified by understanding the changing climate hazards, as well as exposures and vulnerabilities that drive them.

Table 11: Summary of impacts to the Health and social support system and adaptation examples, derived from analysis for the National Assessment. Further details, including information sources, can be found throughout this chapter.

Climate impact	Current	Future			Current climate adaptation examples
	GWL +1.2°C	GWL +1.5°C	GWL +2.0°C	GWL +3.0°C	
Heat-related health impacts	Heatwaves are the deadliest natural hazard in Australia, and increased temperatures have significant adverse health outcomes.	Heat-related mortality rises relative to current – for example: 103% in Sydney, 60% in Melbourne, 94% in Townsville, 68% in Perth, 52% in Launceston and 112% in Darwin.	Heat-related mortality rises relative to current – for example: 190% in Sydney, 126% in Melbourne, 159% in Townsville, 139% in Perth, 88% in Launceston and 199% in Darwin.	Heat-related mortality rises relative to current – for example: 444% in Sydney, 259% in Melbourne, 335% in Townsville, 312% in Perth, 146% in Launceston and 423% in Darwin.	Cooling centres in cities and rural areas. Resilience education for vulnerable groups. Increased capacity for emergency and health services during peak heat seasons. Green infrastructure and effective insulation.
Air quality	Increased air pollution from dust and bushfires impacting respiratory, cardiovascular and mental health.	Susceptibility to fire increases in southern and eastern Australia, increasing the risk of air pollution for large population centres.			Effective insulation. Air filtration systems in homes and schools. Initiatives to improve air quality in public spaces. Education for communities on smoke dispersion and health impacts during fire season.

Climate impact	Current	Future			Current climate adaptation examples
	GWL +1.2°C	GWL +1.5°C	GWL +2.0°C	GWL +3.0°C	
Mental health	Drought, flood and bushfire negatively impacts physical and mental health of communities and emergency services personnel.	Increased frequency and severity of hazards impacting the mental health of communities and emergency services personnel.			Mental health services and support programs. Training for community responders in trauma-informed care. Community resilience programs for post-disaster recovery.
Aboriginal and Torres Strait Islander health	Increased heat, bushfire smoke and air pollution, causing health issues such as premature death from chronic health conditions. Impacts to Country affect health and wellbeing.	Increased population exposed to more frequent and severe heatwaves in northern Australia.	Population exposed to more frequent and severe heatwaves in northern and central Australia with +2.0°C of warming and across Australia at higher warming. Increased displacement after extreme events increases mental and physical health impacts.		Public housing standards that meet cultural needs and suitable for current climate and future scenarios. Shaded public spaces and access to cooling. Health service provision in remote areas. Targeted outreach and education on heat safety. Cool refuges, air conditioning and cooling devices for vulnerable groups.
Infrastructure, including supply chains and water security	Hazards can damage infrastructure supporting health, including supply chains and water-quality infrastructure.	High-intensity rainfall is becoming more frequent, which can increase the risk of outbreaks from pathogens such as cryptosporidium and cyanobacteria.	Disruption to the east–west freight route could increase medicine transport expenses from current costs by 29% in 2050.	Disruption to the east–west freight route could increase medicine transport expenses from current costs by 100% in 2090.	Programs to improve flood resilience and to monitor water supply issues for rural infrastructure. Programs to increase resilience of supply chains and increase local self-sufficiency.
Biosecurity and communicable diseases	Communicable diseases are climate-sensitive and influenced by warming temperatures, rainfall and flooding.	Increases in communicable disease incidence (including, but not limited to, airborne, water-borne and vector-borne diseases) from rising temperatures and increased rainfall variability.	By 2050, tropical monsoon zones may expand, increasing dengue fever risk.	Diseases such as influenza or Japanese encephalitis may mutate due to changes in maximum and minimum temperature and rainfall.	Vaccination against climate-sensitive communicable diseases. Surveillance and public health education on communicable disease risks and prevention in a changing climate. Mosquito control programs (e.g. habitat management).

Heat, bushfires and health

Increasing heat and bushfires are key drivers of escalating climate risks to health in Australia due to their large geographic area of impact and high mortality and morbidity outcomes. Heatwaves are projected to become more frequent, severe and longer-lasting. This will have significant implications for human health outcomes, including increases in hazard-related morbidity and mortality *(high confidence).*

- Extreme weather events such as heatwaves and bushfires cause a range of health issues, including (but not limited to) increased mortality and morbidity from heatwaves and increased cardiovascular and respiratory problems due to bushfire smoke. For example, a +1.0°C increase in temperature is associated with a 2.1% increase in risk of cardiovascular disease-related mortality (Liu et al., 2022).
- Heatwaves have an impact on the everyday quality of life of Australians, including work and recreation. They can also affect the entire social support system, including economic impacts through disruptions to infrastructure, supply chains and business.
Evidence: Health and Wellbeing Technical Report
- The number of severe and extreme heatwaves are projected to increase, with the greatest increases in the northern parts of Australia. Heatwaves will be more extensive, longer-lasting and more severe, leading to an increase in deaths, heat-related illness and pressure on health services. At +3.0°C of global warming, heat-related mortality is projected to increase by 444% in Sydney, 259% in Melbourne, 335% in Townsville, 312% in Perth, 146% in Launceston and 423% in Darwin compared to current conditions (note that the population demographics do not change in these mortality calculations, so changes are relative to today) (Figure 51).
Evidence: Health and Wellbeing Technical Report, Australia's Future Climate and Hazards Report
- The footprint and intensity of heatwaves is changing, with significant spatial and social variation in their impacts. During extreme heatwaves across southeast Australia in January 2009, 5 million people in Adelaide and Melbourne were exposed. In Victoria, this resulted in 374 excess deaths (State Government of Victoria, 2009). Looking ahead, the Australian Climate Service modelling demonstrates that some extreme heatwaves could become larger spatially, and more intense, resulting in a significant increase in deaths (Figure 51).
Evidence: Australia's Future Climate and Hazards Report

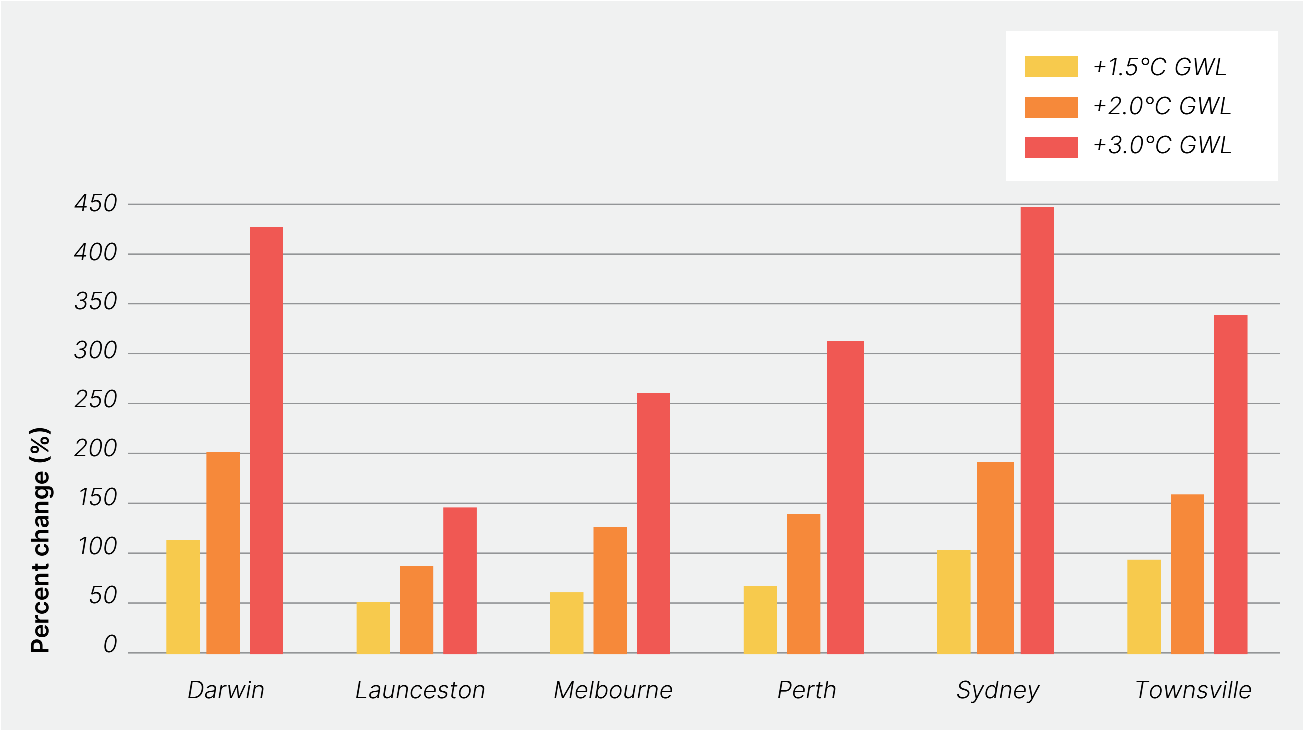


Figure 51: Modelled increase in heat-related mortality for a range of cities by global warming level compared to the current period. *(Source: Health and Wellbeing Technical Report)*

- Australian Climate Service hazard modelling of an extreme heatwave scenario around the year 2050 (Figure 52) shows that the extent of heatwaves could increase significantly. In this scenario, 3 large population centres are exposed simultaneously. This would significantly increase pressure on health services and emergency response.
- The temperature on the hottest day of the year is projected to increase over the Great Dividing Range and some desert regions. These are regions where outdoor workers and emergency management personnel and volunteers are likely to be more exposed to heat extremes. This may have impacts on productivity for some industries, including mining and agriculture, and could make it harder to respond to emergencies safely. Additionally, construction during hot days is becoming more dangerous.

Evidence: National Disasters and Emergency Management Technical Report, Australia's Future Climate and Hazards Report, Real Economy Technical Report

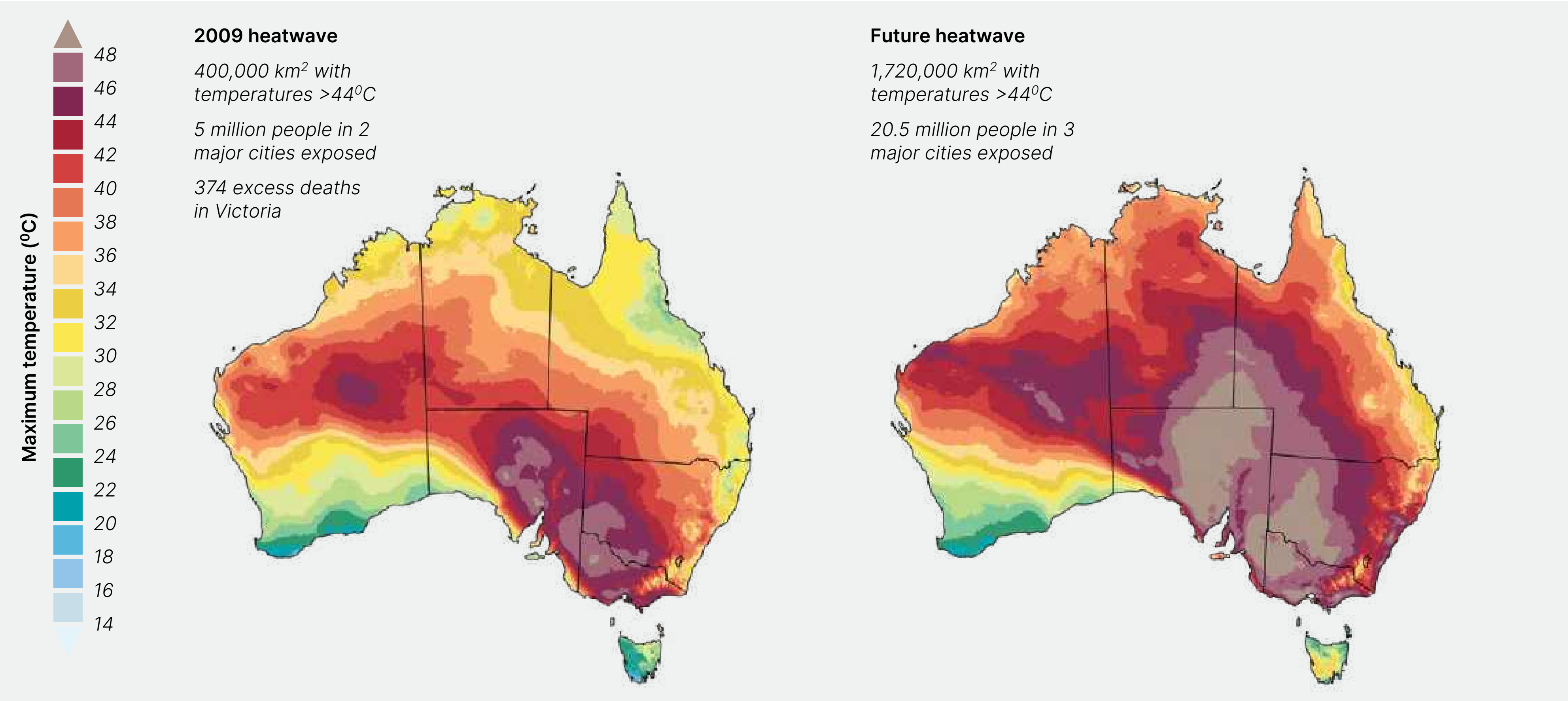


Figure 52: Historical heatwave risks compared to a future heatwave scenario when global warming levels reach +3.0°C above pre-industrial warming.
This future scenario is not a forecast but can help us anticipate and plan for possible future events by comparing with past events.
Note: In this projection, heatwaves occur simultaneously in at least 3 major cities (see case study in Australia's Future Climate and Hazards Report).

Increasing frequency of bushfires, with associated increases in bushfire smoke and air pollution, will result in increased impacts for people with respiratory conditions, with potential increases in mortality in the longer term. Smoke exposure is harmful to the respiratory and cardiovascular systems, and to mental health. There is likely to be greater population exposure to harmful bushfire smoke due to increased bushfires in forest regions close to highly populated areas in the south and east, and more frequent savannah fires affecting northern populations *(high confidence).*

- Bushfire events can cause large emissions of gaseous and particulate air pollutants. Particulate matter is thought to be the main health hazard arising from bushfire smoke – especially Particulate Matter 2.5 (PM2.5), very small particles that make up around 90% of particulate matter emitted from bushfires. Particulate matter has adverse impacts on the respiratory and cardiovascular systems, and on mental health (Australian Institute of Health and Welfare, 2020), and has also been associated with low birth weight (Birtill et al., 2024). Australian cities are frequently affected by bushfire smoke given their proximity to highly flammable native vegetation and their exposure to hot, dry weather conditions that favour combustion.
  Evidence: Air Quality and Communicable Disease Technical Report
- Past events such as the bushfires over the summer of 2019–20 provide evidence of increased damage to health and premature deaths from chronic health conditions such as coronary heart disease resulting from bushfire smoke and air pollution. The impact of past events was higher on some population groups, such as people in lower socioeconomic groups and Aboriginal and Torres Strait Islander people.
  Evidence: Health and Wellbeing Technical Report

Biosecurity and communicable diseases

The risk from communicable diseases is likely to rise. Both vector-borne and non-vector-borne infections pose growing risks in a warming world. Health and climate adaptation strategies must prioritise both the increased prevalence of existing diseases (such as influenza and methicillin-resistant Staphylococcus aureus, or MRSA) and the potential rise of new climate-sensitive diseases (such as vector-borne infections). There is preliminary evidence that the changing climate can induce mutations in diseases such as influenza and Japanese encephalitis, which may increase risks in Australia *(low confidence).*

- The incidence of many communicable diseases is expected to increase with rising temperatures. Recent research found that a +1.0°C increase in annual maximum surface air temperature was associated with an increase in annual viral influenza rates (across Australia) and bacterial MRSA rates (across northern Australia based on the data used for the modelling). As the incidence of these diseases is already high, increases in incidence are likely to have a significant impact on the burden of disease and healthcare demand in the near term.
  Evidence: Air Quality and Communicable Disease Technical Report
- Mosquito-borne diseases are the most climate-sensitive transmission type of communicable disease in Australia, with other vector-borne diseases, food- and water-borne diseases, zoonotic diseases and soil-borne diseases also aggravated by multiple climate conditions (Figure 53). While airborne diseases are aggravated by some climate conditions, the impact is indirect. For example, multiple climate conditions can increase the spread of airborne disease due to increased congregation of people inside, poor ventilation and increased air-conditioning use (He et al., 2023).
  Evidence: Climate and Communicable Disease Discussion Paper
- Salmonellosis is the most common cause of food-borne disease outbreaks in Australia (OzFoodNet Working Group, 2021, 2022). Each year there are around 55,000 cases of non-typhoidal salmonellosis in Australia, amounting to an estimated $140 million in total public health costs (Australian National University, 2022; Hall et al., 2008; Queensland Health, 2024). Warming is likely to increase the incidence of salmonellosis in Australia. A +1.0°C increase in mean temperature is associated with an increase of up to 15% in incidences of salmonellosis (Milazzo et al., 2016; Zhang et al., 2010).
  Evidence: Climate and Communicable Disease Discussion Paper
- There is preliminary evidence that changes in maximum temperature, minimum temperature and rainfall from climate change can induce mutations in pathogens relevant to Australia (influenza and Japanese encephalitis).
  Evidence: Air Quality and Communicable Disease Technical Report

	Climate condition						
	Warming	**Rainfall**	**Flooding**	**Drought**	**Extreme storms, winds and cyclones**	**Bushfires and grassfires**	**Coastal erosion, shoreline change and ocean warming**
Vector-borne – mosquito	Strongly aggravating	Strongly aggravating	Strongly aggravating	Moderately aggravating	Moderately aggravating	Moderately diminishing	Low/little climate sensitivity
Vector-borne – other	Strongly aggravating	Moderately aggravating	Moderately diminishing	Moderately diminishing	Moderately diminishing	Moderately diminishing	Low/little climate sensitivity
Food- and water-borne	Strongly aggravating	Strongly aggravating	Moderately aggravating	Low/little climate sensitivity	Moderately aggravating	Low/little climate sensitivity	Moderately aggravating
Zoonotic	Moderately aggravating	Moderately aggravating	Moderately aggravating	Moderately aggravating	Moderately aggravating	Moderately aggravating	Moderately aggravating
Soil-borne	Moderately aggravating	Strongly aggravating	Strongly aggravating	Low/little climate sensitivity	Strongly aggravating	Low/little climate sensitivity	Low/little climate sensitivity
Air-borne	Moderately aggravating	No published climate link	No published climate link	Low/little climate sensitivity	Moderately aggravating	Low/little climate sensitivity	No published climate link
Blood borne	No published climate link	No published climate link	No published climate link	No published climate link	No published climate link	No published climate link	No published climate link
Sexually transmitted	No published climate link	No published climate link	No published climate link	No published climate link	No published climate link	No published climate link	No published climate link

Climate condition impact

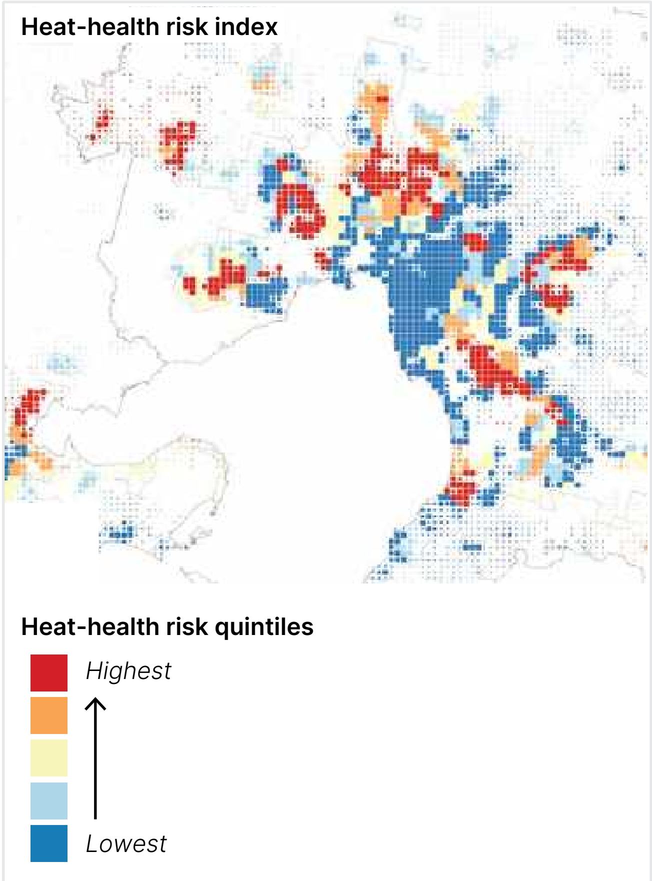
No published climate link	Moderately diminishing	Low/little climate sensitivity	Moderately aggravating	Strongly aggravating

Figure 53: Summary of climate condition impacts on communicable disease transmission categories in Australia. *(Source: Climate and Communicable Disease Discussion Paper)*

Risk factors for climate impacts on health

Climate-driven risks and the severity of potential impacts on health and wellbeing vary considerably depending on individual risk factors, region, socioeconomic vulnerability, local conditions and access to support. These variations in risk can occur in close proximity – for example, in adjacent LGAs or even by neighbourhood *(high confidence).*

- There is considerable variation in health-hazard risk across Australia broadly, but there is also a high contrast between locations in close proximity due to local factors. For example, the risk profile from heatwaves can vary significantly depending on urban greening, access to transport, or concentrations of people with low socioeconomic status (Figure 54).
Evidence: Health and Wellbeing Technical Report
- Different risk factors are relevant for different hazards. For example, older people are vulnerable to heatwaves as they have poorer thermoregulation and so are unable to cool down as effectively (Figueiredo et al., 2024). Meanwhile, older people are vulnerable to tropical cyclones and flooding because mobility issues can mean they are unable to evacuate as quickly (Gamble et al., 2016). There could be important cultural factors that increase vulnerability to severe hazards, including difficulty in understanding official advice or poor awareness of local hazards, as may be the case with culturally and linguistically diverse individuals, tourists, or individuals who have recently arrived in Australia (Weyrich et al., 2018).
Evidence: Health and Wellbeing Technical Report
- The factors that make people vulnerable to tropical cyclones include age, demographics, housing (e.g. what floor of a building they live on) and many other local and individual factors. There are also individual factors that may mean people have a diminished capacity to respond to conditions and may not be able to evacuate to safety (Parry et al., 2019; Xu et al., 2019). Flooding in northern NSW in 2022 had a profound impact on people with disabilities as evacuation information was confusing and inaccessible, essential services were disrupted, and access to safe housing before and after the event was limited (Bailie et al., 2022).
Evidence: Health and WellbeingTechnical Report



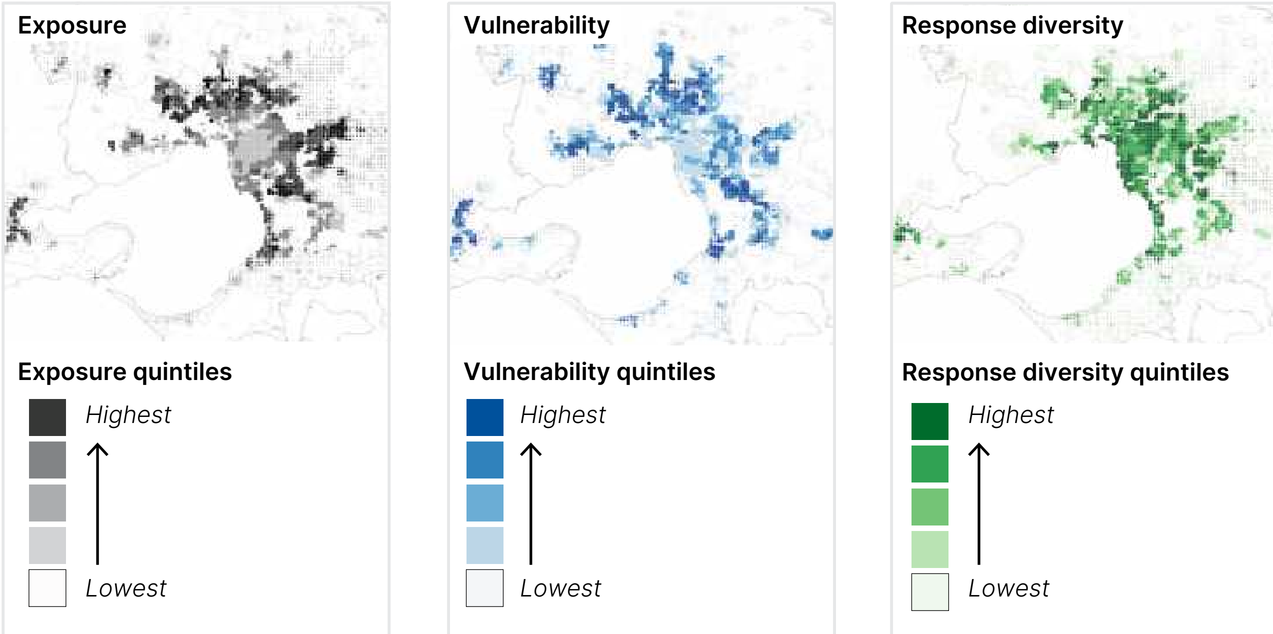


Figure 54: Heat-Health Risk Index maps for the Greater Melbourne area, including maps of exposure, vulnerability and response diversity. Symbol sizes vary based on local population sizes. *(Source: Health and Wellbeing Technical Report)*

- Flooding has been shown to affect the mental health of people who were directly affected by the event (Matthews et al., 2019). Research conducted in northern NSW after flooding in 2017, found that mental health risk was elevated for almost everyone impacted by the event (91%), especially for those whose home was inundated, those who were exposed more than once to flooding, and those who were still displaced after 6 months (Matthews et al., 2019).
- Women have been shown to be particularly vulnerable to climate change (Desai & Zhang, 2021), including risks to reproductive and maternal health from vector-borne diseases linked to climate change (e.g. dengue fever) (Zack, 2022), though the impacts might vary between subgroups of the population (Hanigan et al., 2018; Seneviratne et al., 2021). Vulnerabilities for women also relate to being excluded from decision-making processes and not having the agency to relocate away from climate hazards (Zack, 2022).
- An increased rate of mental health disorders post-bushfire has been found in both the adult and paediatric populations. Mental health impacts include increased rate of post-traumatic stress disorder, depression and generalised anxiety, from the time a bushfire occurs to years after (To et al., 2021). Behavioural changes in children following a bushfire event can include increased irritability and changes in concentration, sleep and academic performance (To et al., 2021).
- Climate extremes such as heat, bushfire, tropical cyclone and floods have significant impact on emergency personnel and volunteers' physical and mental health, fatigue and wellbeing. Impacts to critical services and supporting infrastructure increase the risk to the emergency response, relief and recovery workforce.
  Evidence: National Disasters and Emergency Management Technical Report
- Disruptions to the Primary industries and food system can have a significant impact on population health via a reduction in access to required nutrition, including the availability and affordability of healthy food choices. Food insecurity may also rise due to food spoilage during extreme events (Binns et al., 2020).
- Impacts on the Natural environment system affect the ability of the Health and social support system to draw on nature to supply nutrition and medicines, regulate healthy environments, and provide the cultural services that give people a sense of place and a source of rejuvenation. A healthy natural environment provides critical ecosystem services, such as making a substantial contribution to water quality and security as well as broader mental health benefits.
  Evidence: Natural Ecosystems Technical Report

Climate change impacts are likely to be disproportionately felt in rural and remote areas *(medium confidence).*

- Rural and remote communities are generally at greater risk of health impacts from climate change both for demographic reasons and because critical infrastructure, food and water security, and supply chains are also at risk. Regional and remote communities often have poorer access to healthcare and social support services (e.g. aged care, disability support, homelessness services) and poorer health outcomes.
  Evidence: NCRA Stage 1 Rapid Literature Scan Report
- Health services are being impacted due to the extreme weather and diminished capacity to provide services through a reduced workforce (HEAL Network & CRE-STRIDE, 2021). Already limited health infrastructure in rural and remote areas is at risk from climate change.
- Mental health is one of the biggest current and future concerns for rural and remote communities, and this is likely to be exacerbated by increased risk of community displacement during and after extreme events. In rural communities, direct and indirect impacts from hazards can impact mental health, and extreme events have been shown to increase suicide (Hanigan & Chaston, 2022).
- The elderly and the very young are a highly vulnerable demographic of regional and remote communities; approximately 1 in 3 (34%) older Australians (aged 65 and over) live in rural and remote areas (Australian Institute of Health and Welfare, 2024c). Impacts from extreme events make vulnerable populations a high concern in managing disaster response and recovery operations.
  Evidence: Communities Technical Report, National Disasters and Emergency Management Technical Report
- On average, Aboriginal and Torres Strait Islander people living in remote areas have higher rates of disease burden and lower life expectancy compared with those in non-remote areas (Australian Institute of Health and Welfare, 2024b). Remote communities, particularly Aboriginal and Torres Strait Islander communities, face heightened health risks from water security challenges as remote water assets can be harder to maintain and repair during emergency events.
  Evidence: Water Security Technical Report
- As climate-related impacts worsen, so too do the emotional, physical and mental impacts on primary producers responding to the aftermath of damaging climate hazards to their livestock. When there is a high-mortality event, such as flooding, farmers often deal with the financial loss, but they are also responsible for removing and disposing of animal carcasses when floodwater recedes – an emotional and physically demanding task, with the mental and physical wellness impacts difficult to quantify.
  Evidence: Primary Industries Technical Report

Children and young people will inherit the result of decisions made today to adapt to climate change. Climate change is reportedly already having an impact on their health *(high confidence).*

- Nearly 1 in 5 Australians (18.6%) are aged between 12 and 25, numbering over 4 million. A 2023 poll of Australians aged 16–25 found that 76% are concerned about climate change (Orygen Institute, 2023).

- Analysis of a survey of Australians aged 15–19 by Orygen and Mission Australia found that 13% had been directly impacted by extreme weather events during the previous year (Gao et al., 2024). Such events have disrupted housing situations, schooling, their communities and access to essentials.

Aboriginal and Torres Strait Islander peoples' health

Aboriginal and Torres Strait Islander peoples' health is increasingly impacted by climate change through increasing exposure to climate hazards such as heatwaves and bushfire smoke, compromised water security, and changing conditions for communicable diseases. The impact of these hazards is exacerbated by pre-existing inequalities and contextual vulnerabilities such as overcrowded and poor-quality housing and reduced capacities of healthcare services in regional and remote areas *(medium confidence).*

- Aboriginal and Torres Strait Islander consultations highlighted that Aboriginal and Torres Strait Islander peoples already experience the adverse impacts of climate change, which exacerbates existing health and social disparities. These impacts threaten Aboriginal and Torres Strait Islander peoples' physical, emotional and cultural wellbeing, and they must be empowered to respond to them. Threats include reduced air quality, extreme heat, flooding and energy insecurity, resulting in a lack of cooling, heating, refrigeration and storage of medicine and increased reliance on diesel energy.
Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering
- Aboriginal and Torres Strait Islander consultations highlighted that a crucial aspect of their experience is their deep connection to Country, which strongly drives their reluctance to relocate due to climate hazards or emergencies. Displacement from Country can have severe health and wellbeing consequences, including increased homelessness and threats to identity and belonging.
Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering
- The number of days when severe or extreme heatwaves are experienced is projected to increase under all future warming scenarios, with areas of northern Australia projected to experience the highest increases. The Northern Territory has the highest proportion of Aboriginal and Torres Strait Islander people in Australia (Australian Bureau of Statistics, 2024; Quilty et al., 2023), with large inequalities regarding overcrowded and poor-quality housing (Quilty et al., 2022), poor health outcomes and lower life expectancies (Australian Human Rights Commission, 2020). This population will be increasingly exposed to more frequent and more severe heatwaves, further putting these communities at risk. However, social and cultural adaptations have been shown to be potentially very effective in protecting human health against extreme heat (Quilty et al., 2023).
Evidence: Australia's Future Climate and Hazards Report, Communities Technical Report

Infrastructure, including supply chains and water

Climate-related infrastructure and supply chain disruptions could increase costs for the Australian health system. Risks to water security infrastructure can also compromise health *(low confidence).*

- Acute climate-hazard impacts on supply chains can disrupt the supply of key products or materials for Australia, such as medications and health supplies. Modelling of supply chains during future extreme weather events in 2050 and 2090 undertaken as part of the National Assessment, found that, of the goods blocked from their destination by the disruption, health-related freight (e.g. medicines) had the largest percentage increase in required rerouting of freight and value. A case study of the flooding in NSW and Victoria in October 2022 and projections of the impacts into the future found that health commodities (medicines) was the highest value-blocked freight.
Evidence: Supply Chains Technical Report
- A case study of the closures of the east–west freight route (Eyre Highway and the Trans-Australian Railway line) from ex-Tropical Cyclone Tiffany, a 1-in-200-year rain event in 2022, caused the closure of significant road and rail passages. The effects modelled with a more severe future event of a similar nature found that health commodities (largely, medicines) were the most impacted sector in terms of percentage increase in transport costs to 2090, with a 102% increase. This is highly likely to affect the functioning of the Health and social support system in impacted areas.
Evidence: Supply Chains Technical Report

Climate-driven water security challenges will exacerbate existing public health risks *(medium confidence).*

- Droughts increase risks of mental health. In 4 reviews in Australia drought was the most frequently reported concern related to mental health. Drought impacts the financial and emotional wellbeing of farmers, with resulting mental health impacts (Seneviratne et al., 2021). Daghagh Yazd et al. (2019) reviewed 29 Australian studies and reported that climate variability, particularly droughts in the context of climate change, is the key risk factor affecting farmers' and farm-workers' mental health. Further, another systematic review indicated that an annual decrease in precipitation of 300 mm and exposure to droughts increased 8% of the long-term mean suicide rate in Australia (Kõlves et al., 2013). Batterham et al. (2022) reviewed 17 Australian studies and showed similar findings of a significant impact of droughts on mental health in Australia, which may persist beyond the drought period.
- Climate change may also have adverse effects on drinking water quality (with flow-on effects for health and wellbeing), as communities turn to alternative water sources or water sources become contaminated by harmful algae blooms, or water quality is degraded due to the impacts of bushfires. High-intensity rainfall can also increase the risk of water contamination from cryptosporidium and cyanobacteria outbreaks.
  Evidence: Water Security Technical Report
- Storms damage water and energy infrastructure, leaving communities without access to quality water, impacting filtration systems, and increasing the risk of cross-contamination from sewerage infrastructure. Aboriginal and Torres Strait Islander communities face heightened health risks from water security challenges, particularly in remote communities where water assets are harder to maintain. Communities may resort to buying bottled water, increasing the cost burden.
  Evidence: Water Security Technical Report, Communities Technical Report

Adaptation observations and considerations

This section provides information that can support adaptation planning and approaches.

Increased collaboration across federal, state and local levels of government plays a role in developing policies and allocating resources effectively for the Health and social support system in Australia. *(medium confidence).*

- The Health and social support system is funded from public and private contributions through decisions made by multiple levels of government, while regulatory bodies maintain standards and quality assurance in healthcare and social services. Building strong relationships and fostering cooperation between public, private and civil society actors, and at multiple levels, is important for efficiencies, coherence and responsiveness to emerging or new risks and issues. A coordinated effort across and within many areas, including health, social policy and community development, plays a positive role in reducing future climate change impacts in the Health and social support system.
  Evidence: Governance Technical Report
- Adaptation in this system is mostly undertaken at state and territory scales (Figure 55), in line with these jurisdictions' responsibility for delivering a large proportion of health services in Australia. There are also local and national adaptation projects and programs in this system.
  Evidence: Insights from the Adaptation Stocktake
- The interactions between climate extremes and social, economic and environmental vulnerabilities can overwhelm existing management and institutional capacities relatively directly – for example, when an extreme event overwhelms health services.
  Evidence: Governance Technical Report
- Developing organisational capacities for responding to and monitoring climate change risks, and assessing the effectiveness of actions, was identified as the weakest aspect of risk governance for the Health and social support system.
  Evidence: Governance Technical Report

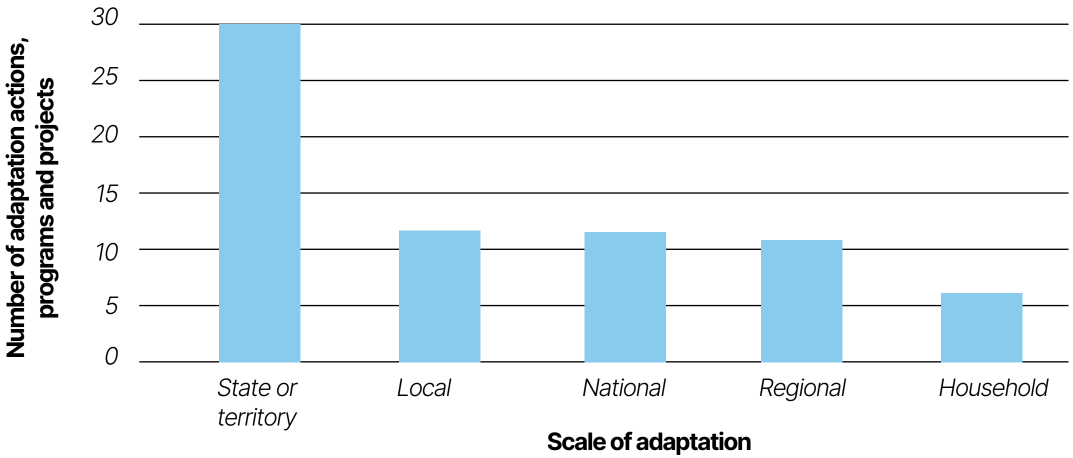


Figure 55: Distribution of adaptation actions, programs and projects by scale in the Health and social support system. *(Source: Insights from the Adaptation Stocktake)*

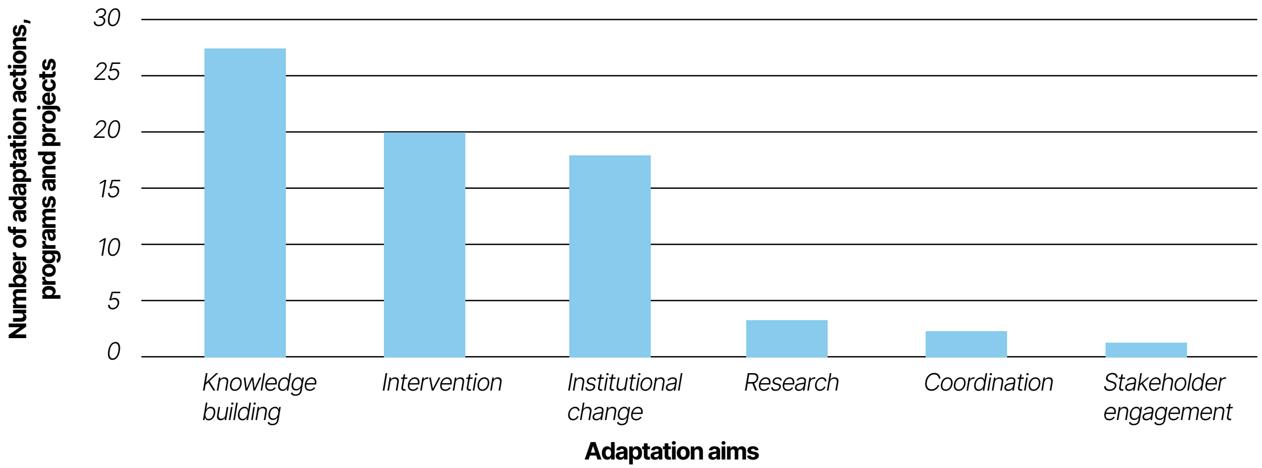


Figure 56: Distribution of adaptation actions, programs and projects across aims in the Health and social support system. *(Source: Insights from the Adaptation Stocktake)*

There is a solid foundation for future adaptation in the Health and social support system as it has a high proportion of both adaptation policies and programs in comparison to other systems. Effective adaptation requires ongoing support, enabled by effective decision-making and governance; however, current actions are not likely to be sufficient to manage increasing climate-driven risks *(high confidence).*

- Most adaptation within this system aims to build knowledge (e.g. through community education on heatwaves) and to implement interventions (e.g. mosquito eradication programs) (Figure 56). A key difference compared with other systems is the high proportion of behavioural and cultural adaptation initiatives within the intervention category (e.g. through climate-sensitive community gardens to support mental health and urban greening). Those factors combined suggest that the Health and social support system is experienced in and geared towards implementation, which is a key asset for future adaptation, if given adequate support.
Evidence: Insights from the Adaptation Stocktake
- Adaptation policies, plans and laws that address the Health and social support system make up 10% of these entries in the newly established *Australian Adaptation Stocktake* and 20% of adaptation programs, projects and actions entries. This is the third-highest number of actions across systems. While this data shows that adaptation is occurring within this system, there is little monitoring and evaluation to establish effectiveness. Additionally, the literature on adaptation shows that these actions are not considered sufficient to manage current or future risks.
Evidence: Insights from the Adaptation Stocktake
- Adaptation policy and planning for Health and social support systems is undertaken mostly by state and territory government agencies, with Queensland undertaking the largest proportion (43% of policies and plans in the Australian Adaptation Stocktake), although other states may not label adaptation planning specifically as climate actions, making comparison difficult. Most of these plans and policies relate specifically to the health sector, and while some strategies may consider social support or wellbeing more broadly, there are few that focus primarily on those factors.
Evidence: Insights from the Adaptation Stocktake
- After general climate change, temperature extremes and fires are the most common hazards addressed by adaptation initiatives within this system (Figure 57), which shows that heat is recognised as a significant concern. 'General climate change' adaptation refers to adaptation programs, projects or actions that are not specific to one hazard and/or apply broadly to initiatives that address vulnerability to climate change or climate extremes.
Evidence: Insights from the Adaptation Stocktake

A wide range of factors underpin risks to health and social support, including household and individual factors, community responses and volunteering, and social and cultural factors. Adaptation to climate-driven risks in the Health and social support system will need to recognise and address multiple contributing factors *(high confidence).*

- Community-level responses should engage with volunteerism and promote relationships within local communities. Hazard-specific risk factors should be considered, such as household mobility (or ability to evacuate) in the case of tropical cyclones (e.g. through sufficient roads and transport), or access to cool places and green infrastructure for extreme heat risks.
Evidence: Health and Wellbeing Technical Report

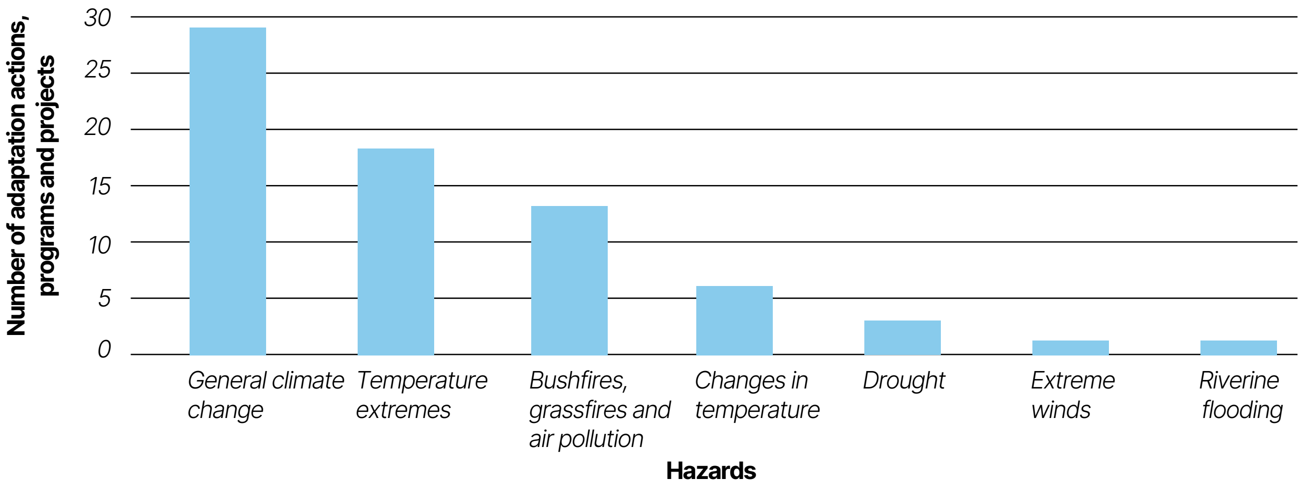


Figure 57: Distribution of adaptation actions, programs and projects by hazard in the Health and social support system. *(Source: Insights from the Adaptation Stocktake)*

- Reducing climate-health risk at the individual level depends on a range of factors including access to health services, social connectedness within local communities, and household mobility (or ability to evacuate, vehicle ownerships). Climate-driven health risks can be reduced by addressing existing vulnerabilities at the individual level, including for outdoor workers, emergency management personnel, Aboriginal and Torres Strait Islander peoples, women, older people and the very young.
Evidence: Health and Wellbeing Technical Report
- Social and cultural adaptations have been shown to be potentially very effective in protecting human health against extreme heat (Quilty et al., 2023). Examples of social and cultural adaptations include having breaks and encouraging social activities for individuals to shelter from hot conditions in the middle of the day (Quilty et al., 2023).
- In regions where outdoor workers and emergency management personnel and volunteers are likely to be more exposed to heat extremes, lessons could be learned from alternative approaches to mitigating this risk. These approaches have been widely deployed in very hot countries and include varying the construction activity time to avoid the hottest time of the day, or conducting activity at night (which brings with it different risks).
Evidence: National Disasters and Emergency Management Technical Report, Australia's Future Climate and Hazards Report, Real Economy Technical Report

Pre-existing disadvantage exacerbates the impact of climate hazards on Aboriginal and Torres Strait Islander peoples and remote communities. Adaptation actions to address these contextual vulnerabilities include improving housing quality and ventilation, building the capacity of remote health services, and improving water and other critical infrastructure in regional and remote areas *(high confidence).*

- Building the capacity of local health services and providing adequate housing offer opportunities to reduce climate-related health risks to Aboriginal and Torres Strait Islander communities (HEAL Network & CRE-STRIDE, 2021). During COVID, Healthy North Coast worked with Aboriginal communities to develop a coordinated approach to reduce the impact of the pandemic. It considered the extensive kinship systems, cultural obligations and close living situations that had the potential to increase the transmission of the disease within Aboriginal families and communities (Healthy North Coast, 2021).
- Planting trees is an example adaptation activity that can help reduce temperatures through providing shade and cooling. Trees also improve physical and mental health through reducing air pollution, reducing stress, promoting community cohesion and encouraging physical activity (Turner-Skoff & Cavender, 2019). Indigenous-led tree-planting programs are both about Caring for Country and promoting healthy environments (ABC Foundation, 2025).
- Remote communities, particularly remote Aboriginal and Torres Strait Islander communities, face heightened health risks from water security challenges driven by climate change. Effective adaptation to water security challenges requires plans to monitor, maintain and repair remote water assets, particularly during emergency events. Aboriginal peoples have extensive knowledge of water sources, including hidden springs and water-holding trees, which can be crucial during prolonged dry periods.
Evidence: Water Security Technical Report, Aboriginal and Torres Strait Islander Peoples Second Gathering.

Case study: Heat-health risk across Sydney

This case study demonstrates the granular nature of heat-health risk and how it can vary over relatively small geographic areas.

Heatwaves cause more deaths in Australia than all other extreme events combined (Steffen et al., 2014).

What drives health impacts in a heatwave is complex. We know that individual factors play a considerable role, such as age and health status, our built and social environments, and access to cooling and health services. Many Australians have multiple heat-health risk factors. For example, an older person with ailing health and living alone in a building without access to cooling is at high risk of adverse health outcomes.

To better understand heat-related risks to health, the Australian Climate Service has developed a Heat-Health Risk Index to provide a more detailed spatial view of people and places most at risk. It involves using the latest data and thinking on the social, economic, built and natural environments to create statistical indicators of how communities are at risk of adverse heat-health outcomes using historical heatwave data.

The example of Greater Sydney is shown below (Figure 58). Overall, there is a large variation in heat-health risk across Greater Sydney, with lower risk in the north and higher risk in the west and south. This is related to the social and physical geography of the region. Areas such as Blacktown and the Outer West have a high heat-health risk. They are inland areas away from the moderating influence of the ocean and sea breezes, so are generally hotter. They also have relatively low vegetation, which can exacerbate the population's exposure to heatwaves.

Sydney's Eastern Suburbs have a moderate heat-health risk. There is a closer proximity to the ocean, and good access to services and cool places, although the housing style and density contributes to a greater exposure to heat with less green space.

The Northern Beaches, north Sydney and Hornsby are generally leafier and more affluent suburbs with a lower heat-health risk. There is lower social vulnerability, good access to services and cool places, and also a higher tree canopy cover. They are also close to national parks, which can mitigate the heat of the heatwaves.

There are also variations within these broad regions of Sydney, demonstrating that heat-health risk can be influenced at the local scale.

For more information on this case study, see the Health and Wellbeing Technical Report.

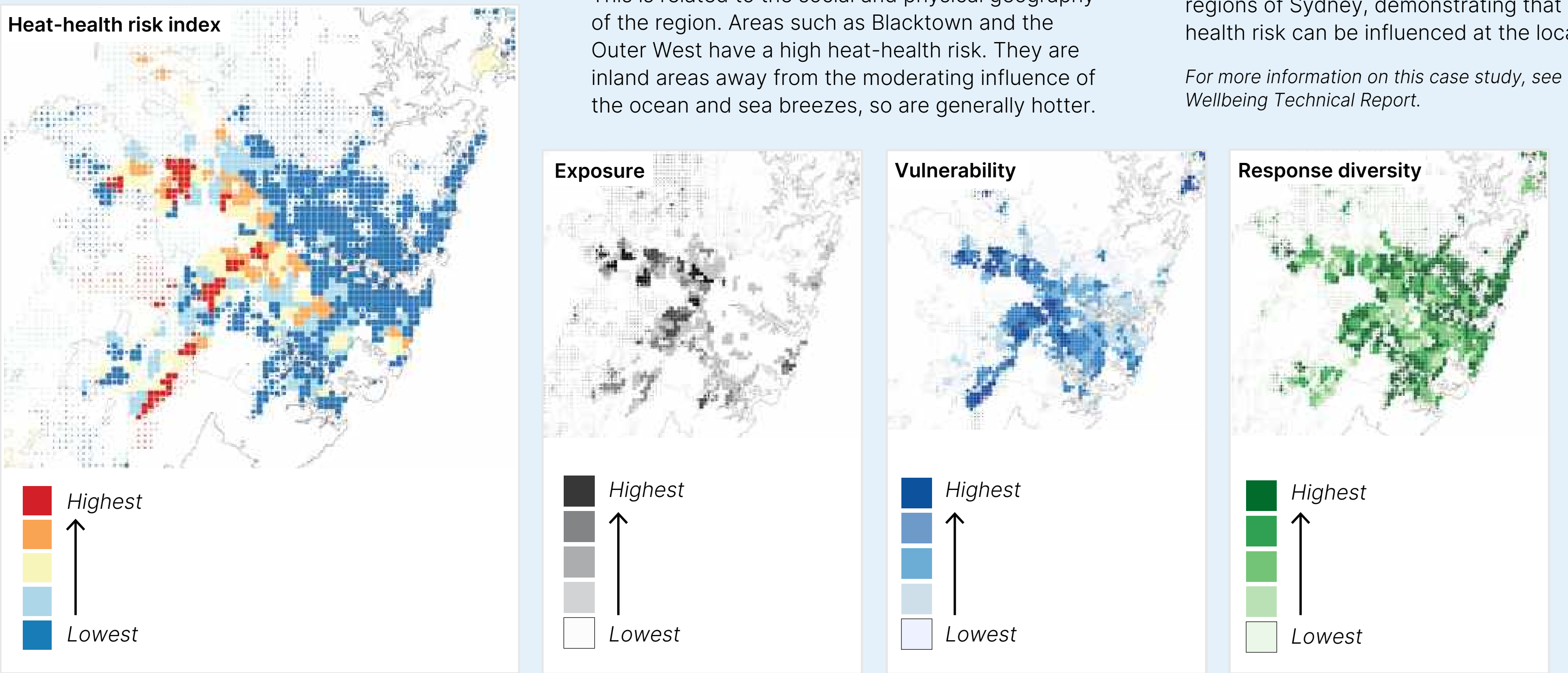


Figure 58: Heat-Health Risk Index maps for the Greater Sydney area, including maps of exposure, vulnerability and response diversity. Symbol sizes vary based on local population size. *(Source: Health and Wellbeing Technical Report)*

Infrastructure and the built environment system

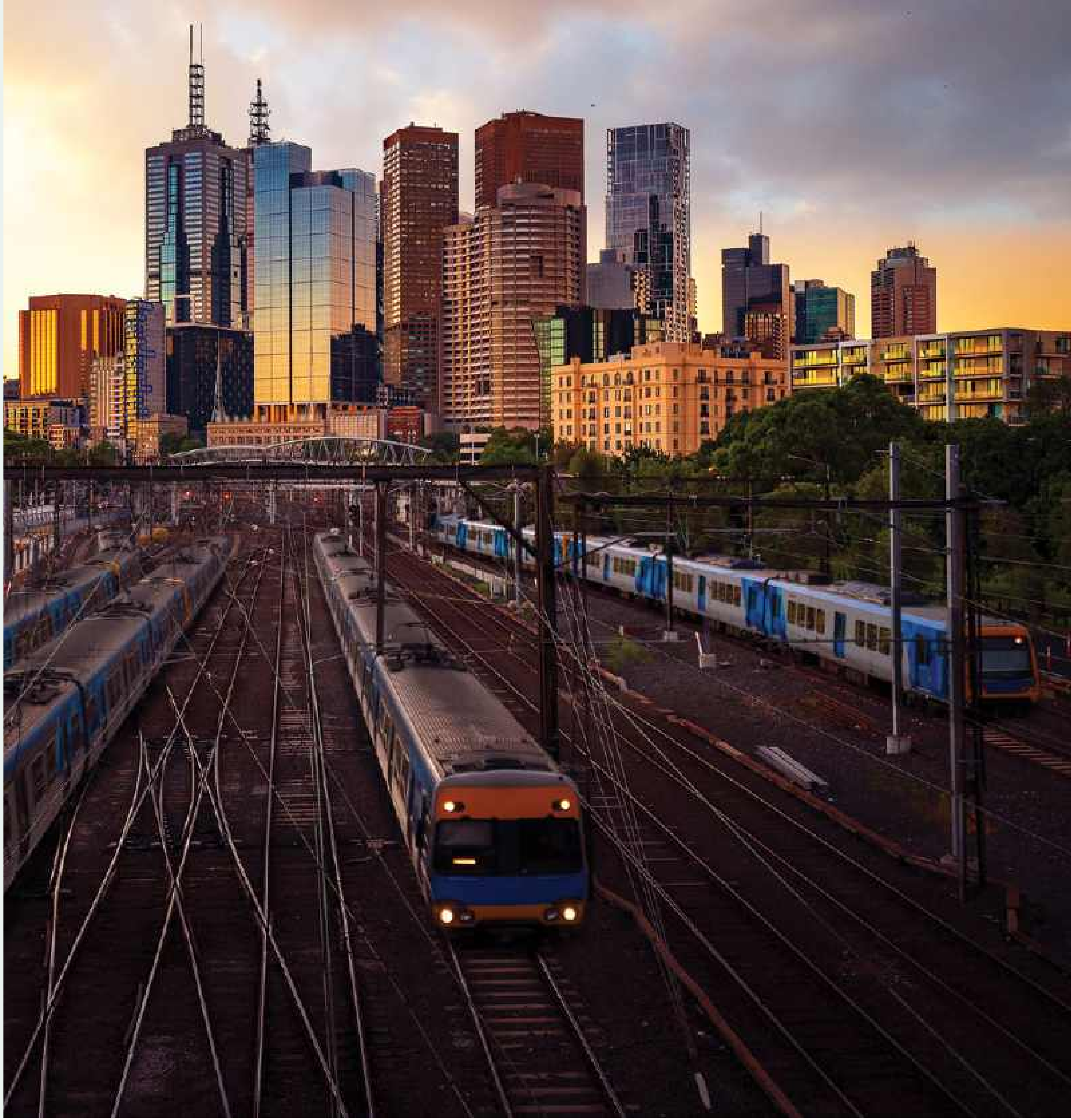
Summary

The Infrastructure and the built environment system refers to the intricate networks of human-made structures across Australia. This system includes physical buildings, green and blue spaces, and their supporting infrastructure such as transport, telecommunications, water and energy systems.

Priority risks

The National Assessment has undertaken quantitative and qualitative analysis for priority risks. The first pass assessment identified 10 nationally significant climate risks for this system. Two priority risks have been analysed as part of the second pass assessment.

- Risks to critical infrastructure that impact access to essential goods and services.
- Risks to supply and service chains from climate change impacts that disrupt goods, services, labour, capital and trade.



Infrastructure and the built environment

Climate risks are determined by the interaction of risk elements, including hazards, exposures and vulnerabilities. This is a risk summary for the Infrastructure and the built environment system.

Climate and hazards

- Bushfires
- Extreme heat
- Flooding
- Extratropical and convective storms
- Sea level rise
- Tropical cyclones

Exposures

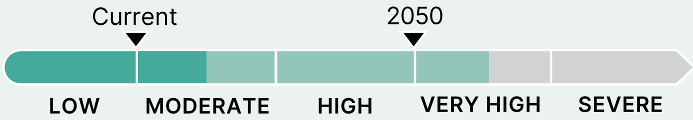
- Community infrastructure
- Energy infrastructure
- Residential dwellings
- Supply chains and transport infrastructure
- Telecommunications infrastructure
- Water infrastructure

Vulnerabilities

- Coastal and remote locations
- Limited redundancy in critical systems
- Locations that are hazard-prone
- Old or not climate adapted infrastructure

IMPACTS AND RISKS

- Disruption to energy supply
- Damage to transport networks
- Compromised telecommunications
- Increasing housing and community infrastructure damage
- Water infrastructure failures
- Coastal infrastructure damaged or destroyed
- Exacerbation of inequalities for Aboriginal and Torres Strait Islander peoples and remote communities
- Supply chain disruptions
- Higher infrastructure upgrade and repair costs



Assessment of current risk

The current risk to the Infrastructure and the built environment system is rated as *low–moderate (medium–high confidence)*, with critical infrastructure generally already engineered for significant climate variability, although increasingly frequent disruptions to critical infrastructure and supply chains are affecting remote communities.

Energy infrastructure is increasingly exposed to extreme heat events, which results in networks being increasingly exposed to heat beyond their safe operating levels, leading to operationally forced disruptions.

Transport and supply chain infrastructure, and energy infrastructure, are also at risk from acute hazards such as bushfires, floods and extreme winds, causing outages and disruptions, particularly in regional and remote communities, though they are not yet resulting in enduring impacts on a national scale.

Water security infrastructure is challenged by climate extremes and increased rainfall variability, while telecommunications infrastructure is at high risk from increasing climate hazards, especially in coastal areas.

Coastal infrastructure is particularly vulnerable to sea level rise and other coastal hazards, affecting urban coastal centres and infrastructure hotspots.

Remote communities, including Aboriginal and Torres Strait Islander communities, face heightened risks due to climate change impacts on their infrastructure and built environment – in particular, where critical infrastructure provision is already inadequate.

Assessment of future risk

By 2050, the climate risk to the Infrastructure and the built environment system is expected to increase to *high–very high (medium confidence)*.

The anticipated rise in climate hazard severity will lead to increased impacts on infrastructure as operating conditions change beyond their design envelopes. Impacts will range from disruption and damage to complete destruction. This will have cascading impacts on business interruption and households across multiple states, with noticeable national impacts and economic costs associated with stockpiling, repairing and hardening infrastructure.

There are heightened risks to safety and security. Energy infrastructure will be increasingly challenged by more frequent and intense extreme heat events and megafires, potentially leading to severe and prolonged disruptions, due either to network damage or to operational constraints (reducing network use to prevent infrastructure damage).

Transport and supply chains will continue to be at considerable risk, with disruptions in regional hubs cascading to distant communities. Residential infrastructure will face increased risks from extreme weather, especially in areas where these hazards have historically been rare. Water infrastructure will be further challenged by extreme variability, with increases in both drought and extreme rainfall.

Telecommunications infrastructure will remain at high risk, particularly in coastal areas. Coastal infrastructure will face greater threats from sea level rise and increased storm surge activity.

Without adequate adaptation, Aboriginal and Torres Strait Islander peoples will continue to be disproportionately affected by infrastructure vulnerabilities, which is likely to exacerbate existing inequalities by increasing costs and reducing access to health and other critical services.

Summary of exposures, vulnerabilities, impacts and risks

Energy

Australia's energy infrastructure is increasingly vulnerable to the impacts of climate change. Extreme heat events, which are becoming more frequent and intense, will result in temperatures that are outside safe operating levels, forcing network operators to increase outages (load shedding). This will lead to disruptions in energy supply when it is most needed to keep people safe. These disruptions are further compounded by damage to energy infrastructure caused by fires and the increasing occurrence of megafires, as well as storms and extreme winds.

Transport and supply chains

Transport and supply chain infrastructure are at significant risk from climate change. Acute hazards such as bushfires, floods, and extreme winds can cause widespread damage, leading to disruptions. Regional and remote communities are particularly vulnerable due to their reliance on long and sparse transport networks. These communities often lack alternative modes of supply, which increases their vulnerability during disruptions. When regional hubs are affected, the impacts can flow to other communities, disrupting the movement of goods and services. This can lead to shortages, increased costs, and significant economic impacts.

Residential infrastructure

Residential infrastructure faces growing risks from climate change, with the number of houses currently considered at high risk potentially doubling by 2100. Modelled high-impact, low-probability wind events show that increases in housing stock loss are expected in coastal and hinterland regions, particularly in Western Australia, the Northern Territory and Queensland. These impacts not only threaten the safety and security of homes but also increase pressure on emergency services and recovery efforts.

Water infrastructure

Water security will be challenged by climate change, especially by increases in climate extremes, including flood, extended dry periods, storms and increased temperatures. Regional and remote communities are at particular risk from compromised water infrastructure.

Telecommunications

Telecommunications infrastructure is at high risk from climate hazards such as extreme heat, bushfires, flooding and extreme winds. Coastal areas are particularly vulnerable, with the risk to telecommunications infrastructure being generally high near the coasts. Disruptions to telecommunications can have far-reaching impacts, affecting emergency responses, business operations, other critical infrastructure and daily communications.

Coastal infrastructure

Urban coastal infrastructure and critical infrastructure hotspots, especially in Queensland, are among the most at-risk areas. Rising sea levels coupled with storm activity can lead to significant damage affecting homes, businesses and critical services, with potential disruption to local and international trade.

Aboriginal and Torres Strait Islander communities' infrastructure

Regional and remote Aboriginal and Torres Strait Islander communities may face heightened risks due to climate change impacts on their infrastructure and built environment. As hazards like severe weather events, extreme heat events, and bushfires intensify, the disproportionate risks associated with already unsafe infrastructure are exacerbated, with cascading consequences. One such risk is the loss of opportunity for education, which will occur if school buildings are unable to withstand all hazards, such as floods and severe weather. Another indirect risk is the loss of access to Country, resulting in reduced opportunities for sharing Lore, caring for Country, and practising ceremonies.

Introduction

This chapter provides a synthesis of the Infrastructure and the built environment system. It draws on a wide range of technical assessments to provide observations that can enable effective adaptation.

It includes:

- System overview
- Priority risk snapshots
- Key climate hazards for the system
- Exposures, vulnerabilities, impacts and risks relevant to the system
- Adaptation observations and considerations
- Case study

The chapter highlights 2 priority risk snapshots and also draws on the analysis from across all the priority risk technical assessments. It is important to note for this first National Assessment that all 63 nationally significant risks have not been fully assessed. The chapter provides a useful national understanding of climate risks and information that can support adaptation. Climate risks are not static – this work is a sound foundation that should be built on over time.

System overview

The Infrastructure and the built environment system refers to the intricate networks of human-made structures across Australia.

This system includes physical buildings, green and blue spaces, and their supporting infrastructure such as transport, water and energy systems.

Infrastructure can be categorised into several key types, including buildings and associated construction, utilities, living infrastructure and transport facilities. Infrastructure is a significant section of the Australian economy, supporting all cities and towns, as well as industry. It is one of the sectors most at risk from the impacts of climate change.

Infrastructure is usually built to last at least several decades, so adapting or modifying existing infrastructure to respond to climate change impacts is likely to be complex and costly. Understanding the impacts of climate change and considering the long lead times for different forms of infrastructure will be vital for planning both remedial and preventative efforts.

The system analysis in this section of the report focuses on the following types of critical infrastructure that are vital to economic activity: transport, supply chains, water infrastructure, telecommunications and energy. The analysis places them at very high levels of importance for ensuring continued operation, even during extreme hazard events. It also covers the risks to residential buildings from wind and flood, but not the associated community or business infrastructure, and not all categories of critical infrastructure.

Priority risk snapshot: Critical infrastructure

Risks to critical infrastructure that impact access to essential goods and services.

Rationale

The risk to critical infrastructure is currently rated as **Moderate**. This risk is expected to increase to **High–Very High** by 2050 and to rise to or remain as **Very High** by 2090 (Figure 59). There is significant inertia associated with this system. There is a need for improved management and incremental adaptation, with substantial possibilities to mitigate these risks through strategic planning and investment in resilient infrastructure such as islanded systems. Transformational adaptation is not required for this risk, although transformations in this system may benefit other risks; for example, decentralised water systems may support adaptation in regional and remote communities.

Key hazards

- Acute hazards, including extreme heat, bushfires, extreme rainfall events resulting in flooding and extreme wind, can severely impact telecommunications, transport and energy infrastructure. The impact of the hazards can range from temporary disruption of services to destruction of infrastructure. These hazards are generally increasing in frequency and intensity with climate change *(medium to high confidence)*.

Exposure

- The nationally significant exposed critical infrastructures analysed in this priority risk include transport (roads, rail, seaports, airports), energy (electricity transmission lines, power stations) and telecommunications (all sites for the 3 major mobile network operators).

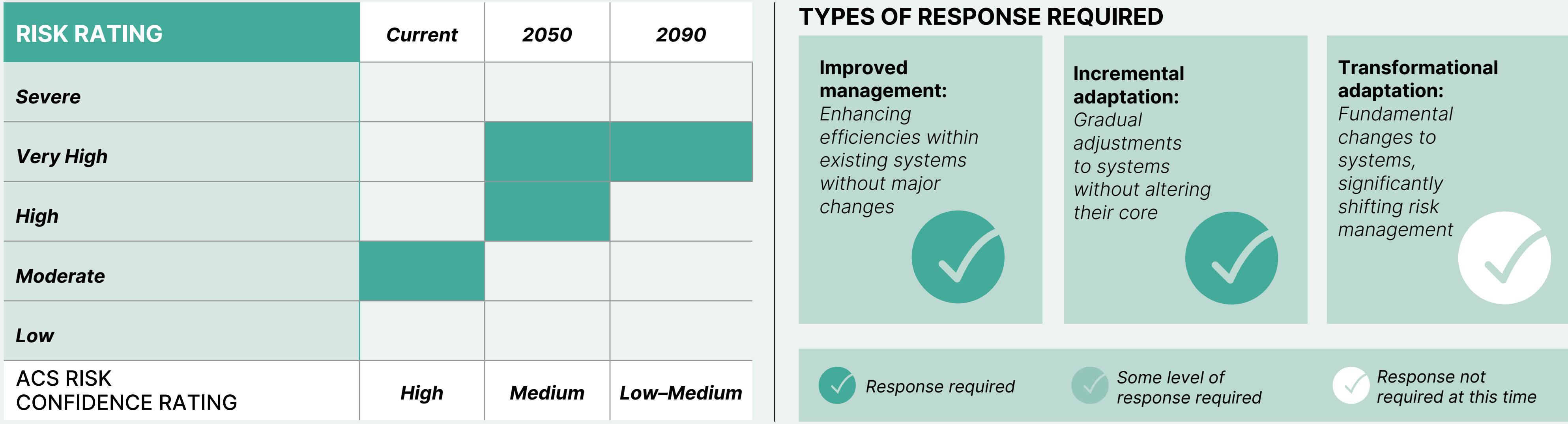


Figure 59: Rating for the Critical infrastructure priority risk for current, 2050 and 2090, and the types of responses required to address the risk. For definitions of risk ratings, please see Figure 9.

Vulnerability

- Vulnerability was embedded within the methodology as a driver of the consequence. As such, when quantifying a hazard event's likelihood and the resulting consequences, the analysis considered the hazard's probability of occurrence, the exposure an infrastructure asset experiences, and its vulnerability to damage and disruption. Specific physical vulnerabilities of types of infrastructure were not considered as this depends on the age, maintenance schedule, engineering, etc. and is not available at a national level.

Impacts and risks

- The social cost is a metric used to quantify some or all of the loss in productivity that could occur where social or economic activity is interrupted due to disruption of key critical infrastructure. This is quantified for roads and seaports infrastructure at +1.2°C and +3.0°C of global warming.
- Quantitative analysis of low-moderate- and high-risk LGAs in relation to a critical infrastructure multi-hazard severity index developed as part of this National Assessment for telecommunications, transport and energy infrastructure resulted in a combined hazard index. Risk analysis was conducted at +1.2°C, +1.5°C, +2.0°C and +3.0°C of global warming. A multi-hazard risk assessment was conducted for transport (major road network, public rail, public airports, public seaports), accounting for bushfires, extreme temperatures, coastal inundation, extreme wind and flooding through extreme rainfall (Figure 66).
- Telecommunications have the greatest overall exposure, especially near coasts (Figure 60 and 61). Transport has moderate exposure, which is highest in rural areas of the major states. This has implications for the criticality of roads supplying regional centres. Energy assets have a high combined hazard index, which is generally high in urban and rural areas.
- For roads, the area with the largest changes in social cost between +1.2°C and +3.0°C of global warming is in Central Queensland, where LGAs including Central Highlands, Isaacs and Western Downs show an increased risk to the major roads.
- Most energy infrastructure was not built to withstand many future climate hazard extremes. Events such as heatwaves can result in conditions outside of safe operating levels, which force network operators to reduce load, often resulting in outages for users. Energy assets are generally exposed in both urban and rural areas, and exposure is highest in southern areas of South Australia, eastern and western Victoria, and central and coastal areas of NSW.
- The socioeconomic cost of failure of seaports due to coastal inundation was calculated for +1.2°C and +3.0°C of global warming. Similar to the results for major roads, LGAs within Queensland are shown to be at high risk, with several LGAs within the highest decile of the Social Cost metric including Mackay Regional and Gladstone Regional.

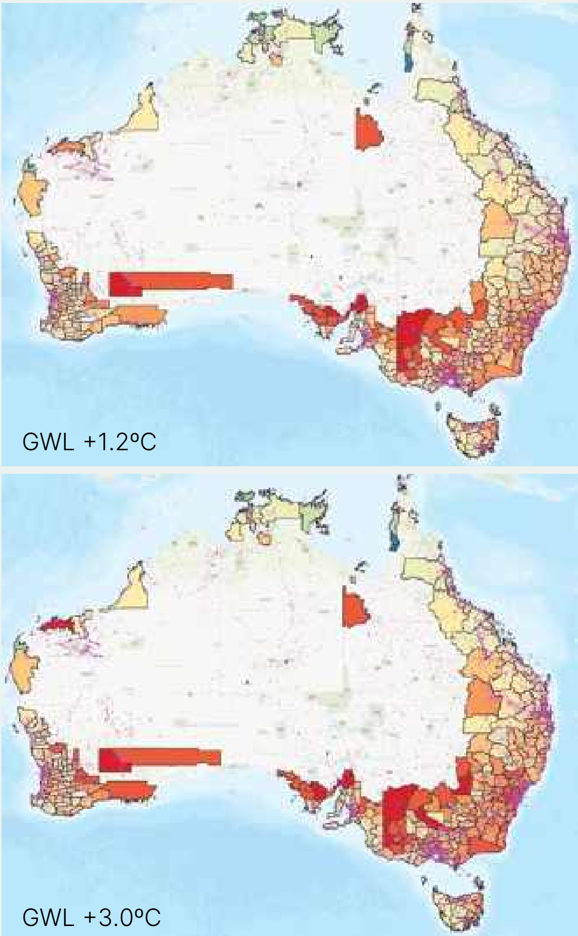


Figure 60: National multi-hazard severity index maps for the global warming level at +1.2°C (current climate) (top) and +3.0°C (bottom) for each LGA for the telecommunications asset classes. Asset locations are shown in magenta. Note that a population density mask is applied.

(Source: Multi-Hazard Severity Headline Metric – Results: Critical Infrastructure Technical Report)

Basemap: Esri "Topographic". Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, DESI, © OpenStreetMap contributors, and the GIS User Community

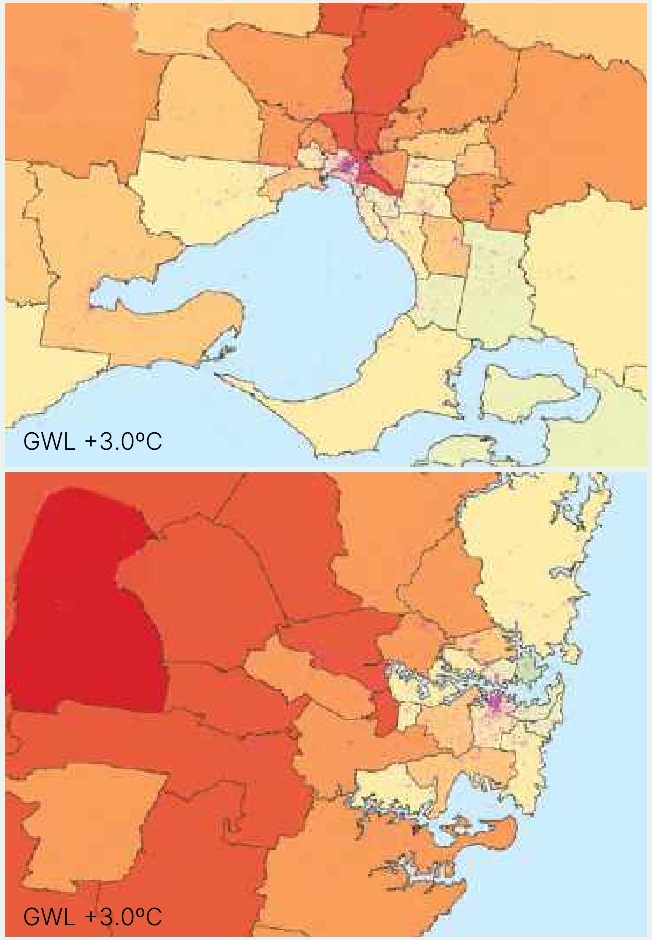
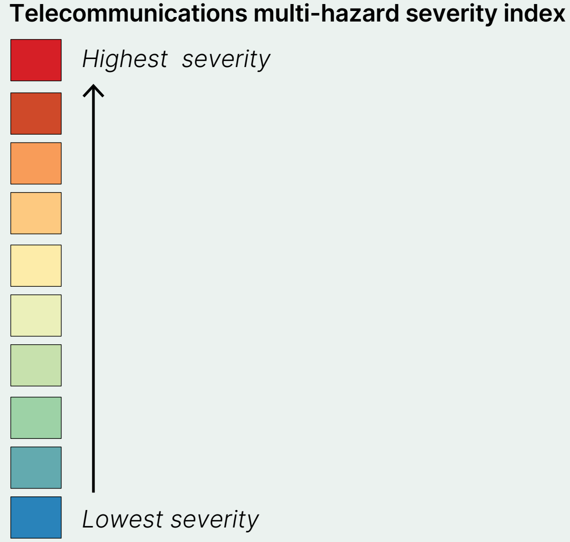


Figure 61: A close-up of telecommunications at +3.0°C global warming level multi-hazard severity index for Melbourne (top) and Sydney (bottom). Asset locations are shown in magenta.

(Source: Multi-Hazard Severity Headline Metric – Results: Critical Infrastructure Technical Report)



Adaptation

- Critical infrastructure has generally been built to withstand Australia's highly variable current climate. However, infrastructure has long lead times and building codes and standards are slow to change, which means current infrastructure is built to often outdated standards. The increasing frequency and duration of extreme events will likely lead to more disruptions and infrastructure requires a very significant investment and long lead times to improve its resilience to climate change.
- Australia's mangroves and tidal wetlands should be conserved and restored, as these provide important natural protection and buffering for coastlines and coastal infrastructure against severe storms and cyclones. They are estimated to be providing protection to $1.7 billion in coastal infrastructure.

Priority risk snapshot: Supply chains

Risks to supply and service chains from climate change impacts that disrupt goods, services, labour, capital and trade.

Rationale

The risk to supply and service chains from climate change impacts is currently rated as **Moderate**. This risk is expected to increase to **High** by 2050 and to **Very High** by 2090 (Figure 62). Currently, supply chains experience occasional impacts, but by 2050, they will become increasingly exposed to intense shocks. Improved management and incremental adaptation are required for supply and service chains. Supply and service chains will benefit from implementing diversified adaptation types that target the different specific needs within this sector and by region. As with critical infrastructure, transformational adaptation is not likely to be necessary to adapt to this risk, but emerging opportunities may arise with new technology.

Key hazards

- Acute hazards can severely impact supply chains as they can disrupt services or destroy parts of critical infrastructure. The impacts of major flood events of 2021–24 demonstrated the vulnerability of Australia's freight routes in transporting critical commodities across the country to urban and regional communities. The key hazards assessed in this priority risk are riverine flooding and tropical cyclones.

Exposure

- This priority risk project investigated when supply chain transport infrastructure (road, rail and shipping) is impacted, considering impacts ranging from disruption to destruction. It modelled the flow-on effect for 8 sectors (agriculture and food, forestry, fuels, minerals, chemicals, general freight, health and construction).

Vulnerability

- The highest supply chain network vulnerabilities occur in remote Australia, where there are sparse and long transport networks, higher risk of closure from natural hazards, and limited resources to respond to road disruptions.

RISK RATING	***Current***	***2050***	***2090***
Severe			
Very High			■
High		■	
Moderate	■		
Low			
ACS RISK CONFIDENCE RATING	***High***	***Medium***	***Low***

TYPES OF RESPONSE REQUIRED

Improved management: *Enhancing efficiencies within existing systems without major changes*

Incremental adaptation: *Gradual adjustments to systems without altering their core*

Transformational adaptation: *Fundamental changes to systems, significantly shifting risk management*

Response required | *Some level of response required* | *Response not required at this time*

Figure 62: Rating for the Supply chains priority risk for current, 2050 and 2090, and the types of responses required to address the risk. For definitions of risk ratings, please see Figure 9.

Remote communities often have limited access to supplies, restricting their ability to provision for disruption events, while regional communities are often providers of primary production to urban and other regional centres.

Impacts and risks

- Future supply chain exposure from point of production through to communities and the market is strongly driven by future changes to population size and distribution. Figure 63 shows how freight may change using the 'balanced outlook' for projected 2090 population (described in the *Supply Chains Technical Report*), and illustrates that the rate of freight growth differs significantly between states and territories.
  - Overall, freight volumes and transport costs to the destinations increase. This is consistent across most sectors and states/territories.
  - Supply chain paths for livestock and cropping commodities, from point of production to domestic market (flour, stock feed, food oil, malt), are significantly different for both 2050 and 2090 compared to 2024, due to projected changes in population and their modelled demand.
- Three case studies were modelled based on identified supply chain vulnerabilities to illustrate the potential impact of future extreme weather events. The case studies used the footprint of historical events projected into a future climate.
  - A major flood, based on the flooding across Victoria and NSW in October 2022, covering a broad geographically dispersed area. The value of blocked freight would rise from $4.9 billion in the current climate to $9.3 billion in 2090. Health-related freight (e.g. medicines), although not the largest impacted sector in terms of tonnes, would have the largest percentage increase in the value of freight blocked and requiring re-routing, suggesting this is a vulnerable commodity for extreme events.
  - A severe tropical cyclone following the path of Tropical Cyclone Jasper. Direct impacts remain largely confined to Queensland north; however, greater shortages of food products would be experienced in major distribution centres across Australia, particularly those products grown in northern Queensland, highlighting that local impacts can reverberate across Australia.

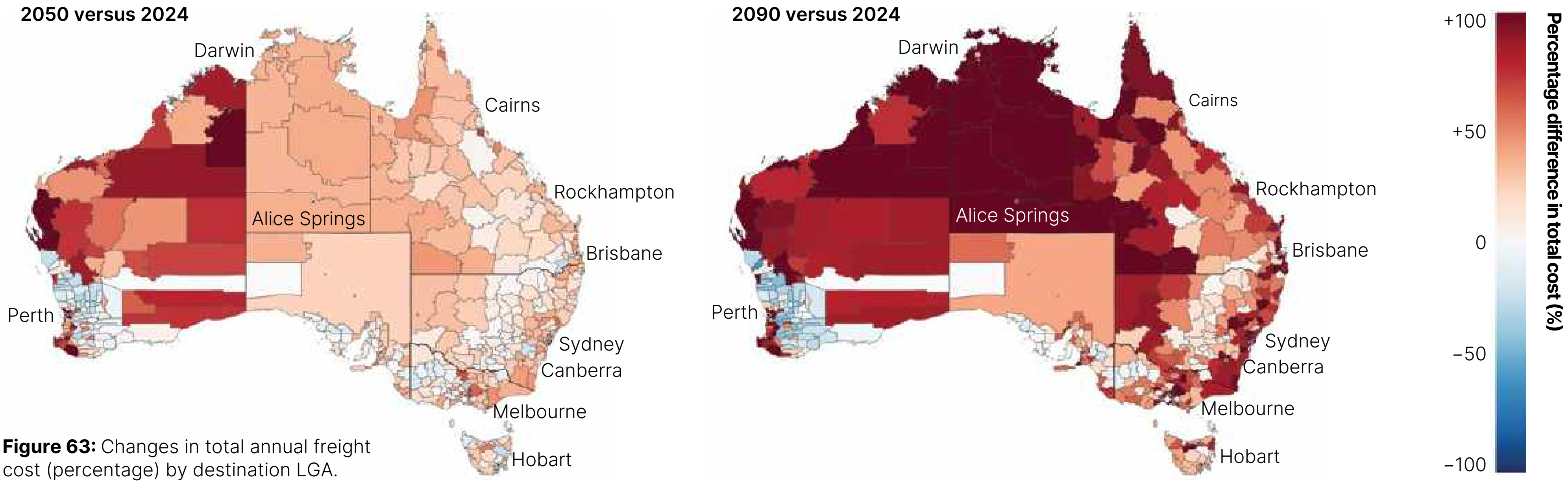


Figure 63: Changes in total annual freight cost (percentage) by destination LGA. *(Source: Supply Chains Technical Report)*

- Disruption to the critical east west supply corridor modelled after the February 2022 flood event that cut the Eyre and Stuart highways. Modelling of a more severe version of this event in 2090 resulted in a detour increase of 730 km on average, but this sometimes increased to over 3,000 km in 2090. The most impacted LGAs were Indigenous and remote communities. The increased length of detours in 2050 and 2090 for this case study are less likely to be absorbed by vehicle fleet capacity, leading to a significantly longer recovery period, a higher inventory depletion, and expensive modal shift (e.g. air freight) in the case of priority commodities.

Adaptation

- Adaptation and/or intervention options include a range of policy, management and investment decisions targeted at the most vulnerable communities, critical commodities and freight routes.
- To reduce impacts on port assets from sea level rise, interventions should prioritise adapting existing ports. This is significantly less expensive than constructing new facilities. There is also sufficient time available to adapt existing ports, as there are long timeframes before forecast sea level rises are predicted to impact port assets.
- States and territory governments may look to invest in adaptation measures that reduce road and rail exposure to future sea level rise and storm surges that can impact supply chains.
- Interventions that could improve the resilience of supply chains to future disruptions include new gazetted freight routes, new distribution facilities and road height upgrades. These are areas for future testing and analysis.

Key climate hazards for the system

This section describes the changing climate hazards for the Infrastructure and the built environment system.

Acute hazards, including extreme heat, bushfires, flooding and extreme wind, can severely impact telecommunications, transport and energy infrastructure. These hazards are generally increasing in frequency and intensity with climate change *(medium confidence).*

- Extreme heat is a major risk for transport infrastructure, although it can also affect the other 2 types of critical infrastructure assessed in this risk assessment (energy and telecommunications). The number and intensity of heatwaves is projected to increase, with the highest increases expected across northern Australia. The impacts of extreme temperatures can be compounded if they occur with other factors such as high humidity (Sherwood & Ramsay, 2023) or arid conditions.
Evidence: Critical Infrastructure Technical Report, Australia's Future Climate and Hazards Report
- Bushfires are highly disruptive for all 3 types of critical infrastructure assessed in this risk assessment. Bushfire risk is expected to increase across parts of Australia under future warming, with increases in the number of dangerous fire weather days and an extended fire season projected for southern and eastern Australia, and a potential for more megafires. In northern regions of Australia, rainfall projections are unclear. A future decrease in rainfall associated with regular drought and seasonal dry periods will result in reduced tree cover and vegetation, leading to lower fire intensity (Beringer et al., 2007; Liedloff & Cook, 2007), while a future increase in rainfall will lead to a short-term increase in vegetation and fuel load and result in hotter, more intense fires (Enright et al., 2012; Fisher, 2024; Harris et al., 2008).
Evidence: Critical Infrastructure Technical Report, Australia's Future Climate and Hazards Report
- Flooding affects all 3 types of critical infrastructure assessed in this risk assessment, but coastal inundation is less important for telecommunications than transport and energy. In parts of the east coast and tropics, an increase in annual severe run-off is projected, with a potentially greater risk of flooding. More intense short-duration heavy rainfall events are also projected, even in regions where the average rainfall decreases or stays the same. This could lead to flash flooding. As sea levels rise, the frequency and intensity of coastal and estuarine flood hazards are projected to increase across Australia. For 0.94 m of sea level rise, coastal locations are projected to experience around 257 days of at least minor-level coastal or estuarine flood days per year.
Evidence: Critical Infrastructure Technical Report, Australia's Future Climate and Hazards Report
- Extreme wind mostly affects telecommunications and energy infrastructure assessed in this risk assessment. Extreme wind can be a result of several different hazards, with extratropical lows, convective storms (thunderstorms) and tropical cyclones linked to the occurrence of extreme winds across Australia. While extratropical storms, tropical cyclones and convective storms may all decrease in frequency *(low-medium confidence)*, when they do occur, they are likely to be more intense *(medium confidence)*. This could lead to more low-probability, high-impact wind events.
Evidence: Critical Infrastructure Technical Report, Australia's Future Climate and Hazards Report

Exposures, vulnerabilities, impacts and risks

This section provides a summary of impacts and risks associated with the Infrastructure and the built environment system (Table 12).

These impacts and risks have been identified by understanding the changing climate hazards, as well as exposures and vulnerabilities that drive them.

Table 12: Summary of impacts to the Infrastructure and the built environment system and adaptation examples, derived from analysis for the National Assessment. Further details, including information sources, can be found throughout this chapter.

Climate impact	Current	Future change relevant to current			Current climate adaptation examples
	GWL +1.2°C	GWL +1.5°C	GWL +2.0°C	GWL +3.0°C	
Energy	Infrastructure susceptible to heatwave, bushfire and flood.	12 LGAs in very high category of multi-hazard severity index for energy infrastructure. All types of energy infrastructure at risk from increasing fires and heat, especially transmission lines.	14 LGAs in very high category of multi-hazard severity index for energy infrastructure. Chance of megafires increases in eastern Australia, with likely impacts to energy infrastructure.	16 LGAs in very high category of multi-hazard severity index for energy infrastructure.	Renewable and distributed energy sources (solar, rooftop solar, wind) to reduce grid dependency. Energy storage systems and microgrids. Energy efficient cooling systems.
Transport and supply chains	Regional and remote communities are most impacted by disruptions to transport infrastructure and supply chains. 6 LGAs in very high category of multi-hazard severity index for transport infrastructure.	6 LGAs in very high category of multi-hazard severity index for transport infrastructure.	9 LGAs in very high category of multi-hazard severity index for transport infrastructure.	22 LGAs in very high category of multi-hazard severity index for transport infrastructure.	Flood resilience assessments on national highways. Regional roads recovery schemes. Increased stockpiles or local resources.

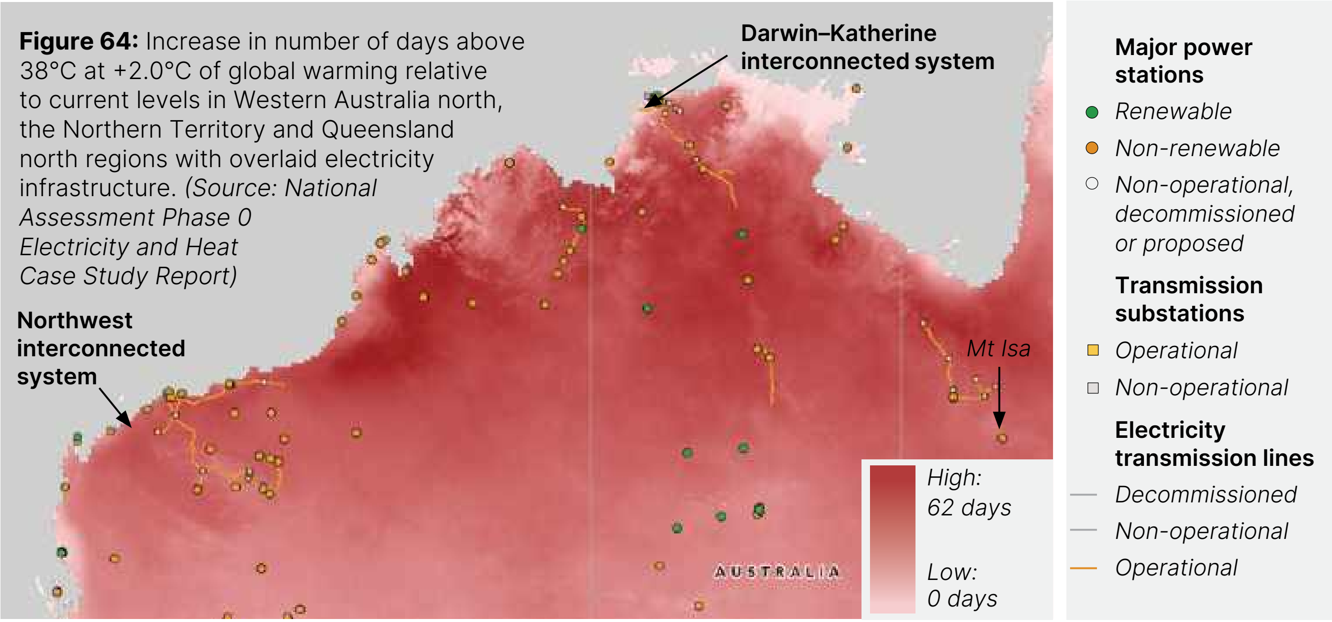
Climate impact	Current	Future change relevant to current			Current climate adaptation examples
	GWL +1.2°C	GWL +1.5°C	GWL +2.0°C	GWL +3.0°C	
Residential infrastructure	8.2% of residential buildings nationally in high-risk areas and 8.7% in very high-risk areas based on a communities multi-hazard risk index.	10.2% of current residential buildings nationally in very high-risk areas based on a communities multi-hazard risk index.	8.9% of current residential buildings in high-risk areas, and 11.1% of current residential buildings nationally in very high-risk areas, based on a communities multi-hazard risk index. Insurance premiums rise for >1.5% of houses to the point the property value declines by 10% (Bellrose et al., 2021).	13.5% of current residential buildings nationally in very high-risk areas based on a communities multi-hazard risk index. +9.0% of houses have insurance premiums rise to the point the property value declines by 10% (Bellrose et al., 2021).	Climate-adjusted building codes. Coastal protection infrastructure and nature-based adaptation (e.g. mangroves).
Water infrastructure	Pressures on water supply systems, particularly in drought-affected areas. Infrastructure maintenance more difficult and costly in rural and remote regions.	Multi-year droughts impact infrastructure assets and staff.	Multi-year droughts impact infrastructure assets and staff. Increasing heavy rainfall increases risks to communities for access to quality water.	Multi-year droughts impact infrastructure assets and staff. Increasing heavy rainfall leaves communities without access to quality water.	Water-recycling plants. Upgraded pipelines and infrastructure for water efficiency. Water conservation initiatives and usage limits during droughts.
Telecommunications	36 LGAs in very high category of multi-hazard severity index for telecommunications infrastructure.	38 LGAs in very high category of multi-hazard severity index for telecommunications infrastructure.	41 LGAs in very high category of multi-hazard severity index for telecommunications infrastructure.	58 LGAs in very high category of multi-hazard severity index for telecommunications infrastructure.	National disaster resilience programs focus on ensuring resilience in telecommunications infrastructure.
Coastal infrastructure	Infrastructure all around Australia is at risk from coastal flooding and inundation.	Seaports are at increased risk of disruption due to coastal inundation.	Coastal north Queensland infrastructure is at increased risk of coastal inundation.	Coastal north Queensland infrastructure is expected to experience severe consequences from coastal inundation.	Programs to improve coastal protection. Early warning systems in high-risk flood zones. Strategic planning strategies for coastal critical infrastructure.

Energy

Most energy infrastructure was not built to withstand the future climate-hazard extremes. Extreme heat events can result in operational curtailing of load and reductions to generation capacity, which leads to disruptions in energy supply when it is needed to keep people safe. These impacts are further compounded by increasing likelihoods of megafires, where the impact may range from reduced load, to the infrastructure being compromised or even locally destroyed *(high confidence).*

- Australia's extensive electricity system assets were built to withstand the weather and temperature extremes of a past climate (subject to the contemporary building standards). However, the number of days when a severe or extreme heatwave is experienced is projected to increase, with the greatest increases in the northern parts of Australia.
  Evidence: National Assessment Phase 0 Electricity and Heat Case Study Report
- The most exposed elements to heat extremes are networks in the far north and north west of Australia, which are already exposed to extreme heat and are likely to see substantial warming this century (Figure 64). Exposure is expected to increase for all locations around the middle of the century. This scenario poses significant operational risks, as the chance of all networks being affected simultaneously increases, with shortages in equipment, skilled workers and supplies possibly making mitigative action more difficult, leaving some communities more at risk of potential outages during extreme heat.
  Evidence: National Assessment Phase 0 Electricity and Heat Case Study Report
- Exposure to prolonged extreme heat can shorten the lifetime of power lines and transformer components, which increases maintenance requirements and the risk of abrupt failure. This will increase the cost of managing the energy networks and damages and losses due to abrupt outages. Total load and wind also affect a transformer's ability to shed excess heat, so the increased demand seen during extreme heat events would exacerbate the risk of transformer failure.
  Evidence: National Assessment Phase 0 Electricity and Heat Case Study Report
- The electrical and mechanical power system components of solar and wind farms are vulnerable to extreme heat (as are traditional electricity generators), with potential disruption to generator output and system reliability. Extreme heat is also a major driver of customer demand, and outages during high-demand periods potentially leave businesses and consumers vulnerable and can incur large economic impacts.
  Evidence: Electricity Sector Climate Information Case Study
- Energy infrastructure exposure to climate change risk is generally high, with the highest risk occurring near the Port Augusta LGA and surrounding regions of South Australia, and the Coffs Harbour and Port Macquarie Hastings LGA and surrounding regions in NSW (Figure 65).
  Evidence: Critical Infrastructure Technical Report
- Australia's forests are expected to be exposed to more frequent drought and heat with increasing global warming levels. This will make forests more susceptible to fire, with increased potential for megafires at high global warming levels and with impacts on infrastructure ranging from being compromised to being destroyed completely. There are substantial numbers of infrastructure assets and large population centres in the regions that are likely to be impacted by these fires, which will likely increase the impacts of disruption.
  Evidence: National Assessment Phase 0 Electricity and Heat Case Study Report, Australia's Future Climate and Hazards Report
- Flooding also affects energy infrastructure, resulting in large-scale and prolonged outages for communities near the hazard and for those sharing the network, resulting in extensive socioeconomic impacts in regional and remote areas (Freeman & Hancock, 2017).

Figure 64: Increase in number of days above 38°C at +2.0°C of global warming relative to current levels in Western Australia north, the Northern Territory and Queensland north regions with overlaid electricity infrastructure. *(Source: National Assessment Phase 0 Electricity and Heat Case Study Report)*



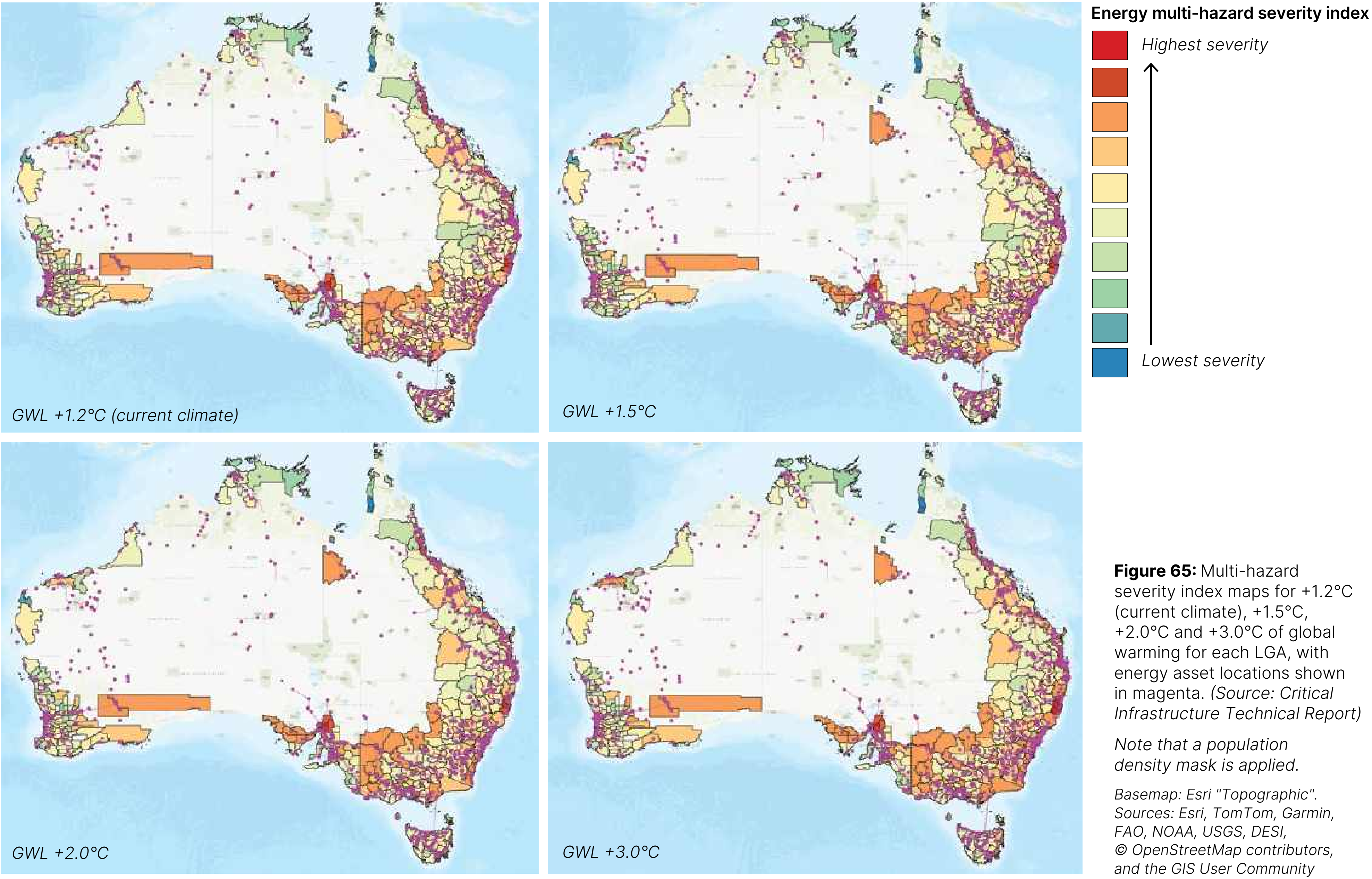


Figure 65: Multi-hazard severity index maps for +1.2°C (current climate), +1.5°C, +2.0°C and +3.0°C of global warming for each LGA, with energy asset locations shown in magenta. *(Source: Critical Infrastructure Technical Report)*

Note that a population density mask is applied.

Basemap: Esri "Topographic". Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, DESI, © OpenStreetMap contributors, and the GIS User Community

Transport and supply chains

Transport and supply chain infrastructure risk from more frequent acute hazards is increasing, with wide-ranging flow-on impacts. Regional and remote communities are likely to be the most impacted by infrastructure and supply chain outages due to their sparse and long transport networks, while impacts on regional hubs can have significant effects on other communities *(high confidence).*

- Extreme weather events that occurred during 2022–23, such as tropical cyclones, resulted in flooding and disrupted transport networks across Australia, which had significant impacts on supply chains between production and market/export. For example, Tropical Cyclone Jasper impacted Far North Queensland in 2023. Not only were the roads flooded, but road, bridge and rail infrastructure was damaged, sometimes taking several weeks to repair. These kinds of disruptions mean that food, fuel, clothing, household products, medical supplies and building materials are significantly delayed or may not reach their final destinations. For a modelled version of Tropical Cyclone Jasper, 168 enterprises were affected causing 150,000 tonnes of blocked freight with a value of $39 million. The cost of transport detours was $2.9 million.
Evidence: Supply Chains Technical Report
- Remote Australia has the highest vulnerabilities to supply chain disruptions due to sparse and long transport networks, a higher risk of closure due to natural hazards, and limited resources to respond to road disruptions. Access to supplies is often limited in remote communities, restricting their ability to supply provisions during disruption events. Another vulnerability is that regional communities are often providers of primary production, supplying other regional centres and urban areas.
Evidence: Supply Chains Technical Report, Communities Technical Report
- Climate change over the coming decades is expected to generally increase the frequency, severity and extent of coastal, estuarine, riverine and flash flooding events. This change is likely to lead to more road closures. These would subsequently increase the risk of supply chain disruptions along key freight routes, risking access to critical supplies by communities and extending the total recovery time after disruption.
Evidence: Communities Technical Report, Australia's Future Climate and Hazards Report
- Transport has a moderate combined hazard index, which is highest around rural parts of major states and territories. The risk to transport infrastructure increases most notably in inland Queensland between the current and future climate for higher global warming levels. This change is particularly evident for Isaac and Maranoa.
Evidence: Critical Infrastructure Technical Report
- While states and territory governments are responsible for the majority of public infrastructure spending, the Australian Government also invests in nationally significant land transport infrastructure through equity, loans and grants. This expenditure has increased to historically high levels in recent years, with the Australian Government's rolling 10-year transport infrastructure pipeline growing from $75 billion in 2018–19 (0.3% of projected GDP) to around $120 billion in 2023–24 (0.4% of projected GDP) (The Treasury, 2023a).
- In February 2022, a 1-in-200-year rain event (due to ex-Tropical Cyclone Tiffany) caused the closure of the Trans-Australian Railway line and Eyre Highway, disrupting freight to and from Western Australia with a value of $84 million and causing transport detours costing $12 million. A modelled version of a similar flood event in 2050 and 2090 demonstrated that detours for impacted freight from an event of this magnitude, with the current transport network but future hazard footprint, would increase on average 730 km for 2090 but could be as much as 3,000 km, leading to a significantly longer recovery period and a higher inventory depletion.
Evidence: Supply Chains Technical Report
- Supply chain disruptions from localised hazards can proliferate across Australia. Tropical Cyclone Jasper in December 2023 caused significant damage to freight infrastructure in Far North Queensland, disrupting the supply of critical commodities to towns and communities on the peninsula, including closure of the Palmerstone Highway and devastating the community of Wujal Wujal. Supply chain modelling of the impacts from Tropical Cyclone Jasper in 2090 found that impacts are still largely confined to north Queensland. However, indirect impacts include greater shortages of food products to the major distribution centres across Australia, particularly for those products grown in northern Queensland.
Evidence: Supply Chains Technical Report
- Across 3 extreme rainfall and flooding case studies that looked at the impacts of road and rail closures on supply chains, there was a larger impact on regional and remote communities than on larger urban areas. Regional freight routes, which generally are expected to carry a lower capacity, play a greater role in detours for the more extreme weather events. That is especially so in areas of a sparse road network such as western Queensland, the Northern Territory, western NSW and South Australia. Critical commodities such as medicines and some food (e.g. horticulture) experience a greater increase in impacted freight to 2050 and 2090 compared to most other sectors.
Evidence: Supply Chains Technical Report

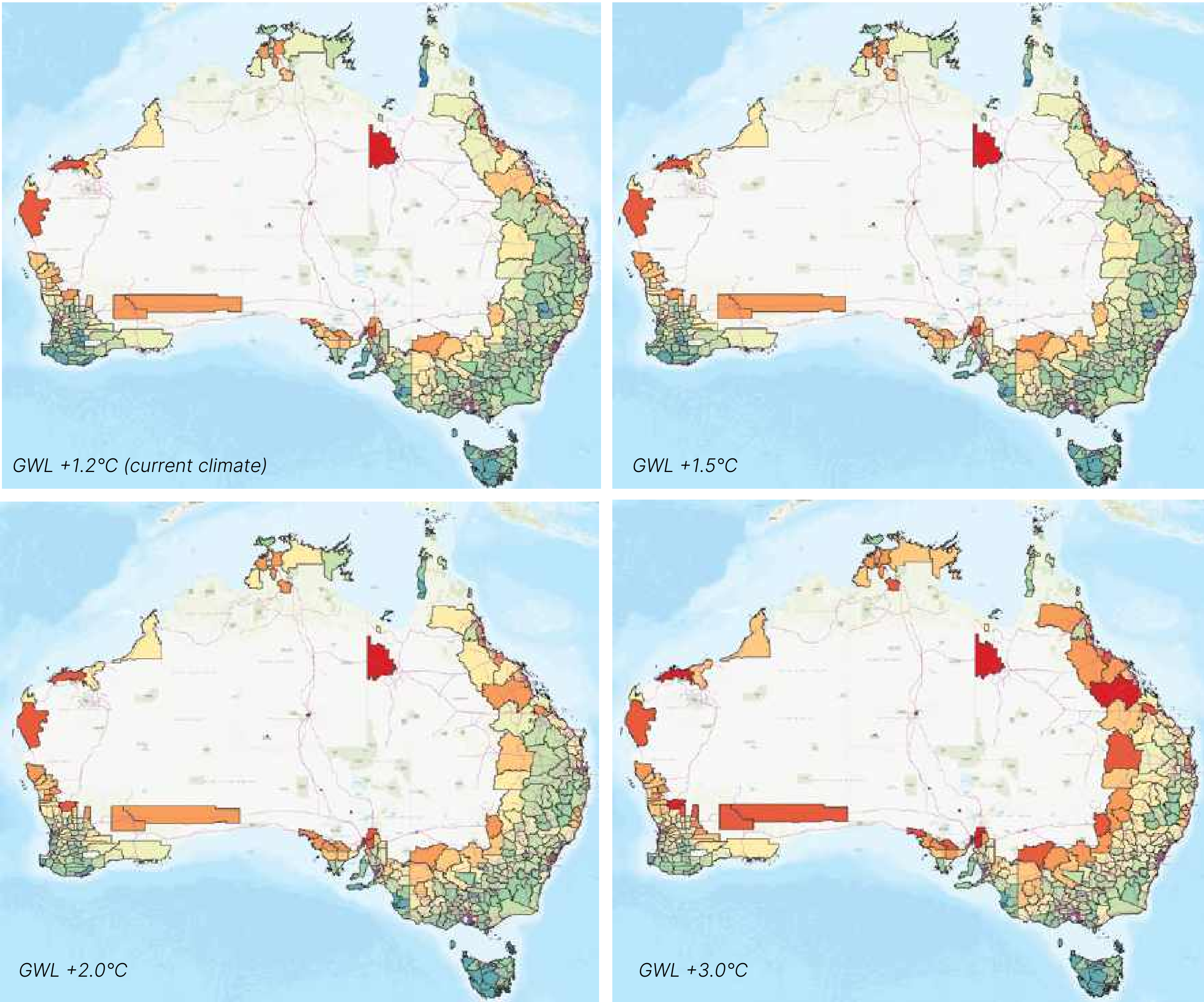


Figure 66: Multi-hazard severity index maps for +1.2°C (current climate), +1.5°C, +2.0°C and +3.0°C of global warming for each LGA, with transport asset locations shown in magenta. *(Source: Critical Infrastructure Technical Report)*

Note that a population density mask is applied.

Basemap: Esri "Topographic". Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, DESI, © OpenStreetMap contributors, and the GIS User Community

- Port Macquarie Hastings is among the LGAs with critical infrastructure most exposed to climate change. It has significant infrastructure running through it, including the Pacific and Oxley highways and the North Coast Railway line. As a regional hub in NSW, impacts here can have a ripple effect on other parts of the region.
  Evidence: Critical Infrastructure Technical Report
- Modelling of future population changes and their demand by location shows a significant increase in freight volumes and value along the major intercity freight routes. This is particularly the case for key freight routes, including the Stuart, Landsborough and Mitchell highways which are important supply chain connections to many remote communities (Department of Infrastructure, Transport, Regional Development, Communications and the Arts, 2023). The Stuart and Landsborough highways are prone to inland flooding, leading to a shortage of supplies in northern Australian towns (Haskin, 2022). An increase in the occurrence of extreme weather events along those routes will cause substantial disruptions of freight to market, communities and industry.
  Evidence: Supply Chains Technical Report

Impacts that stem from the Infrastructure and the built environment system will cascade through Australian society. A key pathway for this is through supply chain disruptions, which cause direct impacts to the Health and social support system and the Economy, trade and finance system. Australia's Infrastructure and the built environment system also has strong decision interdependencies with other systems *(low confidence)*.

- Disruptions to supply chains have cascading consequences across the economy. Impacts include reduced productivity and economic growth, higher food prices and increased cost-of-living pressures (Gao, 2024; Kompas et al., 2018; Lepore & Fernando, 2023; Steffen et al., 2019).
- Increasing physical risks to critical road, rail and port infrastructure supporting trade increases overall risk to regional trade (Gao, 2024) and could reduce the provision of food and health services (IPCC, 2022b). New risks such as rising biosecurity risks from changes in disease vectors may reduce trade, particularly for commodities and food products, and could lead to sudden and unexpected losses in access to key markets.
  Evidence: Real Economy Technical Report
- Stakeholder consultation identified that impacts originating in the Infrastructure and the built environment system are perceived as most likely to go on to impact the following systems: Communities - urban, regional and remote; Economy, trade and finance; Health and social support; and Natural environment.
- The Infrastructure and the built environment system has the strongest decision interdependencies with the Economy, trade and finance, Communities - urban, regional and remote, and Natural environment systems. Decisions in the Economy, trade and finance system generate impacts primarily in the Infrastructure and the built environment system. Decisions in Infrastructure and the built environment have the greatest impact on the Natural environment system (Figure 67).
  Evidence: Governance Technical Report

Residential infrastructure

Using today's housing distribution but future risk profiles from 4 hazards (tropical cyclones, flood, bushfires and extreme temperatures), the number of high-risk areas could double by 2100. Modelled high-impact, low-probability wind events show that higher levels of housing stock loss are expected in coastal and hinterland regions, particularly in Western Australia, the Northern Territory and Queensland *(medium confidence)*.

- The direct impacts of riverine flooding, coastal inundation, forest wildfires, wind storms and ground subsidence in drought could more than double the number of properties considered high risk (based on a value-at-risk of more than 1%) by 2100 and 1.5% could see insurance premiums rise to the point that their property value declines by 10% in 2050, rising to 9% in 2100 (Bellrose et al., 2021).
- Nationally, 8.2% of residential buildings are in high-risk areas and 8.7% in very high-risk areas currently, increasing to 10.2% (an additional 134,000 buildings) in very high-risk areas by 2030. The number of residential buildings in very high-risk areas is projected to increase from 928,000 (10.2%) at +1.5°C of global warming to 1,224,000 (13.5%) at +3.0°C.
  Evidence: Communities Technical Report

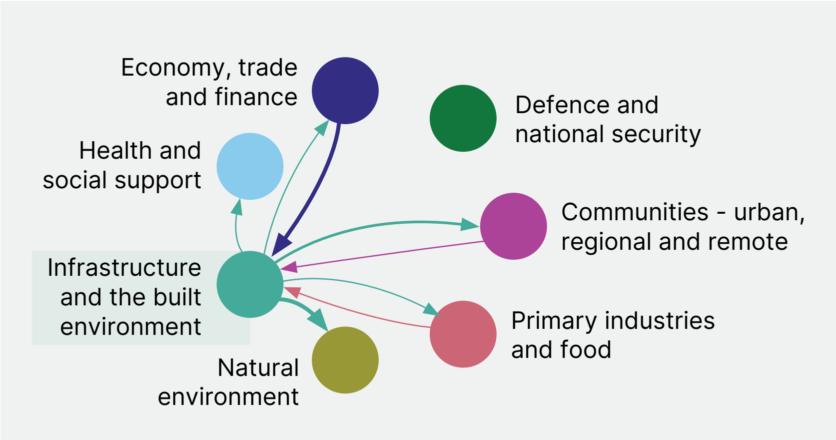


Figure 67: The flow of adverse impacts from decisions between the Infrastructure and the built environment system and other National Assessment systems. *(Source: Governance Technical Report)*

Each arrow originates at the system where the decision is made and points towards the system that is adversely impacted. The weight of each arrow represents the number of interactions identified. This data reflects stakeholder engagement workshops. The Aboriginal and Torres Strait Islander Peoples system followed a different approach and is not represented in this data.

- This pattern is also observed regionally, especially in the Northern Territory, where very high-risk areas are a significant concern. At +1.5°C of global warming, almost one-fifth (19.5%) of residential buildings in the region will be in high- and very high-risk areas, equating to around 52,000 buildings. In Queensland, particularly in the northern region, the number of residential buildings in very high-risk areas is projected to increase slightly across warming scenarios, with 178,000 buildings projected at +1.5°C of global warming, 181,000 for +2.0°C of global warming, and 185,000 for +3.0°C of global warming. The growing intensity and frequency of climate-driven hazards could result in higher impacts, raising concerns about the provision, affordability and accessibility of insurance (Productivity Commission, 2012).
Evidence: Communities Technical Report
- Vulnerability functions for residential separate houses and semi-detached houses relate incident wind speeds to the expected level of structural damage sustained by those houses. A National Wind Vulnerability Assessment conducted for the residential building stock found that damage from a wind event with a 10% chance of occurring in any given year had higher levels of loss occurring in regional areas, including central Queensland, southwest Western Australia and southeast South Australia. However, extreme wind events with a 1% and 0.2% chance of occurring in any given year show the higher levels of loss are expected in coastal and hinterland regions, particularly Western Australia, the Northern Territory and Queensland (Figure 68).
Evidence: National Residential Wind Risk Assessment

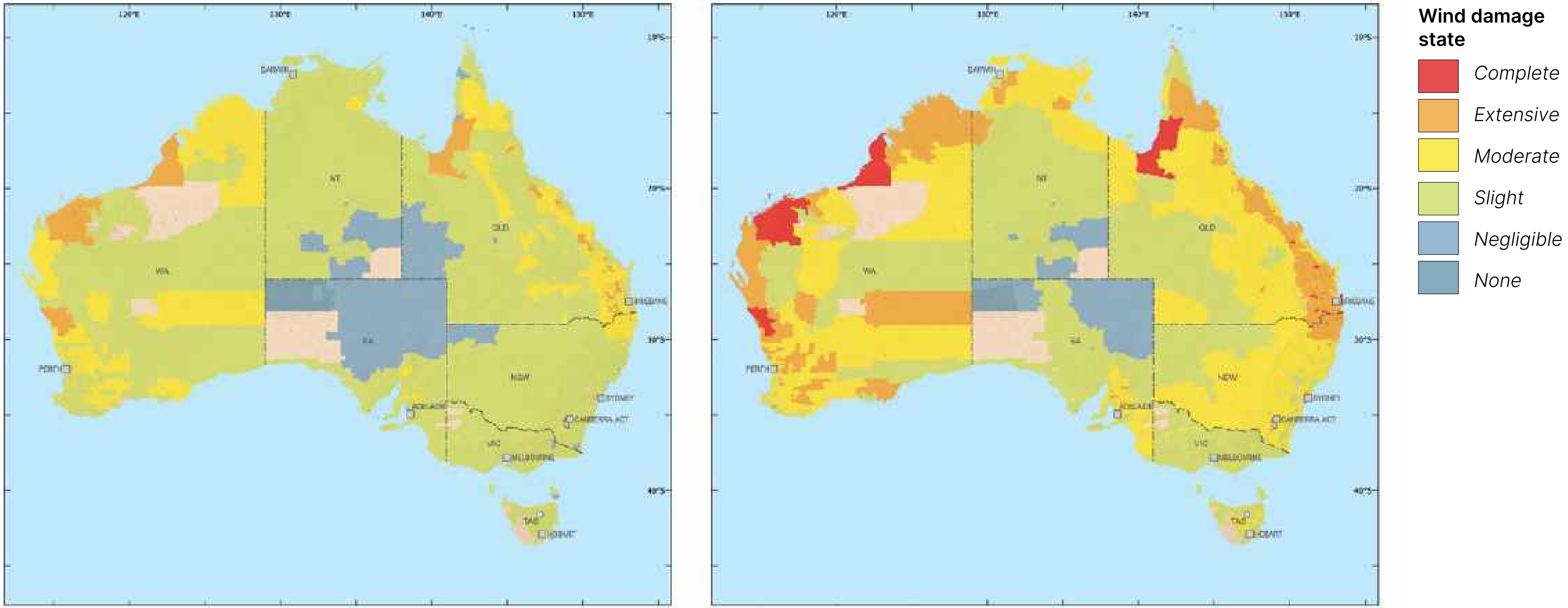


Figure 68: The structural loss ratio (sometimes also called the damage ratio or loss ratio) of the residential building stock for a severe or extreme wind event. Stock is categorised into damage states for the impacts from a 1% or 1-in-100 (left) and 0.2% or 1-in-500 (right) annual exceedance probability event. *(Source: National Residential Wind Risk Assessment)*

Water infrastructure

Water security will be challenged by climate change, especially by increases in climate extremes including flood, extended dry periods, storms and increased temperatures. Regional and remote communities are at particular risk from compromised water infrastructure *(medium confidence).*

- Rural and remote water supplies face increased risk due to infrastructure challenges, with declining populations, high set-up and maintenance costs, and skilled worker shortages impacting water security.
  Evidence: Water Security Technical Report
- Storms damage water and energy infrastructures, potentially leaving communities without access to quality water, impacting filtration systems and increasing the risk of cross-contamination from sewerage infrastructure. At-risk populations, particularly among Aboriginal and Torres Strait Islander communities, face heightened health risks from water security challenges, particularly in remote communities where water assets are harder to maintain. The frequency of intense short-duration heavy rainfall events is projected to increase across most of Australia, raising the risk of infrastructure damage and potentially affecting water quality.
  Evidence: Water Security Technical Report, Australia's Future Climate and Hazards Report, Communities Technical Report
- Multi-year droughts heighten water security risks due to infrastructure impacts from increasing bushfire threats to assets and staff, straining pumping assets during heatwaves and accelerating deterioration of pipes and tanks. These dry conditions also demand more intensive water treatment due to poor water quality, raising the impact of infrastructure failures that can severely impact rural, agriculture-dependent communities. Multi-year dry periods can lead to crop failures, loss of livestock and reduced income, increasing economic vulnerability in those areas.
  Evidence: Water Security Technical Report
- Climate change, particularly through increased extreme rainfall and run-off, will challenge dam safety. Many dams are already below acceptable flood capacity due to climate impacts and this risk is expected to escalate, particularly in regions like the Murray-Darling Basin. At +3.0°C of global warming, our ability to maintain safety standards may diminish, leading to increased community safety risk or to potential abandonment of dams and even relocation of communities.
  Evidence: Water Security Technical Report

Telecommunications

Telecommunications infrastructure is at risk from the increasing frequency of climate hazards such as extreme heat, bushfires, flooding, extreme wind and coastal hazards. The risk to telecommunications infrastructure is generally high, particularly near the coasts *(medium confidence).*

- The risk to telecommunications infrastructure is generally high, particularly near the coasts (Figure 69). Telecommunications had the most LGAs in the very high category compared to the other 2 types of critical infrastructure assessed (energy and transport).
  Evidence: Critical Infrastructure Technical Report
- The loss of telecommunications is a priority impact of concern for water and wastewater infrastructure from cyclones, resulting in the inability to remotely control treatment processes (Water Services Association of Australia, 2021) and provide water services (Department of Agriculture, Water and the Environment, 2021). Impacts on water and wastewater infrastructure could increase short-term risk of communicable disease transmission in remote communities.
  Evidence: Water Security Technical Report
- The loss of telecommunications has flow-on impacts to other systems – in particular, health and the economy. For example, when telecommunications fail, financial transactions cannot be processed (Fu et al., 2016) and people needing emergency help cannot access ambulance services.

Coastal infrastructure

Infrastructure in coastal communities is particularly vulnerable to the impacts of sea level rise and other coastal hazards. Some of the most at-risk areas and communities include urban coastal centres and infrastructure hotspots – in particular, in Queensland *(high confidence).*

- Seaports are exposed to disruption from coastal inundation. If global sea level rise reaches 0.94 m, Australian coastal locations are projected to experience a median increase of around +257 flood days (around 9 months, of at least minor coastal flood days per year. Currently, they experience around 15 days per year.) Using a social cost metric, LGAs within Queensland are shown to be at high risk, with several LGAs within the highest decile of the risk metric including the Mackay and Gladstone regions.
  Evidence: Critical Infrastructure Technical Report, Australia's Future Climate and Hazards Report
- Major urban centres located along the coast, such as Sydney, Melbourne, Brisbane, Perth and Adelaide, are vulnerable to the impacts of climate change, particularly due to their extensive infrastructure, dense populations and economic significance. Coastal suburbs and waterfront developments within these cities face risks from sea level rise, storm surges and extreme weather events.
  Evidence: Communities Technical Report
- Buildings (residential, commercial and industrial), critical infrastructure (roads and transport, power and telecommunications) and transport networks, and water supply close to the coast are particularly at risk when storm surges are combined with sea level rise. By 2050, the risk of climate impacts is expected to escalate, particularly in northern Queensland, where LGAs such as Isaac, Whitsunday and Fraser Coast are projected to face heightened vulnerabilities. By 2090, Livingstone and Fraser Coast are expected to experience severe consequences, indicating a long-term trend of persistent challenges for coastal communities.
  Evidence: Communities Technical Report

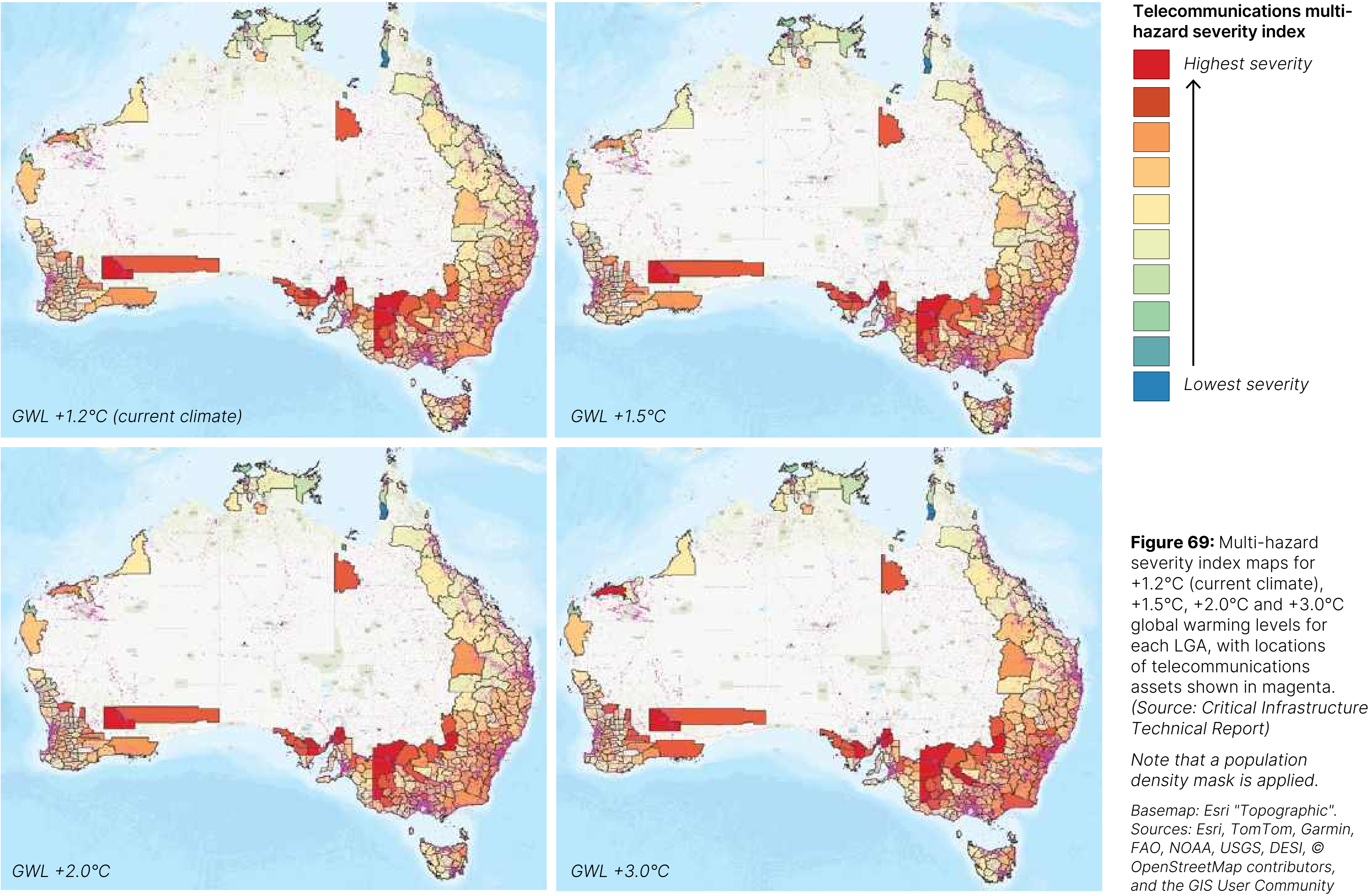


Figure 69: Multi-hazard severity index maps for +1.2°C (current climate), +1.5°C, +2.0°C and +3.0°C global warming levels for each LGA, with locations of telecommunications assets shown in magenta. *(Source: Critical Infrastructure Technical Report)*

Note that a population density mask is applied.

Basemap: Esri "Topographic". Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, DESI, © OpenStreetMap contributors, and the GIS User Community

Aboriginal and Torres Strait Islander communities' infrastructure

Aboriginal and Torres Strait Islander peoples are directly affected when hazards compromise infrastructure and services. These impacts on infrastructure and services can exacerbate pre-existing inequalities and are largest in remote communities *(high confidence).*

- Aboriginal and Torres Strait Islander consultations highlighted that rural and remote Aboriginal and Torres Strait Islander communities may face heightened risks due to climate change impacts on their infrastructure and built environment. As hazards such as severe weather events, extreme heat and bushfires intensify, the disproportionate risks associated with already unsafe infrastructure are exacerbated, necessitating proactive risk mitigation and earlier replacement cycles. One such risk is the loss of opportunity for education, which will occur if school buildings are unable to withstand all hazards, such as floods and severe weather. Another is the lack of access to Country with risks to the ability to teach Lore, care for Country and practise ceremonies.
  Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering
- Aboriginal and Torres Strait Islander consultations highlighted that communities also require additional infrastructure to ensure safety and security during severe and extreme natural hazard events. However, decisions regarding infrastructure development must be made with careful consideration of Aboriginal and Torres Strait Islander peoples' cultural values and knowledges. Prioritising infrastructure solutions that could harm Country or cultural practices, such as flooding a dam without consulting Aboriginal and Torres Strait Islander perspectives, may pose a significant risk to cultural heritage. Future planning must prioritise the preservation of cultural heritage in the context of climate adaptation and infrastructure development.
  Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering

- The number of severe or extreme heatwaves is projected to increase under all future warming levels, with areas of northern Australia projected to experience the highest increases. The Northern Territory has the highest proportion of Aboriginal and Torres Strait Islander peoples in Australia (Australian Bureau of Statistics, 2024; Quilty et al., 2023), with large inequalities regarding overcrowded and poor-quality housing (Quilty et al., 2022). This population will be increasingly exposed to more frequent and more severe heatwaves, further putting these communities at risk. However, social and cultural adaptations have been shown to be potentially very effective in protecting human health against extreme heat (Quilty et al., 2023).
Evidence: Australia's Future Climate and Hazards Report
- Many Aboriginal and Torres Strait Islander communities are in regional or remote areas with vulnerable supply chains and critical infrastructure. These areas are poorly served by emergency response capacity and are highly exposed to extreme hazard events.
Evidence: National Disasters and Emergency Management Technical Report, Communities Technical Report
- Remote communities, particularly Aboriginal and Torres Strait Islander peoples' communities, face heightened health risks from water security challenges during emergency events. Remote communities typically have fewer alternative water resources to turn to and are more likely to access sub-standard drinking water as a result or compromised water from hazards such as drought.
Evidence: Water Security Technical Report, Communities Technical Report
- Aboriginal and Torres Strait Islander consultations highlighted that Aboriginal and Torres Strait Islander peoples' cultural values and knowledges are at risk from decisions to use infrastructure to respond to climate risks in ways that are hazardous to Country or cultural practice – for example, building hard infrastructure or changing waterways to reduce physical exposure to future events.
Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering

Adaptation observations and considerations

This section provides information that can support adaptation planning and approaches.

Adaptation activities within the Infrastructure and the built environment system are diverse. Common activities include risk assessments, direct risk-reduction projects for specific assets or urban environments, and nature-based adaptation projects that offer co-benefits for the Natural environment system *(high confidence).*

- Infrastructure has long lead times and building codes and standards are slow to change, which means that they are built to often out-dated standards for the current (or even previous) climate. Once built, this infrastructure requires a very high investment to improve its resilience to climate change. This increases the importance of climate change-informed planning for this sector.
Evidence: Critical Infrastructure Technical Report
- Coastal infrastructure is also being protected by the natural environment. Mangroves and tidal wetlands are vital ecosystems that almost exclusively occupy the tidal zone, limiting their extent to narrow belts parallel to Australia's shorelines. Australia is home to over half of the world's mangrove species, which provide incredibly important natural protection and buffering for coastline. The fringing nature of mangrove and tidal wetlands stabilises soils and sediments in intertidal zones, acting as natural buffers against severe storms and cyclones, estimated to be providing protection to $1.7 billion in coastal infrastructure. Enhancing this protection will help to reduce risks from coastal hazards.
Evidence: Natural Ecosystems Technical Report
- Most adaptation programs within the Infrastructure and the built environment system focus on tangible interventions, such as new airport runways, flood warning systems and urban greening projects (Figure 70). This system also has a high proportion of risk assessments (a key example of information gathering) compared to others.
Evidence: Insights from the Adaptation Stocktake
- Most adaptation strategies for critical infrastructure are implemented at state/territory or city levels, including building code changes and climate change strategies for urban water management and greening.
Evidence: Insights from the Adaptation Stocktake

Insufficient integration of land-use, building and infrastructure planning can exacerbate climate change impacts, leading to maladaptation and increased vulnerability to hazards. This is particularly critical for rural and remote communities, which require enhanced infrastructure and water security measures to mitigate heightened risks *(high confidence).*

- Insufficient integration of land-use, building and infrastructure planning and regulation can significantly exacerbate the impacts of climate change. For example, development in flood-prone zones, infrastructure that is old or not climate-adapted, or the construction of buildings that do not meet current codes can heighten vulnerability to climate hazards. Such shortcomings in planning and regulation may lead to maladaptation as properties and infrastructures become more susceptible to damage from extreme weather events and sea level rise.
Evidence: Communities Technical Report

- Many urban coastal regions have been developed without adequately considering the long-term implications of climate change, leading to vulnerabilities in existing infrastructure. Legacy infrastructure – such as drainage systems, roads and buildings – often lacks the capacity to withstand the increasing frequency and intensity of extreme events, including storms and floods, as well as future sea level rise (Department of Climate Change, 2009).
Evidence: Communities Technical Report
- Aboriginal and Torres Strait Islander consultations highlighted that rural and remote Aboriginal and Torres Strait Islander communities may experience more pronounced risks due to the impacts of climate hazards on their Infrastructure and built environment system. Therefore, these communities need increased infrastructure provision to provide safety and security during more frequent and extreme natural hazard events.
Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering
- Remote communities, particularly Aboriginal and Torres Strait Islander peoples' communities, face heightened health risks from water security challenges. Effective adaptation to water security challenges may involve making sufficient plans to monitor, maintain and repair remote water assets, particularly during emergency events.
Evidence: Water Security Technical Report

The increasing complexity of the interests and values that need to be balanced or traded-off requires a focus on governance. Governance for infrastructure adaptation requires focus on policy and planning, as well as implemented programs and projects. The high proportion of adaptation policies and actions targeting the Infrastructure and the built environment system provides a strong foundation for further action *(high confidence).*

- Adapting to the distributed risk in this system requires strong coordination and regulation through governance frameworks for urban planning to avoid maladaptation due to fragmented decision-making. Examples of strong governance frameworks include cohesive regulation and planning for vulnerable areas and assets, and sustained agreement on roles and responsibilities for adaptation within complex built environment systems.
Evidence: Insights from the Adaptation Stocktake
- Future climate-related health impacts are compounded by impacts to critical infrastructure and supply chains, potentially disrupting the availability of medical supplies and narrowing health response options such as continued care for displaced persons with complex health needs. Ensuring infrastructure and supply chains are sufficiently adapted to changing risks driven by climate is a necessary step to manage health risks in remote communities.
Evidence: Health and Wellbeing Technical Report
- Institutional adaptation is the most common IPCC type of adaptation in this system, involving changes in governance such as regulation and planning. These institutional adaptations mainly focus on inquiries and planning for specific infrastructure types, such as coastal commercial buildings and transport infrastructure. The Northern Territory has more entries for the Infrastructure and the built environment system than other systems, indicating recognised risks in that region.
Evidence: Insights from the Adaptation Stocktake
- The Infrastructure and the built environment system has the second-largest proportion (16%) of total policies, plans and laws, and the largest proportion (30%) of adaptation actions, within the stocktake of adaptation policies. Most adaptation projects in this system occur at a local scale and are delivered by state, territory and local government agencies, reflecting the need for place-based adaptation focused on key strategic assets in the built environment (Figure 71). This aligns with the risks and governance arrangements for this system.
Evidence: Insights from the Adaptation Stocktake

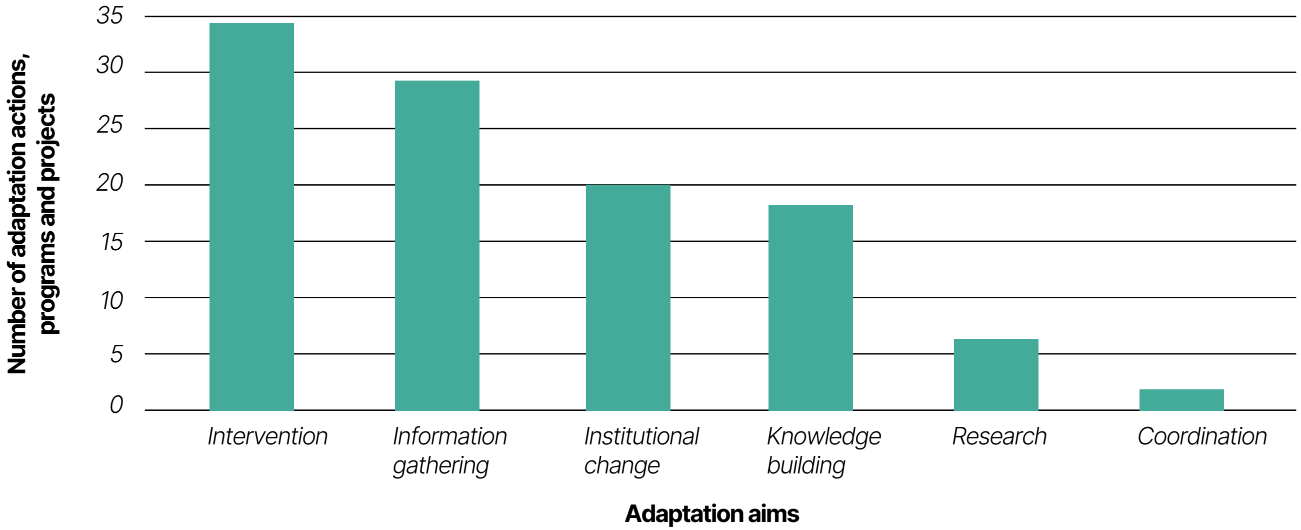


Figure 70: Distribution of adaptation actions, programs and projects across adaptation aims in the Infrastructure and the built environment system. *(Source: Insights from the Adaptation Stocktake)*

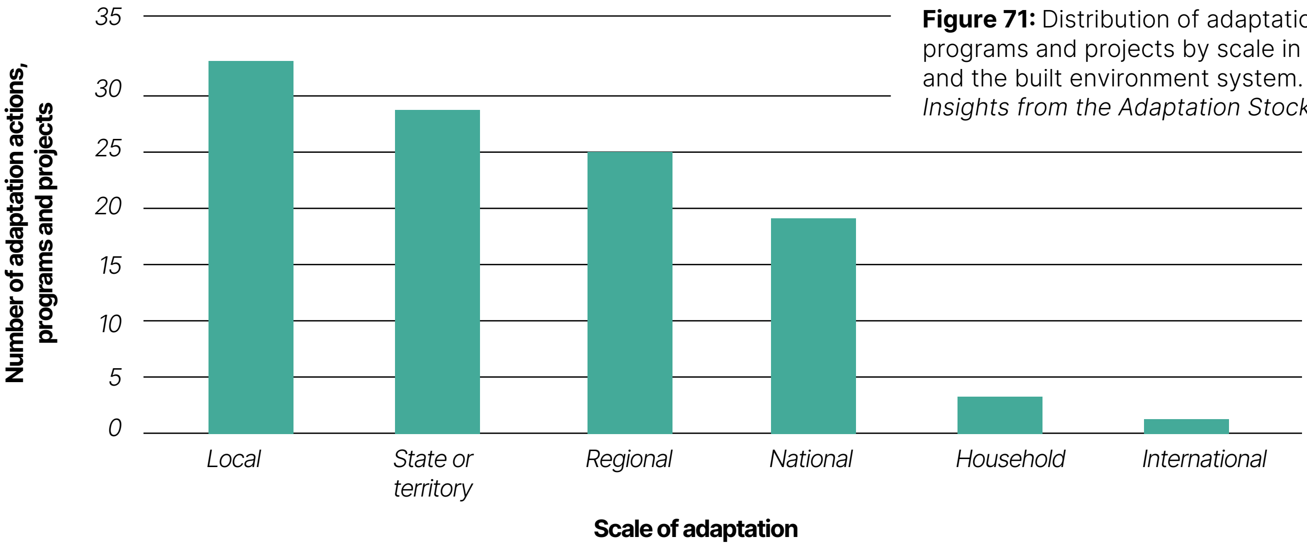


Figure 71: Distribution of adaptation actions, programs and projects by scale in the Infrastructure and the built environment system. *(Source: Insights from the Adaptation Stocktake)*

- Adaptation resources are becoming more sophisticated, with new guides providing quantitative information on considering future climate in flood hazard assessments (e.g. Australian Government Geoscience Australia, 2024). This can support preparation for this key hazard in the Infrastructure and the built environment system.

Adaptation actions, programs and projects in the Infrastructure and the built environment system address general climate-driven risks and specific hazards such as coastal and riverine flooding. These actions align well with the risks identified for this system *(high confidence).*

- Climate change presents risks to Australia's infrastructure and built environment through direct hazards as well as through increasing the complexity of the interests and values that need to be balanced or traded-off through governance. Preparing and deciding on strategies and policies are the greatest challenges for Australia's Infrastructure and the built environment system. The system is likely to be challenged by the need to integrate complex information, interpret knowledge and resolve conflicts.
  Evidence: Governance Technical Report
- After general climate change, the primary hazards being addressed by adaptation projects in this system are coastal erosion, coastal flooding and riverine flooding (Figure 72). General climate change refers to adaptation programs, projects or actions that broadly address vulnerability to climate change or climate variability. Other hazards may be addressed as part of general infrastructure upgrades and hardening.
  Evidence: Insights from the Adaptation Stocktake

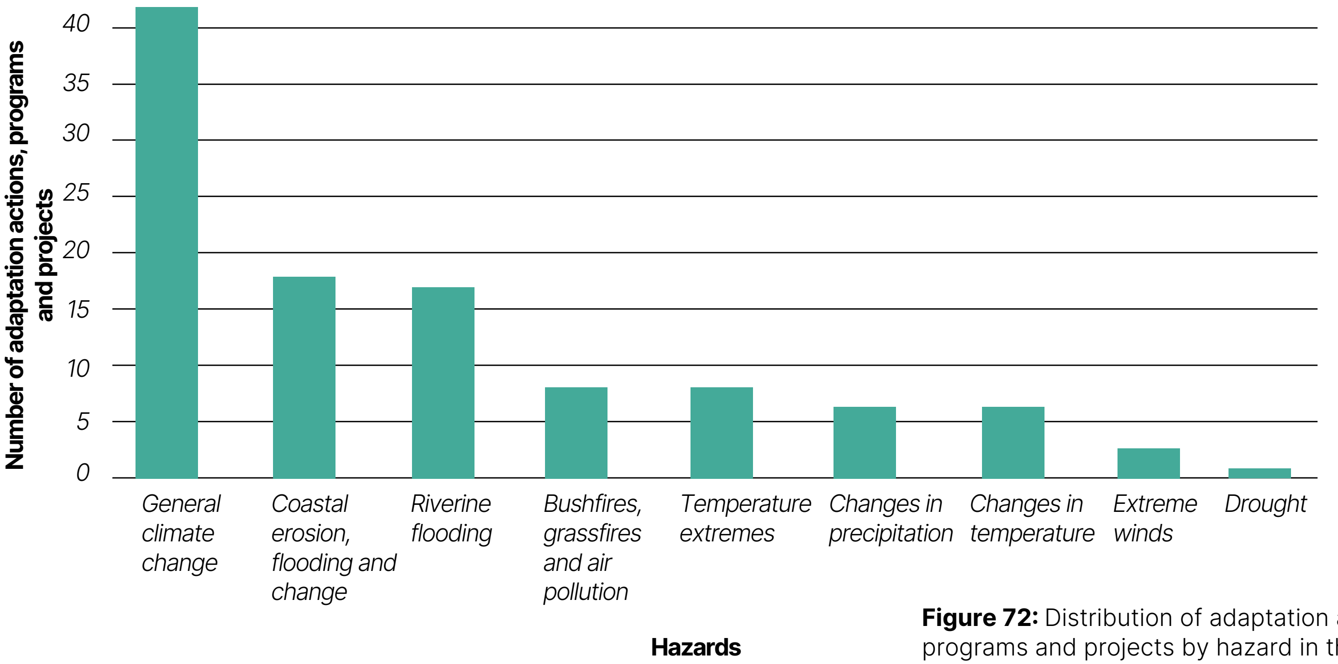


Figure 72: Distribution of adaptation actions, programs and projects by hazard in the Infrastructure and the built environment system. *(Source: Insights from the Adaptation Stocktake)*

Case study: Disruption to the east–west road and rail corridor during February 2022

In February 2022, an extreme rain event with a 0.5% chance of occurring in any year occurred from ex-Tropical Cyclone Tiffany.

The event caused the closure of the Trans-Australian Railway line and Eyre Highway, disrupting freight to and from Western Australia. Agencies used temporary permits to help clear the backlog along the road freight network. This case study was selected to help understand the future impacts of disruptions to national freight routes – in particular, the main east–west connections – and will focus on the impacts of infrastructure closures in South Australia.

The case study was modelled for supply chain impacts as if the event occurred in 2024, 2050 and 2090. Road closures and their extents were used to determine the scale of the hazard, defined through flood extent and depth data. Future hazards were then produced after determining flood depth thresholds that would trigger road closure events in 2050 and 2090. Exposure and vulnerability for the current and future climate were produced using projected demographics and land-use data.

Over the 3 time periods (2024, 2050 and 2090) there was a modelled increase in road closures in the event region: 2050 had an increase of a 42% increase in road closures, while 2090 had a 280% increase, compared to 2024 (Figure 73).

Summary statistics are:

- 192 enterprises (37,000 tonnes) experienced freight blockage during the 7-day event in 2024, increasing to 241 enterprises (40,000 tonnes) in 2050 and to 382 enterprises (54,000 tonnes) in 2090.
- Transport cost of detours for the 7-day disruption was $12 million in 2024, rising to $18 million in 2050 and to $38 million in 2090, using current Australian dollars.

Added to these impacts would be a further 55,000 tonnes of rail freight not able to reach their destination, at a value of $659 million. This translates to 2,750 extra trailers (or 1,400 extra A-double road trains) covering up to 4,000 km per trip required to meet this freight task. The most impacted rail commodities were general freight, building materials and beverages.

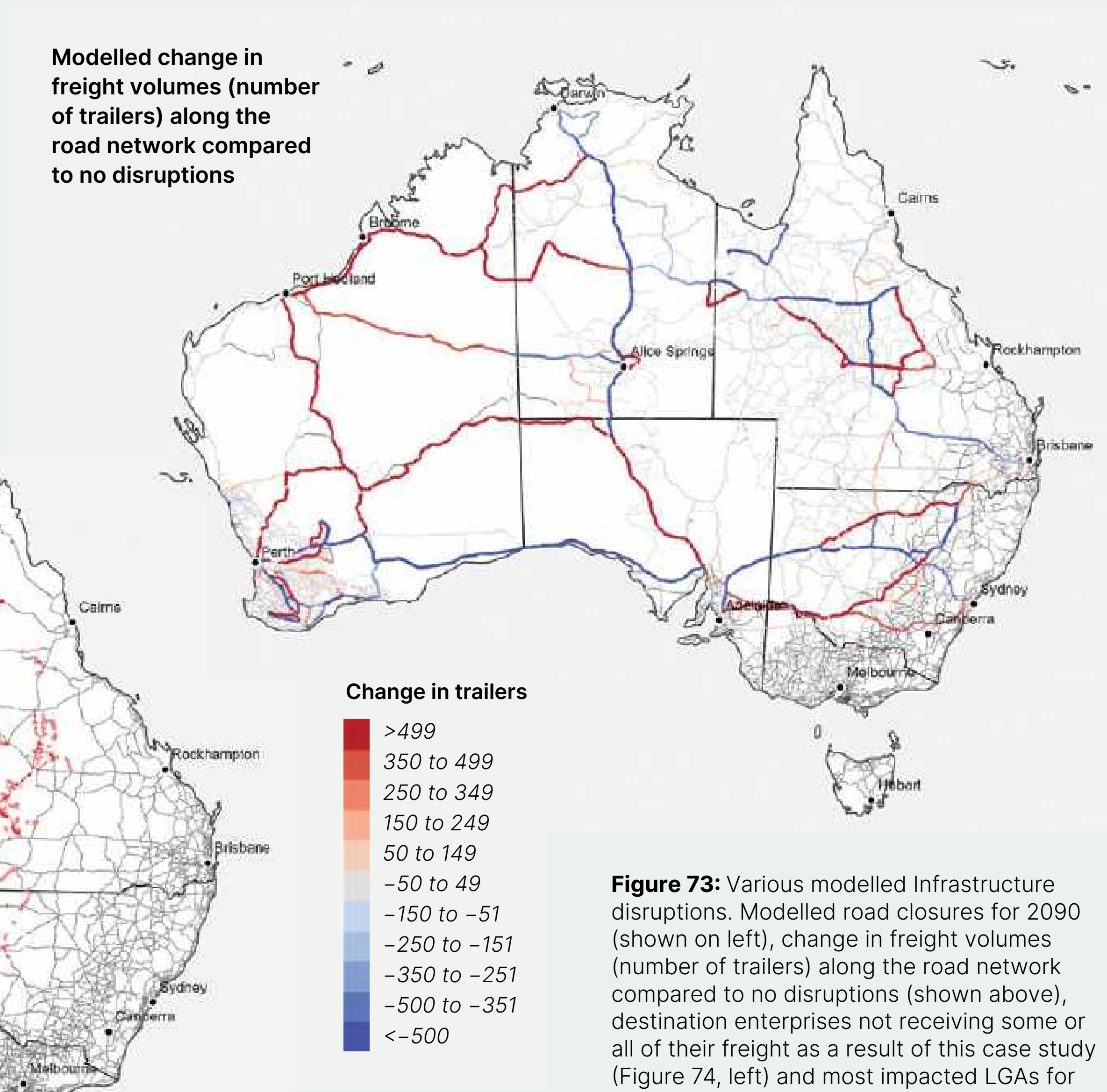
General freight was the most impacted from the perspective of total costs, due to the reliance on the major intercity freight corridors such as the Eyre, Barrier and Stuart highways. Health (largely medicines) was the most impacted sector in terms of percentage increase in transport costs to 2090, with a 101.6% increase. Some sectors such as mining had a reduced rerouting impact, largely because those trips became blocked.

A more severe version of the east–west event led to a significantly larger portion of freight taking longer detours. This was particularly the case for 2090 versus 2024. With the loss of the Eyre and parts of the Stuart and Barrier highways, there were large detours using lower-ranked roads such as the Outback Way, Tanami Road and Goldfield Highway. In practice, many of these detour roads would not be used unless they were upgraded to a higher standard for 2050 and 2090 and supplementary services were available, such as the provision of fuel, food and driver fatigue management facilities.

There was a big increase in fuel disruption in 2090, due to additional road closures preventing fuel movements to regional mines and fuel stations. The blockage of construction materials brings about an added challenge to authorities to source materials to undertake repairs to key freight routes.

For all 3 time periods, enterprises across several remote Gulf of Carpentaria communities were impacted. With a more severe event in 2050 and 2090, the impacted enterprise and communities spread across western Queensland, the Northern Territory and southern part of Western Australia.

There is a significant increase in impacted Central Australia LGAs for both blocked and rerouted freight at 2050 and 2090. Figure 74 demonstrates that most impacted LGAs were Aboriginal and Torres Strait Islander and remote communities.



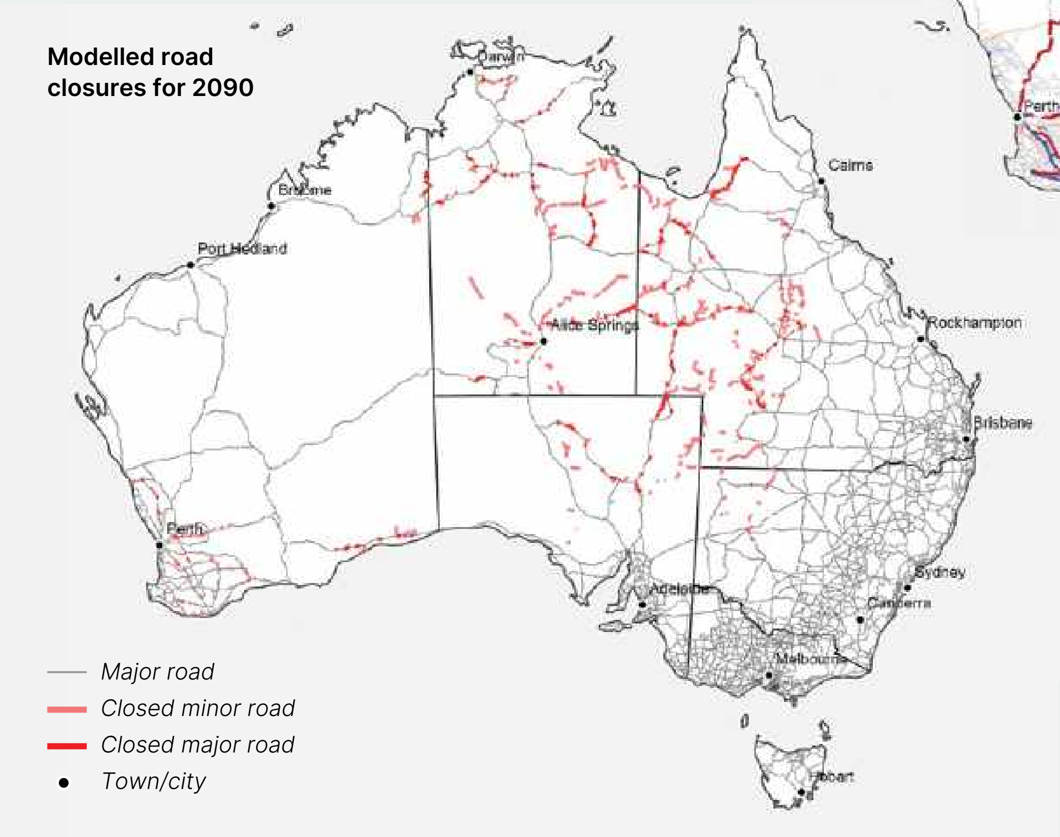
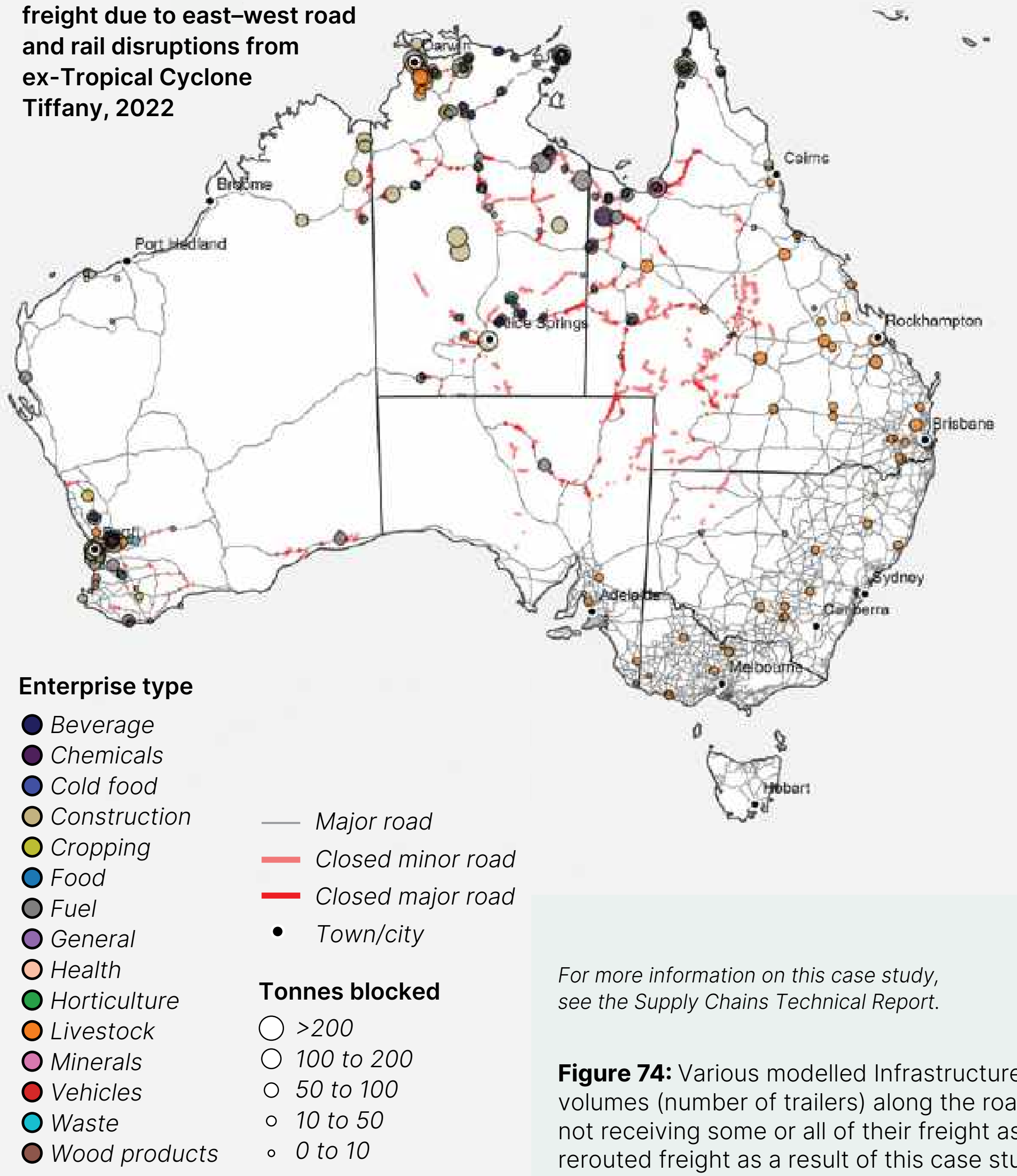


Figure 73: Various modelled Infrastructure disruptions. Modelled road closures for 2090 (shown on left), change in freight volumes (number of trailers) along the road network compared to no disruptions (shown above), destination enterprises not receiving some or all of their freight as a result of this case study (Figure 74, left) and most impacted LGAs for blocked or rerouted freight as a result of this case study (Figure 74, right). Roads data © HERE. *(Source: Supply Chains Technical Report)*

Modelled destination enterprises not receiving some or all of their freight due to east–west road and rail disruptions from ex-Tropical Cyclone Tiffany, 2022



For more information on this case study, see the Supply Chains Technical Report.

Most impacted LGAs for blocked or rerouted freight due to east–west road and rail disruptions from ex-Tropical Cyclone Tiffany, 2022

Destination LGA	Blocked	Rerouted	Blocked or rerouted
Burke	100%		100%
Mapoon	100%		100%
Aurukun	100%		100%
Napranum	100%		100%
Croydon		100%	100%
Wandering		100%	100%
Doomadgee	100%		100%
Barcoo		100%	100%
Diamantina	2%	98%	100%
Carnamah	7%	93%	100%
Carpentaria	98%	2%	100%
Barkly	22%	75%	97%
Boulia	96%		96%
Central Desert	19%	77%	96%
Mingenew		95%	95%
Flinders (Qld)		95%	95%
Boddington	3%	88%	91%
Torres	91%		91%
Alice Springs	5%	85%	90%
Northam	82%	8%	90%

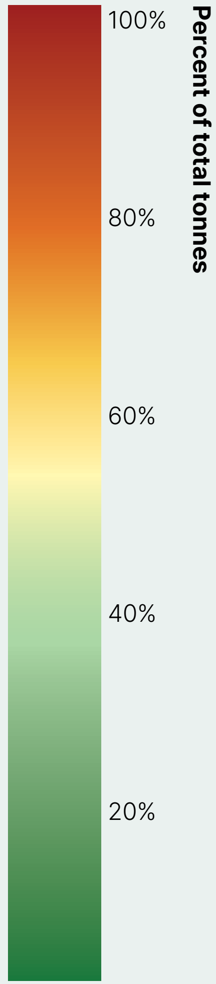
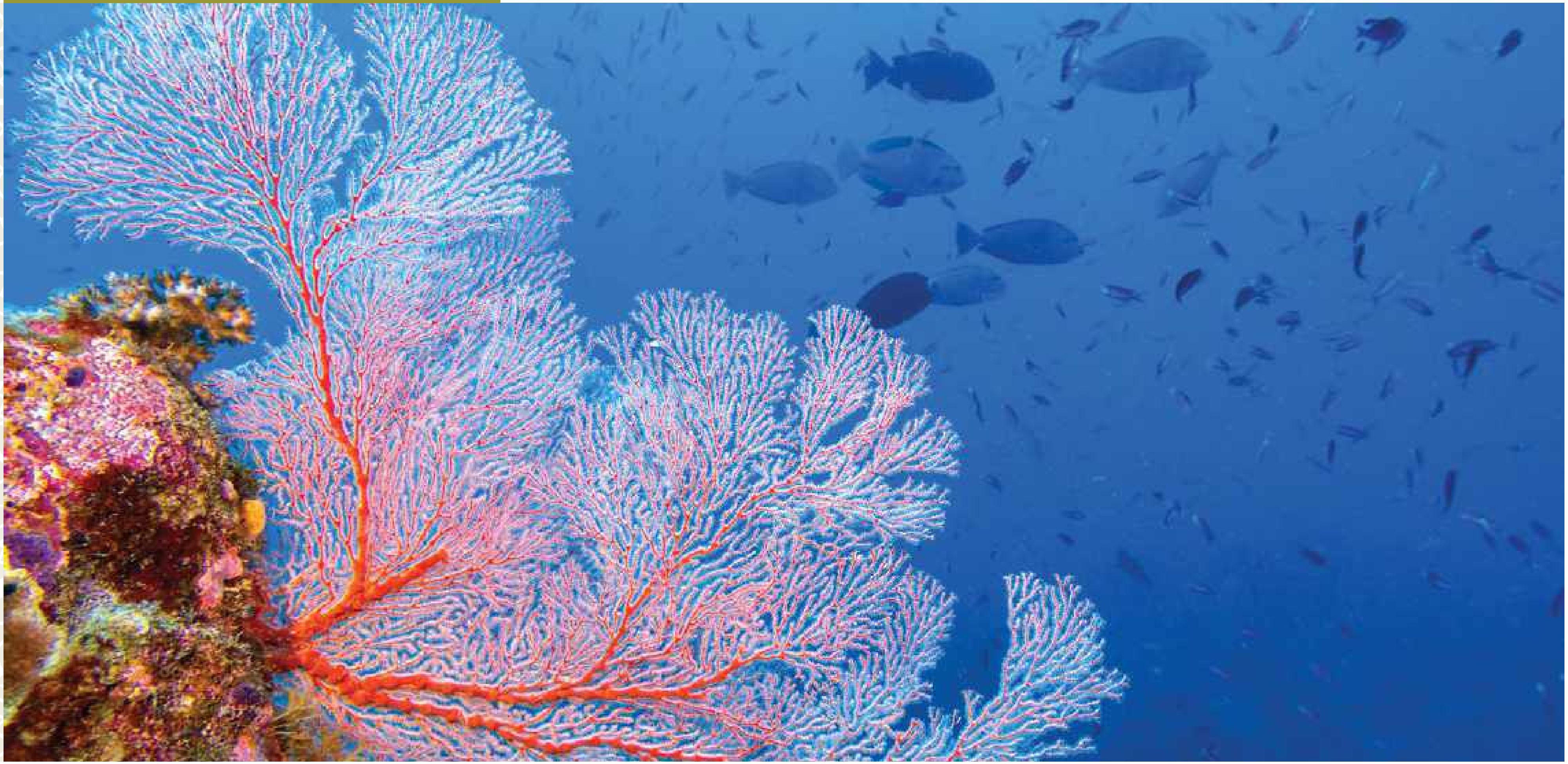


Figure 74: Various modelled Infrastructure disruptions. Modelled road closures for 2090 (Figure 73, left), change in freight volumes (number of trailers) along the road network compared to no disruptions (Figure 73, right), destination enterprises not receiving some or all of their freight as a result of this case study (shown on left) and most impacted LGAs for blocked or rerouted freight as a result of this case study (shown on right). Roads data © HERE. *(Source: Supply Chains Technical Report)*



Natural environment system

Summary

The Natural environment system encompasses Australia's ecosystems and biodiversity. This system includes Australia's lands, waters and oceans.

Priority risks

The National Assessment has undertaken quantitative and qualitative analysis for priority risks. The first pass assessment identified 8 nationally significant climate risks for this system. Two priority risks have been analysed as part of the second pass assessment:

- Risks to ecosystems, landscapes and seascapes, including risk of ecosystem transformation or collapse, and loss of nature's benefits to people.
- Risks to water security that underpins community resilience, natural environments, water-dependent industries and cultural heritage.

Natural environment

Climate risks are determined by the interaction of risk elements, including hazards, exposures and vulnerabilities. This is a risk summary for the Natural environment system.

Climate and hazards

- Bushfires
- Drought
- Changes in temperature
- Flooding
- Ocean warming and acidification
- Changes in precipitation patterns

Exposures

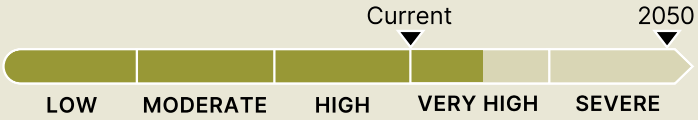
- Aboriginal and Torres Strait Islander communities
- Carbon sequestration
- Communities that rely on ecosystem services
- Freshwater ecosystems
- Marine and estuarine ecosystems
- Terrestrial ecosystems
- Water quality and supply

Vulnerabilities

- Primary industries and tourism
- Biodiversity loss
- Ecosystem degradation
- Habitat connectivity
- Rural and remote communities
- Water use and availability

IMPACTS AND RISKS

- Aboriginal and Torres Strait Islander peoples' connection to Country
- Changes to ecosystem services underpinning other systems
- Ecosystem collapse
- Marine and terrestrial biodiversity loss
- Reduction in ability to sequester carbon and mitigate climate change
- Reduction in ecosystem adaptive capacity
- Increased biosecurity risks and significant species loss
- Tropicalisation of temperate marine ecosystems



Assessment of current risk

The current climate risk to the Natural environment system is rated as *high–very high (high confidence)*.

Impacts on Australia's natural environment are already being felt. These impacts are significant, widespread and cascading across all systems. Climate pressures on ecosystems are compounded by other pressures such as deforestation. This threatens Australia's biodiversity, as well as ecosystem services provided by the natural environment, and is having impacts on health and wellbeing.

The natural environment, which plays a crucial role in stabilising the global carbon cycle, is being fundamentally altered by the broad scale, fast pace and increased intensity of climate impacts.

Forests, wetlands and the ocean, which act as carbon sinks, are increasingly compromised. For example, terrestrial ecosystems are facing significant challenges, with many showing signs of collapse at a local level due to increased temperatures, altered precipitation patterns and more frequent extreme weather events. Freshwater ecosystems are also highly exposed to climate change pressures, particularly issues with water availability as precipitation becomes more variable. Similarly, marine and estuarine environments are experiencing significant impacts, with ocean warming and acidification affecting reefs and other marine ecosystems with associated loss of biodiversity and ecosystem services, including carbon mitigation and coastal protection.

The declining health of Country is already impacting Aboriginal and Torres Strait Islander peoples' access to traditional foods and cultural practices, including caring for Country as a mechanism for climate adaptation and sustainability.

Assessment of future risk

By 2050, the climate risk to the Natural environment system is expected to increase to *severe (medium confidence)*.

The resilience of ecosystems will continue to be tested by increased temperatures, altered precipitation patterns and more frequent extreme weather events. The pace and scale of projected climate change will move beyond the realms of recorded experience, making it difficult to predict outcomes with certainty. Despite this uncertainty, there is strong evidence that the current condition and trajectory of our natural systems is declining, and some systems are reaching the limit to their ability to adapt.

The projected rise in climate impacts will have a noticeable national effect, with broad geographic reach, significant impacts on livelihoods, as well as loss of cultural, spiritual and intrinsic value.

The sustainability and prosperity of all natural systems will be challenged, with severe impacts expected on ecosystems, high risks of resource depletion, loss of species, and the almost certain collapse of some ecosystems.

These changes drive significant additional risk to public health and safety.

Species will be forced to move, adapt to the new conditions or die out, with (on average) half of terrestrial species being exposed to climatic conditions that they do not currently experience, leading to potential species loss. Freshwater ecosystems will be further strained by increased variability in rainfall and more frequent droughts. Marine and estuarine environments will face greater threats from ocean warming and acidification, with significant degradation of coral reefs, macroalgae forests and seagrasses.

Aboriginal and Torres Strait Islander peoples will continue to face heightened risks due to the disruption of traditional practices and knowledge systems.

Summary of exposures, vulnerabilities, impacts and risks

Carbon cycle and sinks

Australia's natural environment plays a crucial role in stabilising the global carbon cycle. However, the broad scale, fast pace and increased intensity of climate impacts have fundamentally altered these natural systems.

Forests, wetlands and oceans, which act as carbon sinks, are increasingly compromised by climate change and other human activities. Widespread clearing and degradation of terrestrial ecosystems have reduced their condition and capacity to sequester carbon, exacerbating climate change.

Ecosystem resilience

Climate change and other human influences have already had impacts on Australia's marine, terrestrial and freshwater environments, with many ecosystems showing signs of collapse at a local level. The resilience of these ecosystems and of native biodiversity is being tested by increased temperatures, altered precipitation patterns and more frequent extreme weather events, with compounding threats like invasive species. For example, higher temperatures and drier conditions are increasing the risk of bushfires, and facilitating increases in invasive species impacts, thereby threatening sensitive ecosystems and species.

Terrestrial

Terrestrial ecosystems across Australia face significant challenges from the changing climate. The capacity for biodiversity to respond to climate shifts will be limited across all regions of Australia, especially in the context of existing pressures on biodiversity, including habitat loss and invasive species. However the specific responses of biodiversity to future climates will vary among regions, in ways that will be important when designing adaptation responses. On average, by +3.0°C of global warming, half of the native plant species occurring in any location will be different from the species that occurred there in 1990. Species will be forced to move, adapt to the new conditions or die out. Increased aridity and higher temperatures are placing ongoing pressure on plant productivity and reproduction, particularly in alpine systems and eucalypt forests. These changes are driving ecosystems towards drier expressions, with impacts on wildlife that depend on current ecosystem conditions for survival. However, the specific responses of biodiversity to future climates will vary among regions in ways that will be important when designing adaptation responses.

Freshwater

Freshwater ecosystems are highly exposed to climate change pressures, particularly water security issues. Increased variability in rainfall, changes in temperature, and more frequent droughts are having devastating impacts on freshwater systems. These changes affect water availability for both ecosystems and human use, leading to increased competition over water resources. Future increases in intense rainfall events, changes in temperature, and prolonged droughts will further strain freshwater ecosystems. For example, changes in maximum temperatures will mean freshwater organisms are increasingly exposed to heat-related stress and may not have sufficient physiological capacity or tolerance to survive.

Marine and estuarine

Australia's marine and estuarine environments are experiencing significant climate change impacts. Ocean warming and acidification are affecting biodiversity and ecosystem services. Coral reefs, such as those in the Great Barrier Reef and Ningaloo World Heritage areas, are particularly degraded. Seagrasses and macroalgae forests are also impacted by warming, sea level rise and altered storm patterns. The poleward migration of the East Australian Current is intensifying the 'tropicalisation' of temperate ecosystems, posing high risks to coastal temperate ecosystems.

Aboriginal and Torres Strait Islander peoples

Climate change is putting at risk Aboriginal and Torres Strait Islander peoples' ability to connect with Country, affecting their physical, mental, community, and cultural health and wellbeing. Aboriginal and Torres Strait Islander peoples are directly impacted by hazards that compromise natural environments and services, particularly in remote communities. Recognising and integrating Aboriginal and Torres Strait Islander peoples' knowledge into climate adaptation strategies, particularly across the extensive Indigenous estate, can help mitigate climate change impacts and support the resilience of both natural environments and Aboriginal and Torres Strait Islander communities.

Introduction

This chapter provides a synthesis of the Natural environment system. It draws on a wide range of technical assessments to provide observations that can enable effective adaptation.

It includes:

- System overview
- Priority risk snapshots
- Key climate hazards for the system
- Exposures, vulnerabilities, impacts and risks relevant to the system
- Adaptation observations and considerations
- Case study

The chapter highlights 2 priority risk snapshots and draws on the analysis from across all the priority risk technical assessments. It is important to note for this first National Assessment that all 63 nationally significant risks have not been fully assessed. The chapter provides a useful national understanding of climate risks and information that can support adaptation. Climate risks are not static – this work is a sound foundation that should be built on over time.

System overview

The Natural environment system refers to ecosystems, biodiversity and natural processes, including Australia's land, oceans and freshwater environments.

The natural environment includes much more than the lands contained within our national and marine parks and the extensive Indigenous estate. The Natural environment system cannot be separated from other uses of the landscape and seascape. It provides the fabric in which lives and activities take place. While some activities, such as urban development and agriculture, have extensively modified the natural environment, some native species persist and sometimes thrive in these modified landscapes. Restoring natural processes has been shown to have benefits in solving modern challenges such as stormwater management and diversified pollination of crops, as well as having intrinsic value in supporting healthy ecosystems.

Natural ecosystems are fundamental to human society, supporting all other systems examined in the National Assessment. For example, nature underpins the economy, with over half of the world's GDP dependent on it (World Economic Forum, 2020) while also providing cultural and spiritual value. Water security relies on natural ecosystems to regulate and clean water. Primary industries depend on the natural environment for raw materials and services such as pollination. Health and social support systems draw on the natural environment for nutrition, mental health, medicines and cultural services. The dependence of all other systems on the natural environment highlights its critical role in the National Assessment.

Priority risk snapshot: Natural ecosystems

Risks to ecosystems, landscapes and seascapes, including risk of ecosystem transformation or collapse, and loss of nature's benefits to people.

Rationale

The risk to Natural ecosystems is currently rated as **Very High**. This risk is expected to remain **Very High–Severe** by 2050 and to rise to or remain **Severe** by 2090 (Figure 75). Already, significant impacts are observed in marine and mountain ecosystems, with local ecosystem collapse already occurring. Ecosystem degradation will reduce the effectiveness of carbon sinks which currently absorb global carbon emissions. Improved management and incremental adaptations are required across the Natural environment system. The natural environment also has the highest likelihood of reaching limits to adaptation so targeted transformational adaptation – for example, to different species composition – will be needed to retain some ecosystem functions.

Key hazards

- Increased temperatures and more frequent and intense heatwaves are threats to ecosystems and species across the continent in our terrestrial, freshwater, coastal and marine areas. Higher temperatures and drier conditions are increasing the risk of bushfires in most currently forested areas, threatening ecosystems that rely on longer intervals between fires and leading to the loss of fire-sensitive tree species and the biodiversity that relies on these ecosystems. Increased aridity and higher temperatures are also placing ongoing pressure on plant productivity and reproduction.

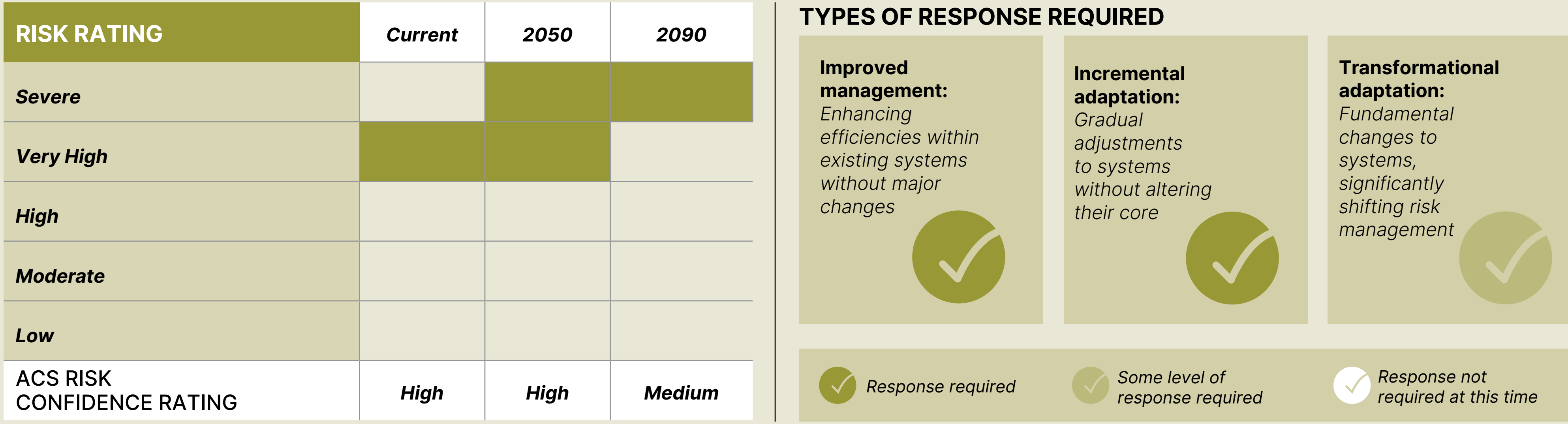


Figure 75: Rating for the Natural ecosystems priority risk for current, 2050 and 2090, and the types of responses required to address the risk. For definitions of risk ratings, please see Figure 9.

- Increased variability in rainfall and more frequent droughts are having significant impacts on freshwater systems. These changes affect water availability for both ecosystems and human use, leading to increased competition for water resources. The future increase in intense rainfall events and time spent in drought will further strain freshwater habitats and their species.
- Ocean warming is now regularly exceeding record levels, our oceans are becoming more acidic, marine heatwaves are longer and hotter, and ocean currents are spreading marine species south. These changes and rising sea levels are collectively affecting biodiversity and ecosystem services in both coastal and marine ecosystems. Tropical areas are hyper-tropicalising, and temperate areas are tropicalising.

Exposure

- **Carbon cycle:** Australia's natural environment plays a crucial role in stabilising the global carbon cycle. Forests, wetlands and the ocean act as carbon sinks but are under pressure from climate change.
- **Alpine and open eucalypt forest:** Large areas of alpine and open eucalypt forest along the eastern seaboard and in southwestern Australia face challenges from repeated extreme fires, threatening the loss of wildlife habitat and carbon storage.
- **Water security in freshwater ecosystems:** Freshwater ecological systems face heightened exposure to water security challenges stemming from climate change. Climate change threatens to shift many aquatic ecosystems beyond their natural variability, including turning persistent streams into ephemeral streams. Species adapted to freshwater systems often have limited adaptation options, and many freshwater systems are already exposed to pressures associated with low water security due to overallocation of water resources and river regulation. The risk is highest in some southern Australian forested catchments.
- **Perennial and ephemeral streams:** In all catchments of Australia, perennial and ephemeral streams are sensitive to changes in maximum temperatures. Compounding effects of low inflows and higher temperatures will mean freshwater organisms are increasingly exposed to heat-related stress and changes in the availability of suitable refuge habitat.
- **Tidal wetlands:** Mangroves and saltmarshes currently have very low condition and are under threat from sea level rise and shoreline encroaching. This may have implications for carbon sequestration.
- **Continental shelf ecosystems:** Marine ecosystems on the continental shelf, particularly corals, seagrasses and rocky reefs, are greatly exposed to climate pressures and ecosystem degradation.

Vulnerability

- **Terrestrial ecosystem degradation:** Widespread clearing and degradation of natural ecosystems has left many terrestrial ecosystems vulnerable to climate pressure. Continental Australia has lost half of its habitat capacity since 1750, weakening the ability of terrestrial ecosystems to adapt to climate change.
- **Extreme limits:** Species at the edge of ecosystem boundaries and at the extremes of Australia's temperature and aridity boundaries are most vulnerable to climate change (e.g. central Australia and alpine habitats).
- **Marine biodiversity:** Biodiversity in Australian marine ecosystems is particularly vulnerable to climate change because of the fast rate of warming when compared to the rest of the world. This is exacerbated in some areas of Australia where connectivity and habitat availability does not allow for movement further south as the climate warms, leaving many marine species vulnerable to climate pressures.
- **Flood regime in riverine ecosystems:** Many freshwater systems in Australia are accustomed to intermittent large flood events, with species and ecological functions adapted to the 'river flow regime', leaving them vulnerable to increasingly variable rainfall.
- **Rural and remote communities:** These communities are more dependent on natural ecosystems for vital services, including food, water, biodiversity and sources of livelihoods. Widespread change to ecosystems may degrade livelihood sources, including agricultural production.

Impacts and risks

- **Ecosystem composition and resilience:** Predicted climate change will cause most Australian native species to be outside the environments to which they are currently adapted (Figure 76). Compositional change in ecosystems under climate change is expected to be substantial across Australia. By 2050, species will be forced to move, adapt to the new conditions or die out, with 40–70% of native plant species needing to respond to the changed climatic conditions in their original range. There will be a lag before the impacts are realised, but over the long term, species will be forced to move, adapt or perish.
- **Ecosystem collapse:** Ecosystem collapse at the local level has already been documented in at least 17 of Australia's ecosystems spanning marine, terrestrial and freshwater environments, which may lead to local species extinctions, carbon loss and losses to other ecosystem services that we rely on. Newly assembling ecosystems will also be particularly vulnerable to invasion by non-native species.
- **Tropicalisation of marine systems:** In marine systems, the 'tropicalisation' of temperate ecosystems has been observed where increasing temperatures result in the movement of species from subtropical and tropical environments into temperate ecosystems. Effects on the species diversity, ecosystem functioning and the condition of communities is uncertain.
- **Decreasing marine animal biomass:** Pelagic animal biomass is projected to decline across most of Australia's Exclusive Economic Zone. The Great Barrier Reef, Torres Strait and Temperate East bioregions are projected to have the largest decrease in marine animal biomass with climate change.
- **Freshwater ecological function:** In a warmer future, it is likely that climate pressures will result in pressure on water quality, reduced availability of refuge habitats and lower connectivity between freshwater habitats. This has implications for many species and for water management.
- **Changing rainfall patterns:** Changes in rainfall patterns will have major implications for our freshwater ecosystems. Freshwater ecosystems are likely to experience significant variability, change in flood regime, and greater pressure on low-flow refugia to support species during extended drought conditions. Increases in flood intensity can result in high rates of erosion, particularly following periods of drought.
- **Ecosystem services:** Projected changes in the natural environment will have implications for the delivery of ecosystem services, and for the primary industries and economies they support.
- **Carbon cycle and sinks:** The current condition of our natural systems is declining. The natural environment is the world's largest carbon sink; degradation of this system is virtually certain to reduce its ability to absorb carbon and is likely to reinforce climate change.
- **Mental health:** The predicted change in ecosystems is likely to put additional pressure on mental health and wellbeing issues as Australians grapple with the loss of familiar ecosystems and species. They will need to come to terms with dead and dying trees, other plants and animals across the nation as ecosystems transition, face new challenges in the new environments, and overcome the loss of critical ecosystem function.

Adaptation

- Accelerated climate change mitigation, as well as reducing human-induced pressures, is the best defence against future climate impacts on natural and other systems.
- Adaptation interventions such as climate-adapted habitat restoration, ecosystem-based management and improved sustainability of harvesting may help species and ecosystems acclimatise or adapt to climate change, but evidence for this is early stage and small scale.
- Connected habitats with higher levels of ecosystem integrity will be more resilient to future climate change, so actions to rapidly halt land clearing, to reinstate hydrodynamics and restore integrity, and to reconnect ecosystems and habitats are critical to minimise the impacts of climate change on our species.
- Water management frameworks and reporting often ignore environmental outcomes achieved (e.g. a wetland inundated to facilitate a bird- or fish-breeding event). Understanding and reporting on environmental outcomes are critical to understand and ensure ongoing ecosystem health and resilience during drought, and in informing effective and timely adaptation.

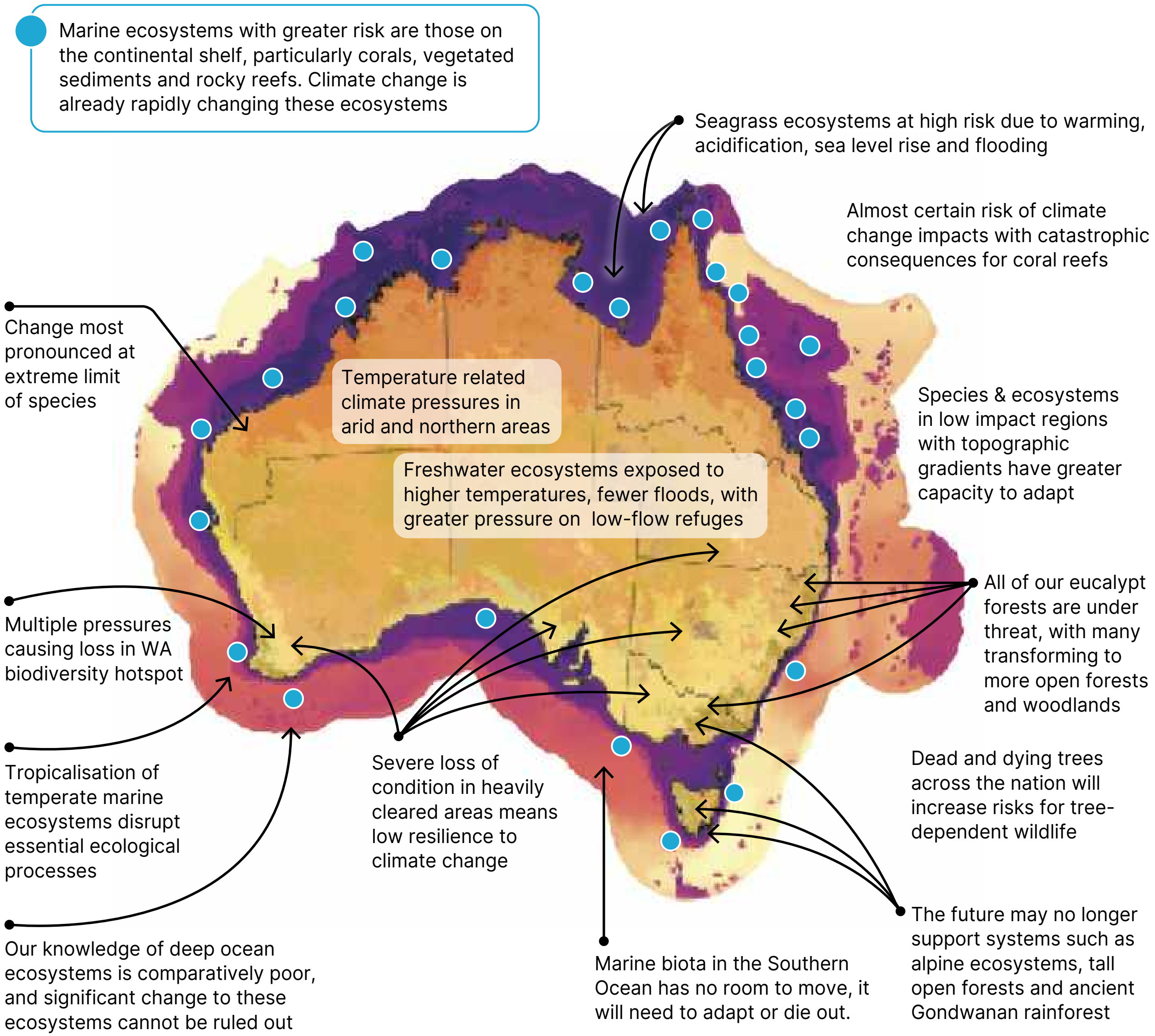


Figure 76: All levels of biodiversity will be affected by a changing climate in the future. Examples of changes are indicated in the map. *(Source: Natural Ecosystems Technical Report)*

Priority risk snapshot: Water security

Risks to water security that underpins community resilience, natural environments, water-dependent industries and cultural heritage.

Rationale

The risk to water security is currently rated as **High**. This risk is expected to increase to **Very High** by 2050 and to become **Very High–Severe** by 2090 (Figure 77). Rainfall changes and water storage vary across regions, with the risk of a quick onset of water security issues for some communities and regions, especially in the event of an abrupt drought. There will also be increasing impacts on freshwater ecosystems with potential loss of integrity and biodiversity, as well as compromise to the vital role that freshwater ecosystems play in water quality and security. Improved management and incremental adaptation are required, through new infrastructure and demand management, in order to increase climate resilience in urban water and agriculture. Notably, there are limits to the level of support that dam-based structures can provide to regional and remote communities in the face of water scarcity pressures, and so some transformational adaptation is also required, including decentralising water systems. This will interact with transformational adaptation opportunities for regional and remote communities.

Key hazards

- **Seasonal rainfall volumes, drought and aridity** are key drivers of water security risk, but some regions and uses are more sensitive to factors such as rainfall intensity, timing or catchment processes.
- **Aridity:** As aridity increases, evapotranspiration rises, causing crops and vegetation to demand more water. This leads to heightened competition for available resources, particularly in agricultural regions, and increases stress on water supply systems during dry periods. Increased aridity can reduce water infiltration into soils, thereby decreasing groundwater recharge, particularly in diffuse recharge zones.
- **Drought:** Future multi-year droughts, in addition to a long-term drying trend, is a primary water security hazard of concern for many regions. Long-term reductions in rainfall and runoff are projected to increase across southern Australia (Figure 78), leading to decreased water inflows, reduced groundwater recharge, lower water allocations and increased competition, making them less resilient to prolonged periods of drought. This is in addition to declines in cool season rainfall and runoff across southern Australia.

RISK RATING	*Current*	*2050*	*2090*
Severe			
Very High			
High			
Moderate			
Low			
ACS RISK CONFIDENCE RATING	*High*	*Medium–High*	*Low*

TYPES OF RESPONSE REQUIRED

Improved management: *Enhancing efficiencies within existing systems without major changes*

Incremental adaptation: *Gradual adjustments to systems without altering their core*

Transformational adaptation: *Fundamental changes to systems, significantly shifting risk management*

Response required | *Some level of response required* | *Response not required at this time*

Figure 77: Rating for the Water security priority risk for current, 2050 and 2090, and the types of responses required to address the risk. For definitions of risk ratings, please see Figure 9.

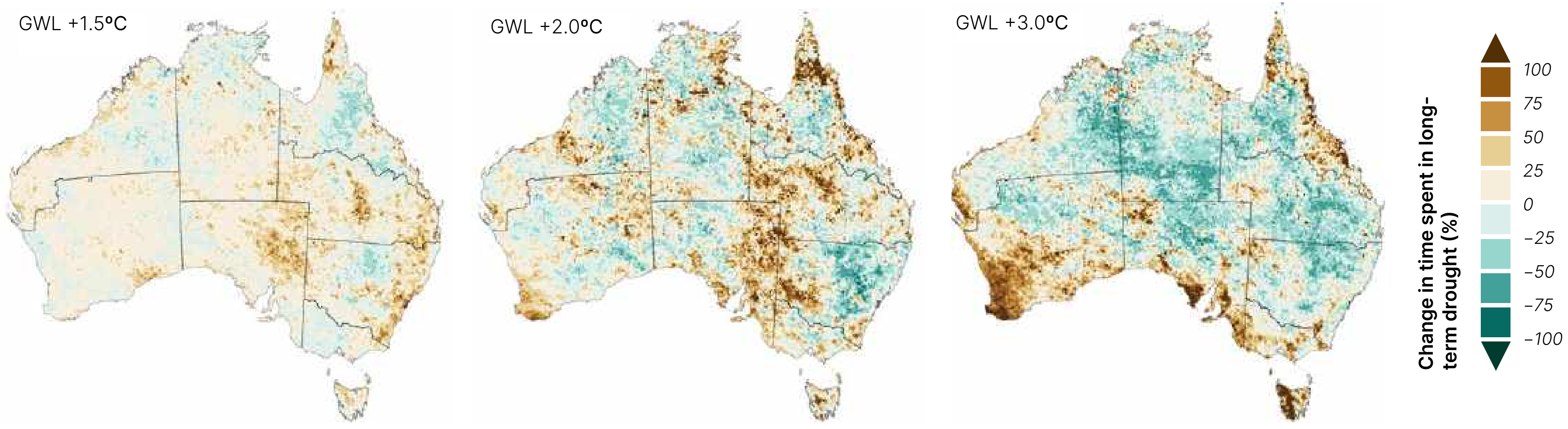


Figure 78: Maps of the standardised precipitation 24-months drought index (SPI24=−1, model mean) used as indicator for multi-year drought.

While 24-months of dry is a useful way to compare across many regions nationally, some regions will be more sensitive to other definitions of drought, and therefore operational planning uses risk indicators based on system-specific sensitivities and risks. (Source: Water Security Technical Report)

Exposure

- **The Murray–Darling Basin is a vast and complex ecosystem in southeastern Australia**. It supports large water uses and therefore features significant exposure to water security risks. In the southern basin, water is primarily sourced from regulated systems, where infrastructure such as dams and weirs control water flow. In contrast, the northern basin relies on unregulated water sources, meaning water availability is more dependent on natural river flows and rainfall, making it less predictable and harder to manage.
- **Aquatic ecosystems** often have specific watering requirements with limited adaptation options, and some are already exposed to low water security due to overallocation of water resources. The risk is highest for some southern Australian forested catchments.
- Regional and remote communities in areas with low water security are highly exposed to the changing climate hazards.

Vulnerability

- **Regional and remote communities:** Many remote communities, which are highly vulnerable to drought and drying, rely heavily on local rainfall and groundwater. They face challenges, including shortages of skilled management, sustainable supply issues and the high operating costs of local water infrastructure.
- **Health and wellbeing:** Remote communities, particularly Aboriginal and Torres Strait Islander peoples' communities, face heightened health risks from water security challenges during emergency events. These communities typically have fewer alternative water resources to turn to and are more likely to access sub-standard drinking water as a result or compromised water from hazards such as drought.
- **Farming communities:** Communities lacking alternative water supplies or reliant on annual surface inflows are most vulnerable to future climate water security risks. The vulnerability of water sources depends on their type and capacity; for example, systems reliant on groundwater are more secure, while those dependent on annual flows are at higher risk.
- **Agriculture:** Regional agricultural areas crucial for specific commodities and regional food security remain vulnerable. Perennial crops, due to their long-term water needs, are likely to be particularly vulnerable to future water scarcity, especially as demand for high-value crops requiring reliable water grows. Livestock systems, particularly dairy, are also vulnerable to water shortages.

- **Freshwater fish species:** Freshwater fish species are particularly vulnerable to rainfall deficits and to more frequent and intense hot temperatures; climate change is expected to cause major reductions in the ranges of Australian inland fish species (Beatty et al., 2014).

Impacts and risks

- **Agricultural productivity:** Projected increased water security challenges will impact agriculture through intensifying water competition and may result in reduced water allocations. Water quality risks from salinity, algae, bushfires and increased rainfall variability will further challenge agricultural productivity.
- **Freshwater ecosystems:** The expected increase in future drought may push freshwater ecosystems beyond resilience, increasing ecological risks, particularly where water is fully allocated or poorly managed during low-flow periods. Projected aridification across Australia will impact river morphology, connectivity and water quality, affecting all water users. During drought, populations of many aquatic taxa decline with some undergoing local extinctions. During the Millennium Drought (1997–2009), the Ramsar wetlands in the Coorong and the lakes at the seaward end of the Murray River became toxic due to such algal blooms. Species such as water birds, which use water level as a cue for breeding, are particularly sensitive to changes in the hydrological cycle.
- **Freshwater ecosystems:** Intense rainfall events can cause blackwater events, increasing sedimentation and affecting downstream ecosystems. The 2019–20 bushfires burnt large areas of forest and produced large amounts of ash which were then flushed into waterwayswhere they biodegraded water and caused deoxygenation and hypoxic blackwater events downstream. As a result, between October 2019 and May 2020, there were over 65 recorded events of fish death across the Murray–Darling Basin.
- **Wetlands:** Projected impacts include damage or loss of nationally and internationally important wetlands such as Macquarie Marshes, Gwydir, Narre Lake, the Great Cumbung Swamp and the Ramsar wetlands in the Coorong in the Murray–Darling Basin.
- **Water security infrastructure:** Storms damage water and energy infrastructures, leaving communities without access to quality water, impacting filtration systems, and increasing the risk of cross-contamination from sewerage infrastructure.
- **Mental and physical health:** Droughts increase risks to mental health, as well as reducing the quality of drinking water, as communities turn to alternative water sources, or water sources become contaminated by harmful algae blooms or become subject to bushfires-related degradation to water quality. High-intensity rainfall can also increase the risk of water contamination from cryptosporidium and cyno-bacteria outbreaks.

Adaptation

- Water management is one of few adaptations available to mitigate climate-driven water scarcity risks, and current actions are considered inadequate in preparing for long-term declines or managing periods of acute water scarcity. Management frameworks and reporting often focus on the amount of environmental water delivered, rather than the environmental outcomes achieved (e.g. a wetland inundated to facilitate a bird- or fish-breeding event), or the sufficiency of environmental water allocations to achieve environmental outcomes, as may be specified in water plans (Productivity Commission, 2024), which is critical to assure ongoing ecosystem health and resilience during drought.
- Effective adaptation to water security challenges is likely to require augmented plans to monitor, maintain and repair remote water assets, particularly during emergency events.
- Aboriginal and Torres Strait Islander knowledge can play a valuable role in mitigating the impacts of climate change on water security.
- Cities and large towns are investing in climate-resilient water sources, though geographic, economic and regulatory hurdles present serious challenges.
- The national water scarcity index provided here (Figure 79) starts to explore national assessments of risk; however, further work is needed to explore ways to refine exposure and vulnerability representation in a national water security risk index which can be used to guide policy and action at a national level.
- Key adaptation strategies for agriculture include diversification, technological innovation, improved water-use efficiency, and utilising climate services. Technological innovations, such as plant-based water sensors and more efficient irrigation systems, can enhance resilience, but the rate of climate change is putting more pressure on these innovations.

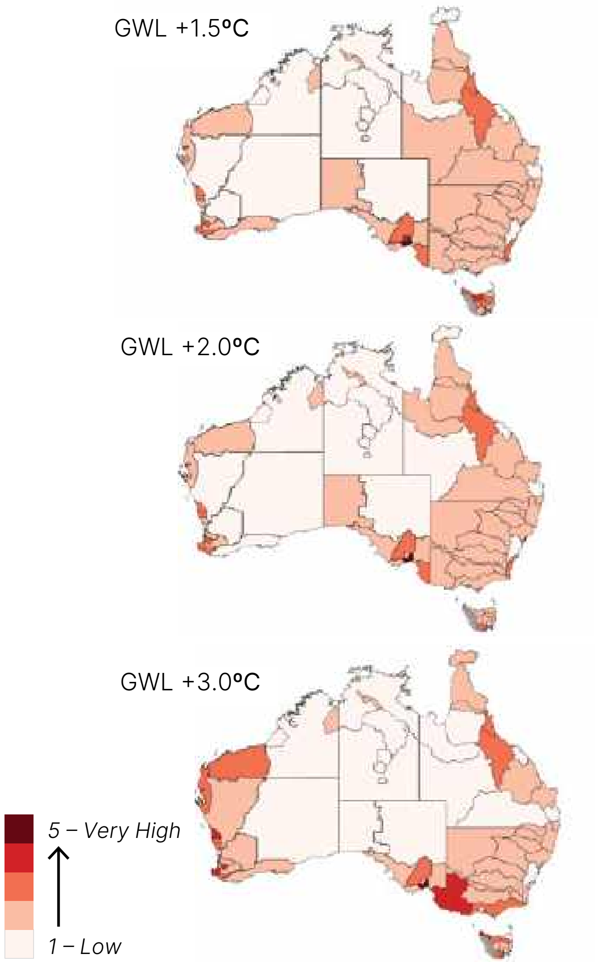


Figure 79: Future climate water scarcity index for the 24-month extreme dry hazard at GWL +1.5°C (top), GWL +2.0°C (centre) and GWL +3.0°C (bottom).

The risk metric combines exposure, vulnerability and hazard via a ranking matrix. 1 (low) to 5 (very high) multi-year dry risk. As this metric uses total water entitlements to represent exposure of risk, it emphasises risk to high-volume irrigation regions. A simple vulnerability ranking adjusts risk for only the most vulnerable or resilient systems, while most systems remain in a middle category where nuanced vulnerabilities are hard to assess nationally. (Source: Water Security Technical Report)

Key climate hazards for the system

This section describes the changing climate hazards for the Natural environment system.

Exposure to the long-term pressure of increased temperature combined with more frequent and intense heatwave events is threatening species and ecosystems across the continent. This includes extreme temperatures in the arid interior and the north, and high summer temperatures in relatively intact temperate systems and in areas not adapted to heat or previously sheltered by moist or shaded microclimates *(high confidence).*

- Extreme temperatures are likely to increase nationwide *(very high confidence)*, with the greatest increases over the Great Dividing Range in the southeast, and in northern Australia and desert regions (Australian Climate Service, 2025). Severe and extreme heatwave events are projected to double if global warming reaches +2°C and to more than quadruple under +3°C of warming *(very high confidence)*.
  Evidence: Australia's Future Climate and Hazards Report
- Over the coming century, Australia is projected to become drier and to experience shifts in aridity (Dey et al., 2019; Grose et al., 2023), with longer periods of drought on average in the south and east *(low to medium confidence)*, and increased aridity in southern areas *(high confidence)*.
  Evidence: Australia's Future Climate and Hazards Report
- The time spent in drought averaged across Australia is projected to increase under all future warming scenarios, with areas of southern Australia (Victoria, South Australia, Tasmania, Western Australia south) likely to experience the highest increases *(low to medium confidence)*.
  Evidence: Australia's Future Climate and Hazards Report

Higher temperatures and drier conditions will bring increased risk of bushfires in most currently forested areas, threatening terrestrial ecosystems that rely on long intervals between fires, and resulting in changes in the stand structure of trees and loss of fire-sensitive tree species *(medium confidence).*

- Bushfire risk is expected to increase across parts of Australia under future warming, with increases in the number of dangerous fire weather days and an extended fire season projected for southern and eastern Australia, with the potential for more megafires *(high confidence)*. The susceptibility of wet forests to fire is projected to increase due to reduced rainfall and increasing heat, which dries vegetation.
  Evidence: Australia's Future Climate and Hazards Report

Global ocean temperatures are now regularly exceeding record levels. Marine and coastal waters of Australia are generally becoming warmer and more acidic, and are experiencing more intense and longer marine heatwaves, although trends are variable in space *(medium confidence).*

- Nationally, marine heatwave duration (currently 18 days) will increase by 22 days at a global warming level of +1.5°C and by 161 days at a global warming level of +3.0°C, but this is spatially variable *(high confidence)*. Under a fixed baseline, this means that Australia's Exclusive Economic Zone (Oceans) is projected to be in a marine heatwave state for almost half of the year at a global warming level of +3.0°C *(high confidence)*.
  Evidence: Natural Ecosystems Technical Report, Australia's Future Climate and Hazards Report

Exposures, vulnerabilities, impacts and risks

This section provides a summary of impacts and risks associated with the Natural environment system (Table 13).

These impacts and risks have been identified by understanding the changing climate hazards, as well as exposures and vulnerabilities that drive them.

Table 13: Summary of impacts to the Natural environment system and adaptation examples. Results that are sourced directly from the literature are referenced in the table. New results from the National Assessment are not assigned references in the table. All sources are referenced throughout the chapter.

Ecosystems	Current	Future			Current climate adaptation examples
	GWL +1.2°C	GWL +1.5°C	GWL +2.0°C	GWL +3.0°C	
Coral reefs	Coral bleaching events occur roughly every 4 years	Increase in bleaching from ocean warming and acidification; for example, Ningaloo Reef, WA, is projected to lose 62.5% of species	Further increase in bleaching from ocean warming and acidification	Bleaching becomes annual in northern reefs; coral mortality accelerates	Coral reef restoration programs Bioengineered reefs for coastal ecosystem protection
Seagrasses and kelp forests	Degraded from marine heatwaves and tropicalisation of habitats	Marine heatwaves threaten seagrass survival; for example, Shark Bay, WA, seagrasses are projected to lose 96% of species Tropicalisation of kelp forests	Seagrasses at risk from sea level rise, affecting seagrass survival and forcing shifts in distribution	Significant decreases in seagrass abundance due to sea level rise, ocean warming and acidification Sea level rise is likely to alter the suitability of habitats for kelp forests	Seagrass restoration programs Management of water quality to improve clarity and therefore maximise light penetration to offset impacts on seagrass from sea level rise (Saunders et al., 2013)

Ecosystems	Current	Future			Current climate adaptation examples
	GWL +1.2°C	GWL +1.5°C	GWL +2.0°C	GWL +3.0°C	
Eucalypt forests		Declining extent, with 29% loss since 1750. Temperate eucalypt forests grow in temperatures already higher than the optimal mean annual temperature for tree growth	Increases in aridity due to decreases in seasonal or annual total rainfall or greater rainfall variability will place ongoing pressure on plant productivity and reproduction	12% decline in the proportion of temperate climate for Eucalypt forests, causing a shift toward a subtropical climate In temperate eucalypt forests tree growth rates are likely to drop by 22%, as is the amount of carbon stored, and the rate of recovery from disturbance such as wildfire	Planting native eucalypt species and revegetation projects Enhanced prescribed burning programs Fuel reduction programs Community engagement programs for forest stewardship and threatened species management Pest and weed management initiatives
Mangroves and saltmarshes	Low resilience to climate change impacts			Coastal erosion threatens habitat suitability	Blue carbon conservation programs
Freshwater			Perennial and ephemeral streams in all catchments of Australia increasingly exposed to compounding effects of low inflows and higher temperatures, increasing exposure of freshwater organisms to heat-related stress and decreased availability of suitable refuge habitat	Likely increase in aridity impacts for perennial and ephemeral streams Higher and longer occurrences of dry sections in ephemeral watercourses and changing of perennial watercourses to ephemeral; this may cause lower numbers of stream organisms and localised loss of freshwater species	Urban waterways restoration and ecological health initiatives River health and floodplain surveys

Ecosystems	Current	Future			Current climate adaptation examples
	GWL +1.2°C	GWL +1.5°C	GWL +2.0°C	GWL +3.0°C	
Tussock and hummock grasslands	Tussock grasslands have low resilience to climate change impacts Hummock grasslands have generally not been cleared but face pressure from seasonal conditions such as drought and cyclonic events, as well as land management practices			Tussock grassland areas will have from 40–50% to 90–100% fewer colder nights. Temperate tussock grasslands require frosts as part of their environmental cues Increased fire weather increases area burnt and size of fires, which can negatively impact species in hummock grasslands	
Alpine regions	Snow cover has shortened by about 10–20 days per year.	Snow cover continues to decrease, with 15–30 fewer days in the season	Snow cover continues to decrease, with 20–55 fewer days and decreases in depth of up to 90% by 2050.		

Carbon cycle and sinks

Natural systems play an integral role in stabilising the climate cycle. The broad scale, fast pace and increased intensity of climate impacts have already fundamentally changed these natural systems. While change to our natural environment is inevitable, action to protect and increase the resilience of natural systems will help to mitigate climate change *(high confidence).*

- The natural environment is the world's largest carbon sink. Degradation of this system reduces its ability to absorb carbon, likely creating a positive feedback loop that exacerbates climate change. About one quarter of climate mitigation for 2030 under the Paris Agreement is expected to come from land-based mitigation options. These include reduced deforestation, forest sinks, soil carbon sequestration, agricultural management and ecological restoration. Expansion of forest area typically removes carbon dioxide from the atmosphere and thus dampens global warming (IPCC, 2023).
- Estuaries, shelf seas and a wide range of other intertidal and shallow-water habitats play an important role in the global carbon cycle. They contribute through their primary production of rooted plants, seaweeds (macroalgae) and phytoplankton, and also by processing riverine organic carbon. Mangrove, salt marsh and seagrass habitats are widely recognised as blue carbon ecosystems with mitigation potential (IPCC, 2023). Although mangroves and saltmarshes represent a much smaller area than terrestrial forests, their total contribution to carbon sequestration is comparable. However, these habitats have a very low condition and are under threat from sea level rise and shoreline encroaching.
- Degrading the natural system will worsen climate change. *There is strong evidence* that the current condition and trajectory of our natural systems is declining. Conversely, restoring and repairing the natural system can reduce the impacts of climate change. Healthy natural systems will also provide climate adaptation services. These services regulate climate impacts, such as storm surges, extreme heat, floods and fires.

Evidence: Natural Ecosystems Technical Report

Ecosystem resilience

Climate change and other human influences on the landscape have already had a negative impact on Australia's marine, terrestrial and freshwater environments, and several local ecosystems have already collapsed *(high confidence).*

- Predicted climate change takes most of our native species outside the environments to which they are currently adapted. Living organisms have adapted over the last 10,000 years to thrive in existing relatively stable climatic conditions. Altering temperatures and changing the availability of water, food and habitat threatens organisms' viability in fundamental ways. Climate change is interacting with other pressures to accelerate the intensity and rate of change to which organisms need to adjust. Where climate change occurs rapidly, species will be forced to adapt, to move or will die off (Bellard et al., 2012). *Evidence: Natural Ecosystems Technical Report*
- Ecosystem collapse at the local level has been noted in at least 17 of Australia's ecosystems, spanning marine, terrestrial and freshwater environments. All experienced multiple climate change pressures as well as other regional, human-induced pressures, such as land clearing and introduced non-native species. Reductions in species richness and biomass accompany documented ecosystem collapses. Although novel ecosystems may assemble after a collapse, these changes are likely to leave Australia's natural system less able to absorb carbon and deliver other ecosystem services that we rely on (Bergstrom et al., 2021). *Evidence: Natural Ecosystems Technical Report*

Cascading impacts and risks

Critical change to Earth systems, biodiversity loss and ecosystem collapse, and natural resource shortages are assessed by the World Economic Forum as 3 of the top 4 global risks in the next 10 years *(medium confidence).*

- Environmental risks are listed as 5 of the top 10 global risks ranked by severity over a 10-year period, according to the findings of the World Economic Forum Global Risks Perception Survey, with the top 4 risks listed as: extreme weather events, critical change to Earth systems, biodiversity loss and ecosystem collapse, and natural resource shortage (World Economic Forum, 2024). The report highlights the interconnectedness of risks, linking the environmental risks most closely to involuntary migration, infectious diseases and chronic health conditions.

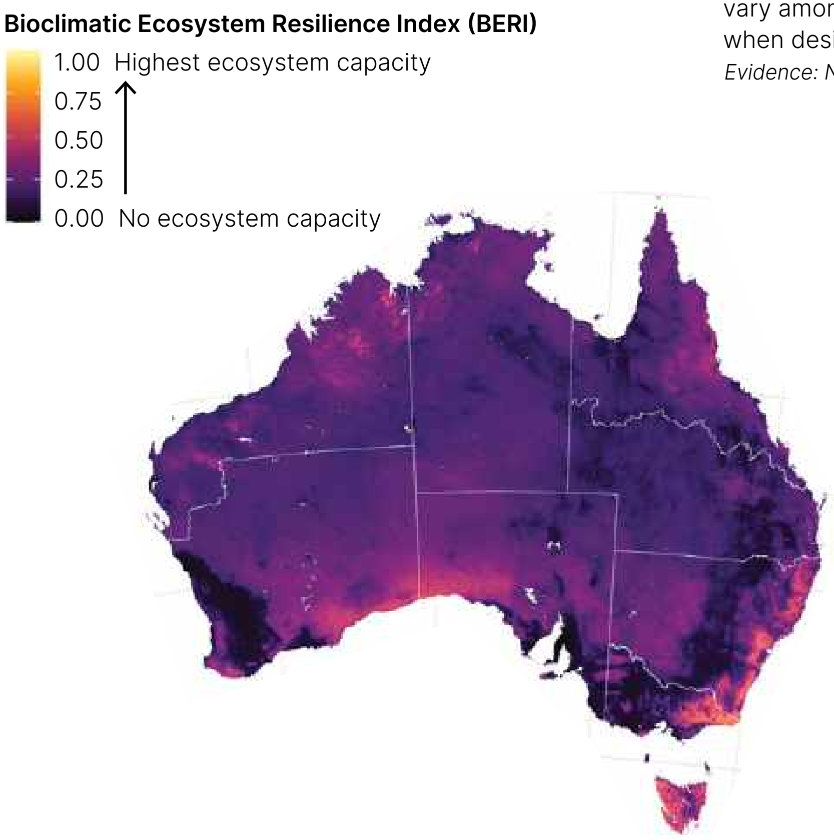
Projected changes in the natural environment will have implications for the delivery of ecosystem services and the primary industries they support, and may lead to broader economic losses *(high confidence).*

- Projections indicate an overall reduction in primary productivity across Australian oceans. Consequently, marine animal biomass is projected to decline at global warming levels of +2.0°C and +3.0°C, with subsequent declines in biomass available to fisheries. *Evidence: Natural Ecosystems Technical Report*
- The vulnerability of seagrass and mangrove forests to severe cyclone events can have a major impact on important fishery species, such as banana prawns and barramundi, which rely heavily on these environments as nurseries (Stokes & Howden, 2010). *Evidence: Natural Ecosystems Technical Report*
- Climate change projections highlight the need for species to migrate to follow suitable conditions. This will also apply to agricultural species such as pastures, crops and orchards that rely on the surrounding natural systems and need to respond to the same pressures and extreme events. New interactions with native and introduced species will need to be considered. *Evidence: Natural Ecosystems Technical Report*
- Johnson et al. (2021) estimate that the collapse of 3 ecosystem services – wild pollinators, aquaculture and forestry – will reduce global GDP permanently by 2.3% annually by 2030, relative to no ecological tipping points triggered. This is expected to be an underestimate as the analysis did not model further interactions between ecosystem services. *Evidence: Real Economy Technical Report*
- Non-market values of coastal ecosystems, including regulating local temperature and humidity as well as providing flood control and protection against coastal erosion, are generally not included in estimates of potential economic losses from climate change. Kompas, Che and Grafton (2024) estimated the non-market value losses from sea level rise in the Kimberley's coastal ecosystem and wetlands to be $4.3 billion by 2050 and $15.8 billion by 2100 under the RCP8.5 climate scenario. Estimates of the physical and economic impacts of coastal sea level rise and storm surge across Victoria are from $9.44 billion per year to 2040, $14.77 billion per year to 2070, and $23.66 billion per year to 2100 (Kompas et al., 2022). *Evidence: Real Economy Technical Report*

Terrestrial

Widespread clearing and degradation of natural ecosystems has left many terrestrial ecosystems vulnerable to climate pressure and reduced their ability to adapt to climate change *(high confidence).*

- Australia has lost half of its habitat capacity – the potential ability to provide suitable habitat for populations of plant and animal species – since 1750. The most severe declines in condition and connectedness have occurred in the most developed regions. Nationally, more than 1.2 million km^2 of remnant vegetation has been lost since 1750, an area greater than the combined areas of NSW, the ACT, Victoria and Tasmania. This clearing has had serious effects at the continental scale; the most severe losses of condition have occurred in heavily cleared areas in southwest Western Australia, southeast South Australia, western Victoria, central NSW and southeast Queensland, where large areas have been cleared for agriculture. This has weakened the ability of terrestrial ecosystems to adapt to future climate change.
  Evidence: Natural Ecosystems Technical Report
- Eucalypt woodlands are particularly fragmented and in poor condition having been extensively cleared since 1750; this is by far the largest change in any ecosystem type by area since 1750.
  Evidence: Natural Ecosystems Technical Report
- Mangroves and saltmarshes are in worse condition than other ecosystems; however, assessment is limited. They also have a much smaller extent, meaning they are likely to have low capacity to adapt to the impacts of future climate change. Mangroves and saltmarshes have high ecological importance, providing feeding and breeding habitats for many marine species, reducing erosion and maintaining water quality, acting as a carbon sink, and providing protection from storms and cyclones for coastal communities. A reduction in fresh groundwater flows is a key climate-sensitive process that is putting these systems at risk, alongside threats from sea level rise and shoreline encroaching.
  Evidence: Natural Ecosystems Technical Report
- Rising temperatures and altered precipitation patterns are facilitating the spread of invasive pests, diseases, and feral species, while simultaneously reducing the resilience of native ecosystems. The recovery period following extreme disturbance events can create windows of opportunity for invasive species to establish and spread. This can reduce ecosystem condition, capacity to support native biodiversity, and resilience to future climate change impacts.
  Evidence: Primary Industries Technical Report; Natural Ecosystems Technical Report



The capacity for biodiversity to respond to climate shifts will be limited across all regions of Australia, especially in the context of existing pressures on biodiversity, including habitat loss and invasive species *(high confidence).*

- Australia's ecosystem resilience to climate change, which can be defined as the extent to which the landscape has capacity to support climate-induced shifts in biological distributions, is low across the country. According to the Bioclimatic Ecosystem Resilience Indicator (BERI) scale (ranging from low to high 0–1), Australia has a national score of 0.24 and the National Assessment regions range from 0.19–0.48 (Table 14). However, the specific responses of biodiversity to future climates will vary among regions, in ways that will be important when designing adaptation responses.
  Evidence: Natural Ecosystems Technical Report

Figure 80: The national map of BERI defined from native plant species at 250 m resolution.

BERI scores are reported on a 0 to 1 scale, where 1 is the highest possible capacity of ecosystems to retain biological diversity in the face of climate change and 0 is no capacity. The Bioclimatic Ecosystem Resilience Indicator (referred to as BERI) assesses how well native species and ecosystems, in their current locations, are connected to places with suitable habitat under future climatic conditions. It includes the current condition, including biological diversity, of each ecosystem, the ability of species to cope and adapt to climate pressures at the locations where they currently exist, and the capacity for species to shift their spatial distributions to track shifts in the environments to which they are adapted. (Source: Natural Ecosystems Technical Report)

Aggregate Ecosystem Group	NSW/ACT	NT	QLD North	QLD South	SA	TAS	VIC	WA North	WA South	Australia
Acacia forests, woodlands and shrublands	0.27	0.24	0.19	0.18	0.32	0.46	0.37	0.25	0.26	0.24
Callitris forests and woodlands	0.27	NA	0.29	0.20	0.34	0.50	0.11	NA	0.29	0.25
Casuarina forests, woodlands and shrublands	0.29	0.27	0.26	0.18	0.26	0.51	0.09	0.36	0.29	0.26
Chenopod shrublands	0.27	0.21	0.18	0.17	0.28	0.45	0.15	0.28	0.35	0.27
Eucalypt forests	0.36	0.27	0.30	0.26	0.10	0.46	0.38	NA	0.28	0.32
Eucalypt woodlands	0.19	0.26	0.25	0.19	0.11	0.45	0.14	0.30	0.18	0.23
Hummock grasslands	0.24	0.23	0.20	0.19	0.24	NA	NA	0.26	0.27	0.25
Mallee woodlands and shrublands	0.30	0.25	0.20	0.18	0.22	0.48	0.16	0.29	0.23	0.22
Mangroves and saltmarshes	0.38	0.2	0.23	0.24	0.11	NA	0.15	0.23	NA	0.22
Melaleuca forests, woodlands and shrublands	0.35	0.27	0.24	0.25	0.09	0.56	0.16	0.45	0.33	0.25
Rainforests and vine thickets	0.38	0.24	0.32	0.23	NA	0.58	0.45	NA	NA	0.34
Sedgelands and rushlands	0.36	0.18	0.23	0.17	0.19	0.55	0.12	0.19	0.21	0.22
Shrublands	0.27	0.20	0.27	0.17	0.25	0.45	0.22	0.27	0.15	0.20
Tussock grasslands	0.22	0.18	0.16	0.17	0.23	NA	0.09	0.28	0.23	0.19
Other terrestrial (forests, woodlands, shrublands, bare)	0.27	0.24	0.25	0.3	0.22	0.48	0.19	0.24	0.16	0.22
Average (geometric mean)	0.25	0.24	0.24	0.19	0.25	0.48	0.19	0.26	0.24	0.24

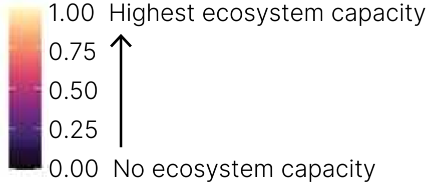
Table 14: Summary scores for the Bioclimatic Ecosystem Resilience Indicator (BERI) Climate Resilience scores reported nationally, by National Assessment region (columns and by Aggregate Ecosystem Group). See Figure 80 for more detail. *(Source: Natural Ecosystems Technical Report; Data Source: Harwood et al., 2024)*

- Terrestrial ecosystems in Queensland south and Victoria have the lowest overall resilience to future climate change. Queensland south has low BERI values for almost all aggregate ecosystem groups. Victoria has the highest BERI values for rainforest, eucalypt forests and acacia forests/shrublands, and medium values for its shrublands, but low values for the other ecosystem groups (Table 14)
  Evidence: Natural Ecosystems Technical Report
- Resilience is lowest in historically cleared areas such as the Western Australian wheatbelt and areas to the west of the Great Dividing Range, and highest in areas with intact ecosystems such as the southeastern forests and Tasmania (BERI score 0.48) where there is also topographic relief, enhancing the ability to find suitable habitats in future (Table 14, Figure 80).
  Evidence: Natural Ecosystems Technical Report

The continental scale and magnitude of the predicted climate impacts means that it is almost certain that widespread change to our native ecosystems will occur. This may increase risks from climate change to communities that depend on ecosystem services *(high confidence).*

- Compositional change in ecosystems under climate change is expected to be substantial across Australia. By +3.0°C of global warming, species will be forced to move, adapt to the new conditions or die out, with 40 to 70% of native plant species being exposed to climatic conditions that they do not currently experience. Roughly half of the native plant species occurring in any location in a +3.0°C of global warming climate will become different to the species that occurred in that location in 1990. There will be a lag before the impacts are realised, and ecosystem responses will vary in ways that will be important to monitor when designing adaptation responses.
  Evidence: Natural Ecosystems Technical Report

Bioclimatic Ecosystem Resilience Index



- Change is expected to be most pronounced in areas where ecosystems are already at the extremes of their distributions (i.e. where species are most limited by temperature or moisture availability). Areas and species that will change first will be at the edges of ecosystem boundaries and at the extremes of Australia's temperature and aridity boundaries (e.g. Central Australia) (Figure 81).
Evidence: Natural Ecosystems Technical Report
- Increases in aridity will place ongoing pressure on plant productivity and reproduction within ecosystems, especially those that rely on the highest and most reliable rainfall (rainforests and eucalypt forests). Increasing aridity will force ecosystems to shift towards a drier expression (e.g. forest to woodland) or to form novel ecosystems with consequences for wildlife relying on the current ecosystem for survival.
Evidence: Natural Ecosystems Technical Report
- Some industries and livelihoods, particularly agriculture and primary industries, are dependent on sensitive ecosystem services such as water quality and security, pollination, and biodiversity that supports best control, as well as contributing to the climate resilience of communities.
Evidence: Communities Technical Report
- Fire-sensitive ecosystems, such as temperate Gondwanan rainforests (Godfree et al., 2021) and tall open eucalypt forest, are highly vulnerable to ecosystem collapse (Lindenmayer et al., 2022).
Evidence: Natural Ecosystems Technical Report
- Large areas of open eucalypt forest along the eastern seaboard and in southwestern Australia are under threat from repeated extreme fires. Forests are at risk of transitioning towards open grassy woodlands, resulting in significant wildlife habitat and carbon loss to the country.
Evidence: Natural Ecosystems Technical Report

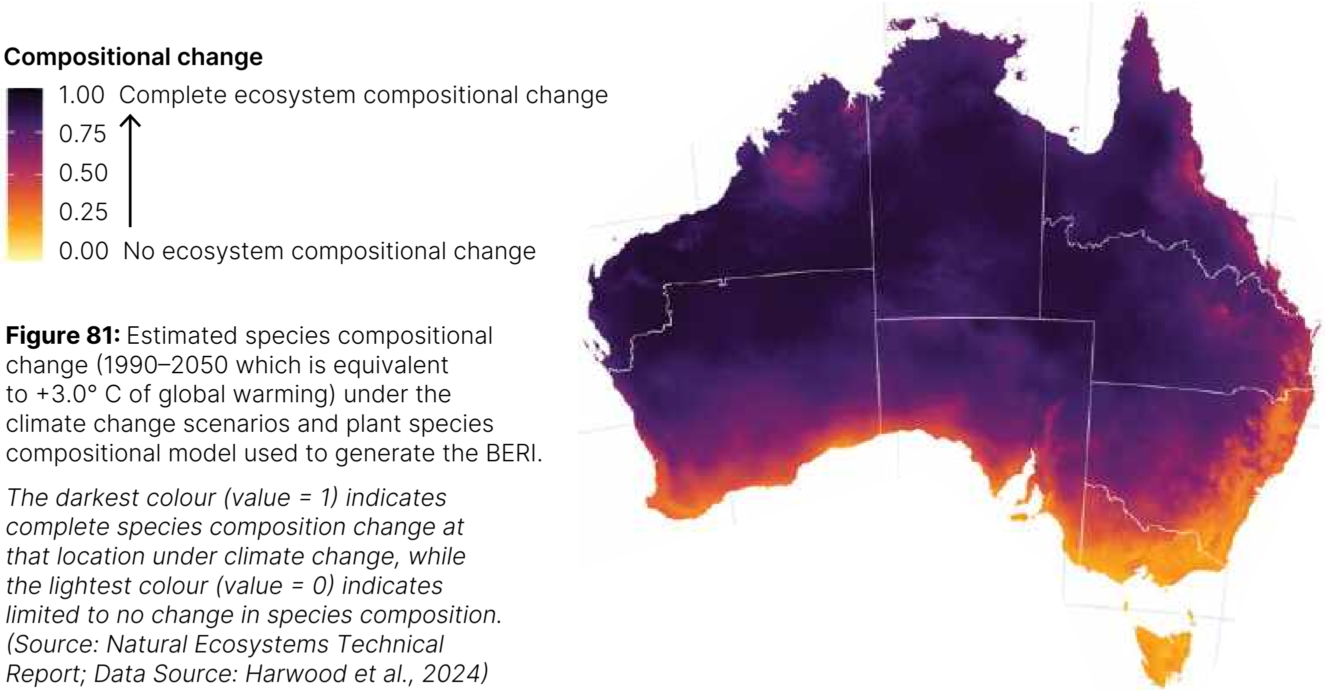


Figure 81: Estimated species compositional change (1990–2050 which is equivalent to +3.0° C of global warming) under the climate change scenarios and plant species compositional model used to generate the BERI.

The darkest colour (value = 1) indicates complete species composition change at that location under climate change, while the lightest colour (value = 0) indicates limited to no change in species composition. (Source: Natural Ecosystems Technical Report; Data Source: Harwood et al., 2024)

- More fire-tolerant systems are still likely to experience change, with increasing fire resulting in changes in the stand structure of trees and loss of fire-sensitive species, especially as weather conditions result in higher-intensity fires than in today's environment.
Evidence: Natural Ecosystems Technical Report

Freshwater

Freshwater ecological systems are highly exposed to water security pressures stemming from climate change. Many natural environments and ecosystems have already felt the impacts of reduced water quality with significant loss of flora and fauna *(high confidence).*

- Aquatic ecosystems often have specific watering requirements with limited adaptation options and some are already exposed to low water security due to overallocation of water resources. The risk is highest for some southern Australian forested catchments.
Evidence: Water Security Technical Report
- During drought, populations of many aquatic taxa decline with some undergoing local extinctions (Bond et al., 2008). As streams dry up, plants and animals can become stranded and the temperature of the remaining water increases, accompanied by increased salinity, acidification, reduced oxygen and nutrient build-up. These conditions can in turn result in algal blooms that are toxic to fish and can harm both livestock and native species (Bond et al., 2008). During the Millennium Drought (1997–2009), the Ramsar wetlands in the Coorong and Lakes Alexandrina and Albert Wetland at the seaward end of the Murray River became toxic due to such algal blooms. Species such as waterbirds that use water level as a cue for breeding are particularly sensitive to changes in the hydrological cycle (Steffen et al., 2018).
Evidence: Water Security Technical Report

- Intense rainfall events can cause blackwater events, increasing sedimentation and affecting downstream ecosystems. Historic blackwater events leading to fish deaths have been reported in the Murray River basin since 1892 (NSW Department of Planning, Industry and Environment, 2020). One recent case is after the 2019–20 Black Summer bushfires. The fires burnt large areas of forest and produced substantial amounts of ash that were then flushed into waterways, biodegrading water and causing deoxygenation and hypoxic blackwater events downstream. As a result, between October 2019 and May 2020 there were over 65 recorded events of fish death across the Murray–Darling Basin (Green & Moggridge, 2021).
  Evidence: Water Security Technical Report

The future increase in time spent in drought and increase in intense rainfall events over most of Australia will have significant and potentially irreversible impacts on freshwater habitats and their species *(medium confidence).*

- Rivers, lakes and reservoirs across Australia support ecosystems that exist in delicate balance and face water-quality risks from reduced inflows during drier periods, higher temperatures, and increased turbidity from more intense rainfall events.
  Evidence: Water Security Technical Report
- Lower rainfall and greater time spent in drought will drive changes in river morphology, flow regime and sediment distribution. It will also decrease landscape connectivity of freshwater ecosystems, drying of refuge waterholes, reductions in baseflow and increase in saltwater intrusion, degrading water quality. Projected impacts include damage to or loss of nationally and internationally important wetlands such as Macquarie Marshes, Gwydir Wetlands, Narre Lake Wetlands, the Great Cumbung Swamp and the Ramsar wetlands in the Coorong in the Murray–Darling Basin.
  Evidence: Water Security Technical Report
- Many parts of southern Australia have streams that are at risk of changing from perennial to ephemeral, with an increase in no-flow days. Understanding this risk requires detailed catchment-level research. Freshwater fish species are particularly vulnerable to rainfall deficits and to more frequent and intense hot temperatures; climate change is expected to cause major reductions in the ranges of Australian inland fish species (Beatty et al., 2014).
  Evidence: Water Security Technical Report
- There is a high risk of unprecedented climate-driven water scarcity for much of the continent in coming decades due to climate change *(medium confidence)*. Water management is one of few adaptations available to mitigate these risks and current actions are considered inadequate in preparing for long-term declines or managing periods of acute water scarcity. Management frameworks and reporting often focus on the amount of environmental water delivered, rather than on the environmental outcomes achieved (e.g. a wetland inundated to facilitate a bird- or fish-breeding event), or the sufficiency of environmental water allocations to achieve environmental outcomes, as may be specified in water plans (Productivity Commission, 2024), which is critical to ensure ongoing ecosystem health and resilience during drought.
  Evidence: Water Security Technical Report, Natural Ecosystems Technical Report

Watercourses in all catchments of Australia will increasingly experience higher maximum temperatures, exposing freshwater environments to more heat-related stresses than under current conditions.

- Perennial and ephemeral streams are sensitive to changes in maximum temperatures. Compounding effects of low inflows and higher temperatures will mean freshwater organisms are increasingly exposed to heat-related stress and changes in the availability of suitable refuge habitat.
  Evidence: Natural Ecosystems Technical Report
- Freshwater environments are highly sensitive to changes in temperature due to its influence on properties such as dissolved oxygen levels and rates of chemical reactions. Increases in temperature will provide conditions that reduce water quality, mainly dissolved oxygen levels, increase pollution risks, and can enhance the growth of cyanobacteria and algae blooms.
  Evidence: Natural Ecosystems Technical Report
- High-elevation watercourses in coastal catchments of southeastern Australia and Tasmania are at increased risk from increasing temperatures.
  Evidence: Natural Ecosystems Technical Report

Marine and estuarine

Australia's marine environment has experienced significant climate change impacts in recent years, with extreme events and global ocean warming impacting the biodiversity and delivery of ecosystem services in both coastal and deep marine ecosystems. Major changes to marine ecosystems are possible (and in some cases are already being observed). Such changes include widespread warming, dissolution of calcium-fixing organisms (corals, shellfish), broad-scale changes to ocean currents and changes to deep-sea carbon sinks *(high confidence).*

- The ecological impacts of climate-driven changes in the natural fluctuations and mean of ocean temperatures are vast, and will change the growth, fitness, abundance, distribution, reproduction and survival of species (Doney et al., 2012; IPCC, 2022b; Poloczanska et al., 2013). Extreme climatic events in Australia have already caused extensive mortality of foundation and habitat-forming species, such as corals, kelps, seagrasses and mangroves, along more than 45% of the continental coastline.
  Evidence: Natural Ecosystems Technical Report

- Although there is uncertainty in the amount and direction of change, the median total marine animal biomass is projected to decline across most of Australia. By +3.0°C of global warming, the Great Barrier Reef, Torres Strait and Temperate East bioregions are projected to have the largest median decrease in marine animal biomass.
Evidence: Natural Ecosystems Technical Report
- Surface pH is projected to decline (ocean acidity increase) across the entire Australian Exclusive Economic Zone, with the decline becoming more severe with increasing global warming levels. At a future warming scenario of +1.5°C, the mean pH change is –0.036 (compared to the historical baseline), further decreasing to −0.175 at a scenario of +3.0°C global warming. Marine bioregions that will have the largest decreases in surface pH include the temperate east, southeast and southwest, as well as Macquarie Island and Heard and McDonald Islands. Future acidification will greatly impact organisms that make calcium shells, and corals, phytoplankton and zooplankton will have greater difficulty forming hard skeletons.
Evidence: Natural Ecosystems Technical Report

Ecosystem ID	Ecosystem class	Mean CIS GWL +1.2°C	Mean CIS GWL +1.5°C	Mean CIS GWL +2.0°C	Mean CIS GWL +3.0°C	Frequency
8	Oceanic shallow coral reefs	0.870	0.956	0.994	0.999	37,873
9	Shelf vegetated sediments	0.818	0.867	0.935	0.995	702,663
10	Shallow coral reefs less than 30 m depth	0.815	0.898	0.949	0.997	1,274,823
11	Shallow rocky reefs less than 30 m depth	0.765	0.870	0.936	0.996	308,949
1	Shelf unvegetated soft sediments	0.726	0.817	0.894	0.963	25,765,092
15	Rariphotic (dark) shelf reef	0.642	0.748	0.850	0.928	366,707
12	Mesophotic (twilight) coral reefs	0.633	0.725	0.831	0.915	571,567
14	Oceanic mesophotic (twilight) coral reefs	0.626	0.685	0.795	0.892	28,554
13	Mesophotic (twilight) rocky reefs	0.625	0.699	0.834	0.924	319,368
17	Mid slope reef	0.588	0.629	0.675	0.775	231,155
3	Mid slope sediments	0.561	0.604	0.653	0.754	15,436,034
2	Upper slope unvegetated soft sediments	0.557	0.607	0.674	0.796	4,859,014
16	Upper slope rocky reefs shelf break to 700 m depth	0.542	0.595	0.663	0.792	90,093
7	Shelf incising and other canyons	0.539	0.572	0.640	0.739	411,045
18	Seamount reefs	0.533	0.552	0.577	0.618	2,465
6	Seamount soft sediments	0.258	0.386	0.506	0.528	2,721,621
4	Lower slope reef and sediments	0.074	0.193	0.323	0.457	24,205,863
5	Abyssal reef and sediments	0.062	0.183	0.319	0.456	30,298,352

Table 15: Summary of mean cumulative impact scores for all benthic ecosystems across Australia's Exclusive Economic Zone (Oceans) for each GWL. Scores are scales (0, 1) for each GWL.

The table is sorted by the ecosystem class with the highest mean cumulative impact score (CIS). The table colouring is based on each cumulative impact score for each GWL. Frequency represents the total count of each ecosystem class pixels (250 m resolution) across the zone. (Source: Natural Ecosystems Technical Report)

Note: colour scale is opposite to that of Figures 80, 81 and Table 14, so that severity scores are dark in all cases.

- Deep sea floor ecosystems such as abyssal reefs and sediments, seamounts and canyons are projected to be at relatively lower risk from climate change (Table 15). However, significant knowledge gaps on the biodiversity and ecological processes in these systems mean that greater risks cannot be ruled out. Since the deep ocean is the Earth's largest long-term sink of carbon, the consequences of changes to these ecosystems are of critical importance to our national risk from climate change. Further research to better understand the risks to our deep ocean ecosystems is recommended.
Evidence: Natural Ecosystems Technical Report
- Increased extreme heat is occurring across most of Australia, which may be leading to declines in fisheries productivity. Periods of extreme temperature anomalies can lead to severe ecosystem consequences and fishery impacts – for example, through changes to migration, distribution and abundance of marine resources or thermal stress leading to increased mortality of marine species. Ocean primary productivity is projected to decline along eastern Australia and, to a lesser extent, in southern Australia. In contrast, it is expected to increase in north-western Australia and around Tasmania and other islands within the Exclusive Economic Zone. This pattern is consistent across global warming levels and intensifies with increasing warming.
Evidence: Primary Industries Technical Report
- Wild catch fisheries and aquaculture are dependent on healthy marine and estuarine environments. Increasing ocean acidity and temperature will affect these environments (Hobday & Cvitanovic, 2017; Lawrence et al., 2022; Seneviratne et al., 2021; Stokes & Howden, 2010). Fisheries in shallow coastal and intertidal areas, including mud crab fishery and oyster farms (Seneviratne et al., 2021), are expected to become increasingly vulnerable to extreme warming, with exposure of some areas to extreme heat in the summer likely to negatively impact habitat-forming species, such as mangroves, upon which many fish species rely (Duke et al., 2021). Fisheries in shallow waters would be more exposed to temperature increases than deep ocean fisheries.
Evidence: Primary Industries Technical Report

The poleward migration and intensification of the East Australian Current is predicted to continue. This will intensify the 'tropicalisation' of temperate ecosystems and the movement of species south, posing high risk to coastal temperate ecosystems off the east coast *(high confidence).*

- The southeast and southwest coastal and marine areas of Australia contain high biodiversity, with many endemic marine species. Currently, the Tasman Sea is an ocean warming hotspot with rates of warming above the global average where the poleward migration and intensification of the East Australian Current transports more warm water south. This area is a climatic cul-de-sac, with no suitable habitats to the south as the ocean warms up and marine species near their thermal tolerance. Under all future global warming scenarios, this region will experience enhanced ocean warming *(medium confidence)*. At a global warming level of +3.0°C, a near-permanent heatwave state is projected to occur in the Tasman Sea.
Evidence: Australia's Future Climate and Hazards Report
- Ocean warming means that northern marine regions are becoming hyper-tropical, some projected to experience unprecedented temperatures. In this area, most species are near thermal tolerance and often have nowhere to retreat because of land barriers to the south. On average, marine taxa are moving poleward by 72 km per decade or to deeper parts of the ocean, following suitable environmental conditions (Poloczanska et al., 2013).
Evidence: Natural Ecosystems Technical Report
- The strengthening East Australian Current has also facilitated the range expansion of the sea urchin *Centrostephanus rodgersii* from NSW into Tasmania (Ling et al., 2009). Sea urchins can be voracious grazers and have contributed to the decline and hindered recovery of giant kelp forests due to overgrazing, leaving 'sea urchin barrens' in their wake (Ling et al., 2009; Ling & Keane, 2018, noted in Bergstrom et al. 2021).
Evidence: Natural Ecosystems Technical Report
- Some species of phytoplankton can rapidly grow in abundance, forming blooms that may deplete oxygen in the water, leading to hypoxic conditions harmful to marine organisms. One example of this is the conspicuous red tide dinoflagellate *Noctiluca scintillans*. This species has expanded into southeast Australia, and even into the Southern Ocean for the first time as a consequence of the increasing strength of the East Australian Current.
Evidence: Natural Ecosystems Technical Report

Coral reefs, such as the Great Barrier Reef and Ningaloo World Heritage areas, are degraded due to ocean warming *(high confidence).*

- Coral reef habitats are one of the natural systems most affected by cumulative impacts and extreme climate events (Babcock et al., 2021; Trebilco et al., 2021). Coral reefs support high biodiversity, serve as spawning and nursery grounds for numerous fish species, attract tourism and recreational activities, and protect coasts against high tides, rising sea levels and storms (Great Barrier Reef Marine Park Authority, 2024). Overall, coral reefs are assessed to be in a poor condition nationally; however, coral reef condition varies within and among regions, with coral reefs in some localities still in good condition (Trebilco et al., 2021).
Evidence: Natural Ecosystems Technical Report
- Coral reefs in Australia have been severely degraded due to ocean warming. Marine heatwaves result in mass bleaching events, leading to coral mortality at some sites (Gilmour et al., 2019; Pratchett et al., 2021).
Evidence: Natural Ecosystems Technical Report, Australia's Future Climate and Hazards Report

- The projected increasing intensity and duration of marine heatwaves is likely to leave insufficient time for the corals to recover between successive bleaching events, suggesting that impacts of future marine heatwaves can be more pronounced.
  Evidence: Natural Ecosystems Technical Report
- At a global scale, coral reefs are experiencing a shift in their essential metabolic processes due to ocean acidification, evidenced by a declining calcification of 4.3 ± 1.9% per year since 1970 (Davis et al., 2021). Studies have estimated that coral reefs around the world could shift towards net dissolution by around 2050 (Davis et al., 2021; Eyre et al., 2018).
  Evidence: Natural Ecosystems Technical Report

Seagrasses and kelp forests in Australia have been impacted by climate change, including warming and marine heatwaves, sea level rise, altered storm patterns, ocean currents and ocean acidification *(high confidence).*

- Seagrasses stabilise sediments and provide crucial nursery habitats for key commercial, cultural and recreational fisheries. They are also a major source of food for dugongs and a significant global reservoir of carbon. One of the biggest seagrass meadows in Australia, in the Shark Bay World Heritage Area, is approximately 13,000 km^2 in size and has been severely impacted by ocean warming. The 2011 marine heatwaves off the west coast of Australia resulted in an estimated loss of 1,310 km^2 of seagrass across Shark Bay (Strydom et al., 2020). Seagrass loss in this area was related to greater than or equal to 10°C heating weeks and greater than or equal to 94 days of marine heatwaves.
  Evidence: Natural Ecosystems Technical Report
- It is predicted that a sea level rise of 1.1 m will decrease the abundance of seagrass by 17% from 2000 to 2100 in Moreton Bay, Queensland (Saunders et al., 2013). Management of water quality to improve clarity and therefore maximise light penetration may offset this loss (Saunders et al., 2013).
  Evidence: Natural Ecosystems Technical Report
- Giant kelp cover in Tasmania has declined by at least 95% over the last decades, triggering the 2012 declaration of giant kelp forests as a Threatened Ecological Community under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. The declines have been attributed to the increasing influence of the East Australian Current in the region, which increases ocean temperatures in the area (Butler et al., 2020; Layton et al., 2021; Schiel & Foster, 2015). As East Australian Current influence strengthens along the waters of Tasmania, the state has been considered to be a geographic trap for the giant kelp as there is no suitable habitat for it to move to and colonise the south. Additionally, cold and temperate ecosystems are tropicalising, promoting the migration of tropical herbivores that can hinder the recovery of seagrass and kelp ecosystems after extreme climatic events, including marine heatwaves.
  Evidence: Natural Ecosystems Technical Report

Rising sea level, higher temperatures and changing rainfall patterns will impact Australia's key coastal ecosystems, including estuaries and coastal wetlands *(medium confidence).*

- Trends in warming, acidification and changes in salinity gradients are more pronounced in shallow coastal and estuarine environments than in open ocean, but the projection of future changes is a significant knowledge gap.
  Evidence: Natural Ecosystems Technical Report
- Rising sea level is affecting ocean currents and inundating coastal margins, leading to changes in habitat and ecosystems. Rising sea levels will increasingly drive seawater intrusion further up estuaries and/or change salinity gradients along coastal margins, which could impact estuarine species distributions.
  Evidence: Natural Ecosystems Technical Report
- High air temperatures will likely warm shallow coastal waters and lead to exceedance of thermal limits for species. Warming can enhance stratification and deoxygenation in shallow lagoons/estuaries, leading to increased mortality of associated species and range shifts.
  Evidence: Natural Ecosystems Technical Report
- Freshwater run-off to the ocean has a wide range of impacts on downstream fisheries. Some marine species depend on estuaries and freshwater for their reproduction. Freshwater flows can change water column stratification in inshore waters and provide nutrients to fuel ecosystem productivity. Within estuaries, reduced rainfall and flows can lead to increased salinity, decreased river-mouth opening, more-prevalent inverse estuaries (salinity greater at head of estuary than mouth) and reduced connectivity.
  Evidence: Natural Ecosystems Technical Report

Impacts on Aboriginal and Torres Strait Islander peoples

Rapidly changing climate and ecosystems puts at risk the ability of Aboriginal and Torres Strait Islander people to connect with Country, which in turn affects Aboriginal and Torres Strait Islander peoples' physical, mental, community and cultural health and wellbeing *(high confidence).*

- Aboriginal and Torres Strait Islander consultations highlighted that the destruction of land, sea and Country is already impacting Aboriginal and Torres Strait Islander peoples' cultural practices, including caring for Country as a mechanism for climate adaptation and sustainability.
  Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering

- Aboriginal and Torres Strait Islander consultations highlighted that in Aboriginal and Torres Strait Islander knowledges, caring for Country includes land and waterways, so that separating land and water is misaligned with a holistic understanding of caring for Country. They also shared their experiences of the monetary value of water being considered more important than the detrimental effect a lack of water can have on Country.
  Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering
- Risks from changing natural environments put at risk Aboriginal and Torres Strait Islander access to and reliance on bush foods, aquaculture and mariculture opportunities (e.g. kelp farming).
  Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering

Adaptation observations and considerations

This section provides information that can support adaptation planning and approaches.

Widespread predicted ecosystem changes as the climate changes mean that assisting adaptation is essential to preserve the natural system and that early action could be effective for many of the risks *(high confidence).*

- There are a wide range of projects that could contribute to enhancing ecosystem health, such as implementing natural resource management and biodiversity projects. Examples include reforestation and wetland rehabilitation to strengthen ecosystems' ability to withstand climate impacts, and establishing protected areas and wildlife corridors to facilitate species migration and adaptation, ensuring the survival of diverse species in changing climates. Additionally, activities aimed at building community capacity by involving them in local conservation efforts can foster a collective response to climate challenges.
  Evidence: Natural Ecosystems Technical Report
- Action to mitigate climate change, as well as halting and reversing current declines in ecological condition by removing human-induced pressures, is the best defence against future climate impacts to the natural environment.
  Evidence: Natural Ecosystems Technical Report

Habitat restoration and ecosystem-based management are effective climate adaptation strategies that can help species and ecosystems acclimatise to climate change. Maintaining and reconnecting habitats is essential to enhance resilience and mitigate the impacts of climate change on native vegetation and species, while further land clearing would exacerbate these challenges *(high confidence).*

- Beyond natural adaptation, climate adaptation strategies can help species and ecosystems to acclimatise or adapt to climate change. Evidence from various adaptation efforts shows that adaptation interventions such as climate-adapted habitat restoration, ecosystem-based management and improved sustainability of harvesting may be effective (IPCC, 2022b).
  Evidence: Natural Ecosystems Technical Report
- Land use and land-use change to increase carbon sequestration emerge as a critical feature of virtually all mitigation pathways that seek to limit global warming to +1.5°C (IPCC, 2023).
- Connected habitats with higher levels of ecosystem integrity will be more resilient to future climate change, so action to rapidly halt land clearing, reinstate hydrodynamics, restore integrity, and reconnect ecosystems and habitats is critical to minimise the impacts of climate change. Further land clearing will result in smaller, more isolated habitats throughout Australia and accelerate the impacts of climate change on native vegetation and species.
  Evidence: Natural Ecosystems Technical Report

Conserving and restoring mangrove, salt marsh and seagrass habitats can significantly contribute to national climate mitigation efforts and provide numerous societal benefits, including enhanced biodiversity and storm protection. Effective management of these coastal blue carbon habitats, along with local groundwater systems, is essential for maximising their ecological and economic benefits *(high confidence).*

- Conservation and restoration of mangrove, salt marsh and seagrass habitats can contribute to national mitigation efforts for countries with relatively large coastlines where such ecosystems occur naturally (IPCC, 2023). Managing climate change and other impacts to local groundwater systems will be a key conservation requirement.
- Notably, there is a relatively large proportion of nature-based adaptation in the Infrastructure and the built environment system compared to other systems, with key examples including urban greening at state and city scales, and natural buffers used as coastal asset protection. These nature-based adaptations can provide co-benefits across multiple systems, including the Natural environment, Health and social support and Communities - urban, regional and remote systems. Urban greening supports biodiversity and reduces heat-health risks, with the Northern Beaches, north Sydney and Hornsby, generally leafier and more affluent suburbs, found to have a lower heat-health risk (Berthon et al., 2021). Natural buffers, such as wetlands and mangroves, are examples of successful adaptations that provide habitat for wildlife, as well as mitigate the effects of coastal hazards and sea level rise, enhancing the resilience of coastal communities.
  Evidence: Insights from the Adaptation Stocktake, Communities Technical Report

- Measures to protect and restore coastal blue carbon habitats provide many other societal benefits in addition to climate regulation. In particular, there is high confidence that coastal wetlands benefit local fisheries, enhance biodiversity, give storm protection, reduce coastal erosion, improve water quality and support local livelihoods (Costanza et al., 2008; Spalding et al., 2014). Coastal ecosystems may keep pace with sufficiently gradual sea level rise, and may be more cost-effective in flood protection than hard infrastructure such as seawalls (IPCC, 2023).

Strengthened governance to manage water competition, especially during extreme dry periods, will help to support aquatic ecosystems that are highly vulnerable to overallocation of water resources. Effective water management should focus on achieving environmental outcomes rather than just the volume of water delivered, highlighting the need for a cohesive national framework for monitoring and adaptive management *(high confidence).*

- Aquatic ecosystems are particularly vulnerable to overallocation of water resources. These vulnerabilities highlight the need for strong governance, especially to manage competition for limited water in times of extreme dry, which are projected to increase across much of the country. The highest risk exists for some southern Australian forested catchments.
  Evidence: Water Security Technical Report
- Government has a responsibility to recognise the needs and risks of all water users, including the environment. Efforts to do so are evident in various drought governance initiatives, such as environmental water buy-backs and large-scale water infrastructure projects.
  Evidence: Governance Technical Report
- Water management frameworks and reporting often focus on how much environmental water is delivered, rather than on what environmental outcomes are achieved (e.g. a wetland inundated to facilitate a bird- or fish-breeding event), or if sufficient environmental water is allocated for environmental outcomes, as may be specified in water plans (Productivity Commission, 2024), which is critical for ongoing ecosystem health and resilience during drought.
- Approaches to water management differ across jurisdictions. Some regions allow water trading and actively manage environmental water releases from regulated sources (such as dams), while others prioritise environmental water needs and protect these allocations outside of consumptive pools, accounting for sustainable requirements on an annual basis. These differences highlight a fragmented national framework for monitoring and reporting environmental water, with unclear feedback mechanisms to enable water planning and adaptive management (Productivity Commission, 2024), which is crucial for taking timely and effective adaptive actions.
  Evidence: Water Security Technical Report
- Managing catchment health is a critical adaptation strategy, especially for mitigating water-quality risks. Water management occurs primarily at the regional level. The new National Water Agreement, introduced by the Australian Government, aims to establish a standardised, coordinated approach across jurisdictions to address water management in a modern context, while also accounting for the challenges posed by climate change. The Agreement includes adopting climate change scenarios into planning, and imbedding adaptive management approaches that are more sensitive to climate variability when issuing annual allocations for use.
  Evidence: Water Security Technical Report
- Effective management of ecological assets is complicated by the diverse watering requirements of different ecosystems and their associated values. Investing in research to understand eco-hydrological processes and how they may be affected by climate change, alongside the adoption of indicator-based management metrics, are key to enhancing adaptive capacity for addressing these risks.
  Evidence: Water Security Technical Report
- Integrating knowledge from Traditional Owners is a vital strategy for mitigating climate change risks. Traditional Owners possess deep, place-based knowledge of eco-hydrological processes and ecological requirements, offering a holistic understanding of complex systems that may not be available through conventional scientific approaches.

Aboriginal and Torres Strait Islander peoples' knowledge, appropriately recognised and resourced, could help to mitigate the impacts of climate change on water security and the natural environment.

- 192 million hectares of land in Australia (25%) is under some form of Indigenous management, comprising 156 million hectares that is Indigenous managed and 36 million hectares that is Indigenous co-managed (Department of Agriculture, Fisheries and Forestry, 2024a). The Indigenous Rangers Program provides a significant opportunity to assist and learn from Aboriginal and Torres Strait Islander people in managing Country using traditional knowledge and cultural practices, combined with Western science, to protect and improve ecosystem health while delivering cultural, social and economic development outcomes (National Indigenous Australians Agency, 2024).
- Aboriginal and Torres Strait Islander consultations highlighted that Aboriginal and Torres Strait Islander peoples' knowledge systems and caring for Country practices should be more highly valued, recognised, resourced, and integrated into assessments and responses to environmental hazards, including water security and access. These knowledge systems are fundamental to sustaining biodiversity, ecosystems and reliable water sources, and can significantly contribute to understanding, mitigating and adapting to risks from climate change.
  Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering

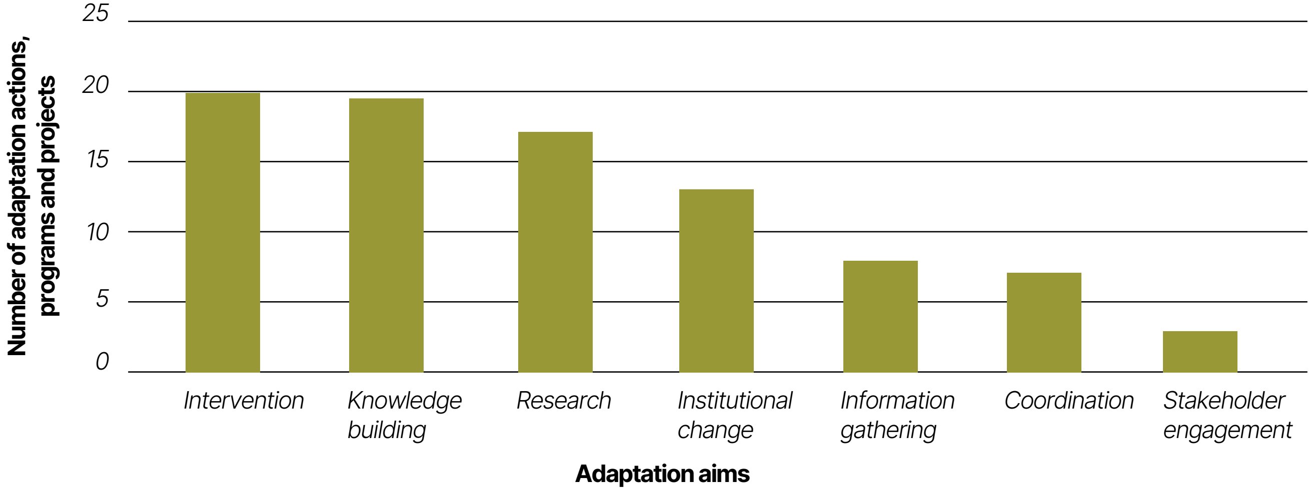


Figure 82: Distribution of adaptation projects, programs and actions across adaptation aims in the Natural environment system. *(Source: Insights from the Adaptation Stocktake)*

- Aboriginal and Torres Strait Islander knowledges can help reduce bushfires, an identified Health and social support system hazard. Cultural burning is a practice that can assist in reducing this risk and benefit Aboriginal and Torres Strait Islander people through economic participation.
  Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering
- Aboriginal and Torres Strait Islander consultations highlighted that as climate change evolves, caring for Country practices must adapt accordingly, ensuring sustainable water management and equitable access for communities.
  Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering

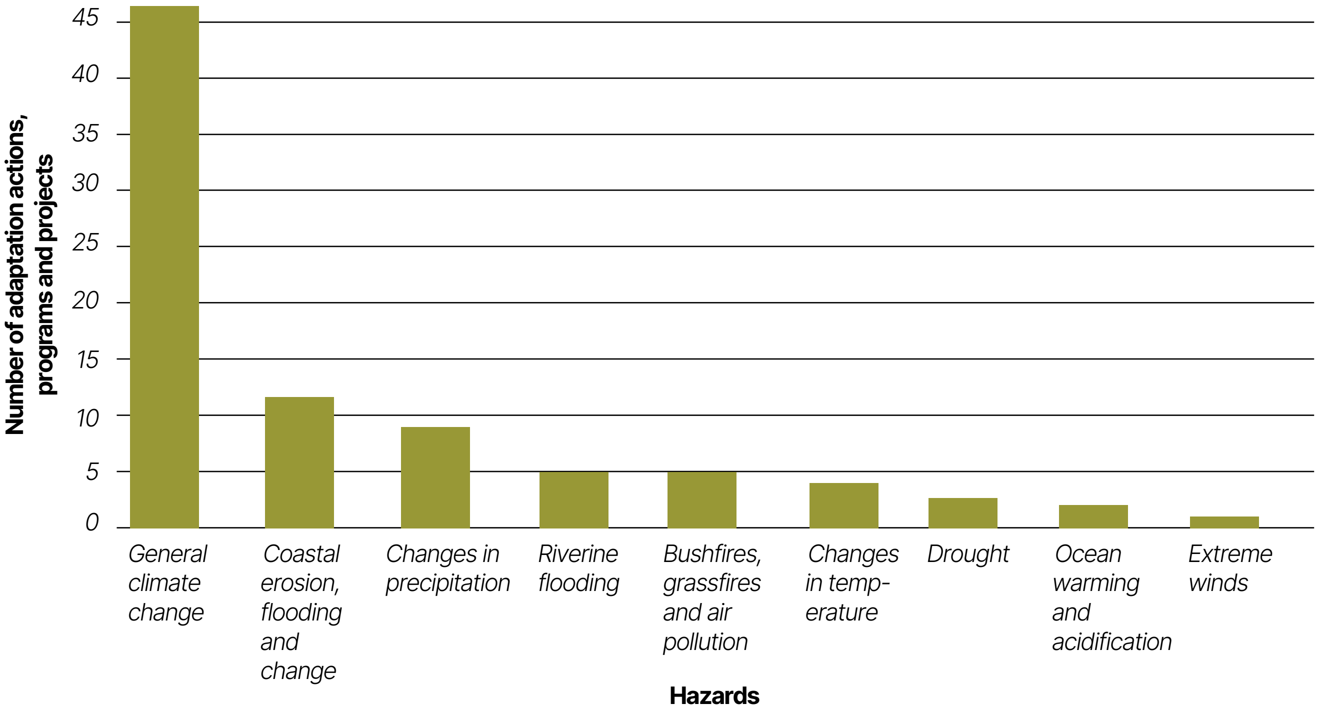
The Natural environment system has a high proportion of both adaptation policies and programs, which is a strong basis for further action *(high confidence).*

- Nearly half of the adaptation actions within this system are aimed at increasing understanding of risks from climate change to the natural environment (through knowledge building and research), with examples such as research and communications on revegetation options for communities and regions (Figure 82). Adaptation actions in this system also focus on implementing interventions, such as the restoration of wetlands and projects to improve the ecological health of waterways. The high proportion of research and implementation compared to other systems could suggest a higher level of progress in this system than those predominantly focused on planning and information gathering.
  Evidence: Insights from the Adaptation Stocktake
- The Natural environment system has the largest proportion of adaptation policies, plans and laws compared to other systems (22%) and the second-largest proportion of projects, programs and actions (24%). While these data show that adaptation is occurring within this system, the literature on adaptation shows that these actions are not sufficient to manage current or future risks from climate change.
  Evidence: Insights from the Adaptation Stocktake
- Adaptation policies and plans in the Natural environment system are diverse and cover a wide range of policy areas, including species conservation, ecosystem resilience and non-urban forestry. Many examples reference climate change but do not strictly focus on adaptation, aiming to manage current risks rather than promote change in response to future risks.
  Evidence: Insights from the Adaptation Stocktake

The complexity of impacts on the natural environment is challenging decision-making in the system. Governance for adaptation requires both policy and planning, in addition to the implementation of actions, programs and projects *(low confidence).*

- Australia's environmental governance has been under considerable pressure in recent years and there are discussions underway as to how to update legislative frameworks. The Australian Government has powers to regulate the environment, primarily through international treaty obligations and issues of national significance. The states and local government control land-use and resource management decisions.
  Evidence: Governance Technical Report
- Gathering and interpreting knowledge was identified as the weakest aspect of risk governance for the Natural environment system and suggests the value of systematic risk assessments as well as providing access to good-quality, nationally consistent information.
  Evidence: Governance Technical Report

Figure 83: Distribution of adaptation actions, programs and projects by hazard in the Natural environment system. *(Source: Insights from the Adaptation Stocktake)*



Adaptation actions, programs and projects in the Natural environment system aim to address both general climate-driven risks and particular hazards and are implemented at scales that reflect both where the risks occur and the scale of governance arrangements for this system *(high confidence).*

- Nearly half of the adaptation actions identify climate change as a risk without targeting a specific hazard. Coastal erosion and flooding and changes in precipitation were commonly addressed hazards in this system (Figure 83). For coastal erosion, these programs mostly involved coastal habitat restoration and coastal ecosystem rehabilitation.
  Evidence: Insights from the Adaptation Stocktake
- Adaptation in the Natural environment system mostly occurs at a regional scale, followed by state/territory and then local scales and a smaller percentage at a national scale (Figure 84). The regional scale refers to actions that aim to affect adaptation across multiple LGAs but not an entire state or territory. The high proportion of regional-scale adaptation is a key difference with other systems and reflects the need for catchment- and landscape-scale responses to climate change within this system, as well as the existence of regional authorities and organisations that enact governance across LGAs.
  Evidence: Insights from the Adaptation Stocktake

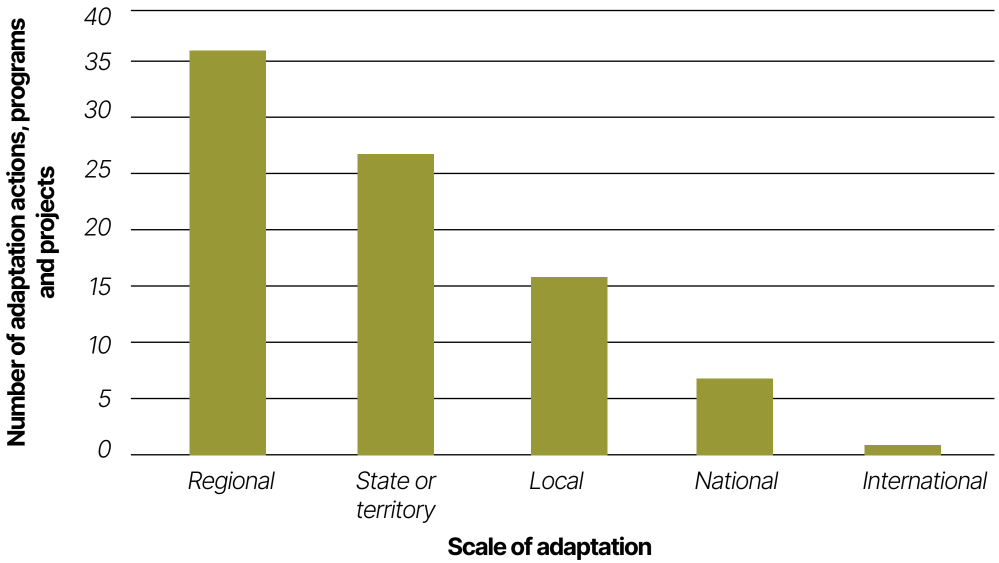


Figure 84: Distribution of adaptation actions, programs and projects by scale in the Natural environment system. *(Source: Insights from the Adaptation Stocktake)*

Case study:
Temperate eucalypt forest growth

Most of Australia's temperate eucalypt forests already grow in temperatures higher than the optimal mean annual temperature for tree growth of around 11°C (Bowman et al., 2014; Prior & Bowman, 2014a, 2014b).

Above or below this temperature, growth is slower. This is especially the case for large trees that grow in areas above this temperature. By a future warming scenario of +3.0°C, tree growth rates in these forests are likely to drop substantially (22%), as will the amount of carbon stored, with a reduced rate of recovery from disturbance such as wildfire. Many of the largest trees also grow in the cooler, wettest areas. The hazard projections of higher temperatures, less rainfall, more time in drought and increased frequency of fire weather mean that less water will be available, and fires will become more frequent and intense. This trend will result in slower-growing trees with shorter average life spans, potentially shifting away from the species that define the current ecosystems that have developed with long fire-return intervals and high water availability. Loss of old trees will have negative flow-on effects with our tree-dwelling animals, especially those species that require tree hollows to nest in (Figure 85). Tree hollows are directly correlated with age of the tree.

This case study and related evidence can be found in the Natural Ecosystems Technical Report.

Figure 85: Mature temperate eucalypt forest showing tree hollows.
(Photo by Dana Bergstrom. Used with permission)

Case study: Climate pressure on the Great Barrier Reef

The Great Barrier Reef Marine Park covers an area of 348,000 km^2 and has a network of almost 3,000 coral reefs, hosting a wide variety of fish, seabirds and marine reptiles.

The Great Barrier Reef also provides important sites for carbon storage, which have been accumulating for thousands of years. Coral reefs in the Great Barrier Reef are already severely degraded due to ocean warming. Future increases in atmosphere and ocean temperatures, an increase in acidity, rising sea levels, more intense tropical cyclones, and intensifying frequency and strength of marine heatwaves are projected to impact coral reefs in the Great Barrier Reef (Henley et al., 2024). The reef and its habitats have an enduring natural resilience, where it has and can survive and recuperate from natural disturbances such as cyclones, rainfall floods and marine heatwaves (Hopley et al., 2007). However, climate and ocean changes are exacerbating disturbances, shrinking recovery windows and overwhelming the resilience of key species such as corals.

Mass bleaching events due to marine heatwaves have affected 30% to 65% of all reefs that make up the Great Barrier Reef (Henley et al., 2024) leading to coral mortality at some sites (Gilmour et al., 2019; Pratchett et al., 2021). The projected increasing intensity and duration of marine heatwaves will leave insufficient time for the corals to recover between successive events, suggesting that impacts of future marine heatwaves could be more pronounced (Great Barrier Reef Marine Park Authority, 2024).

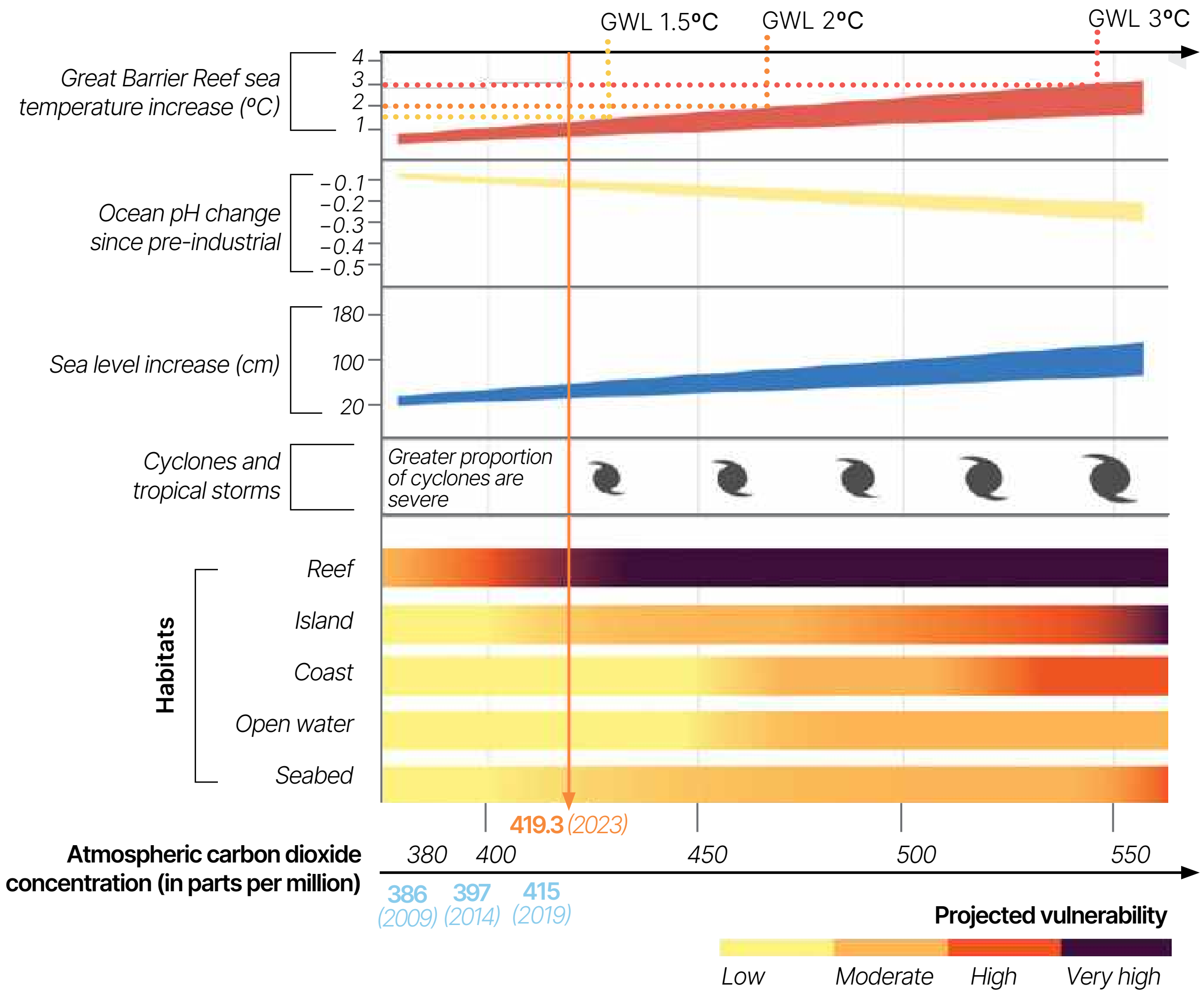


Figure 86: Projected trends of environmental threats (top) and ecosystem vulnerabilities (bottom) expected from climate change on the Great Barrier Reef in relation to carbon dioxide concentrations.

The top chart shows the likely future warming scenarios for 3 CMIP5 decades GWL +1.5°C (2015–24), GWL +2.0°C (2030–49) and GWL +3.0°C (2053–72). (Source: Modified from Great Barrier Reef Marine Park Authority, 2024)

Corals in the Great Barrier Reef, and around the world, have and are undergoing phase shifts from high coral cover to alternate, degraded macroalgal assemblages due to the combined effects of overfishing, declining water quality, and the direct and indirect impacts of climate change (Fabricius et al., 2023; Hughes et al., 2007). Recently, declines in cover of crustose coralline algae (up to 3.1-fold) and coral juvenile density (1.3-fold) have been attributed to decreasing aragonite saturation state (increased acidity) in the Great Barrier Reef World Heritage Area (J. N. Smith et al., 2020). At the same time, non-calcifying microalgae have increased up to 3.2-fold in the same area, suggesting a change in community biodiversity and function. Data suggest a tipping point at aragonite saturation of 3.5 to 3.6, at which point crustose coralline algae cover reaches low levels, coral juvenile densities decline and non-calcifying microalgae cover starts to increase. These conditions are projected to be reached, on average, in the Great Barrier Reef area at a future warming scenario of +1.5°C, suggesting this system is close to reaching this tipping point.

The risks to the Great Barrier Reef are rising, with the expected increasing global warming levels exacerbating acute and chronic disturbances, resulting in the reduction of likely recovery and with a net effect of losing resilience for the coral and its ecosystem (Great Barrier Reef Marine Park Authority, 2024). The magnitude and pace of climate and ocean changes are now the pivotal drivers of vulnerability in the reef ecosystem, and their combined effects will negatively impact the reef's structural complexity, other species and habitats, and alter their services across the Great Barrier Reef (Figure 86). To date, the only climate refugia in the Great Barrier Reef region are located in deeper water where favourable hydrodynamic conditions provide protection from thermal extremes (Cheung et al., 2021).

For more information on this case study, see the Natural Ecosystems Technical Report.

Primary industries and food system

Summary

The Primary industries and food system refers to land, marine and estuarine activities dedicated to producing food, fibre, wood, fuel and other products. This system includes agriculture, aquaculture, fisheries and forestry sectors spanning large-scale and smallholder operations, covering the entire chain from production to the consumer.

Priority risk

The National Assessment has undertaken quantitative and qualitative analysis for priority risks. The first pass assessment identified 6 nationally significant climate risks for this system. One priority risk has been analysed as part of the second pass assessment:

- Risks to primary industries that decrease productivity, quality and profitability and increase biosecurity pressures.

Primary industries and food

Climate risks are determined by the interaction of risk elements, including hazards, exposures and vulnerabilities. This is a risk summary for the Primary industries and food system.

Climate and hazards

- Bushfires
- Changes in rainfall patterns, including drought
- Extreme heat
- Flooding
- Ocean warming and acidification

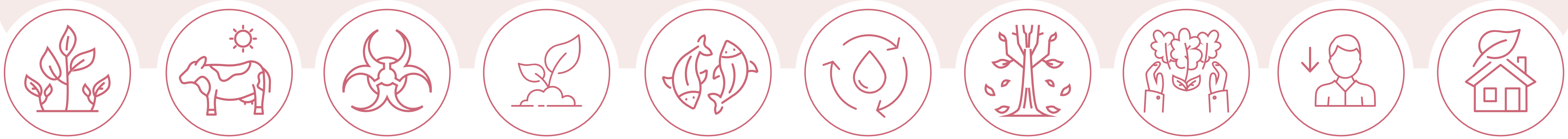
Exposures

- Agricultural workers
- Cropping
- Fisheries and aquaculture
- Forestry
- Horticulture
- Livestock

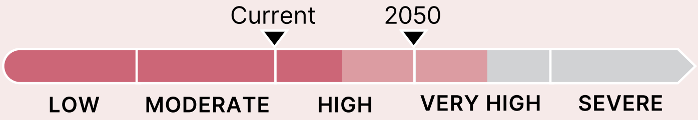
Vulnerabilities

- Communities that rely on agriculture
- Biosecurity
- Ecosystem services and soil health
- Financial stability of producers
- Infrastructure and resilience
- Supply chain
- Water security

IMPACTS AND RISKS



- Reduced yields for some crops
- Increasing livestock heat stress
- Higher biosecurity risks
- Declining forestry growth rates
- Impact on productivity of fisheries
- Increasing water competition
- Destruction of forest assets
- Risk of food insecurity
- Reduction in workforce
- Challenges for agricultural communities



Assessment of current risk

The current climate risk to the Primary industries and food system is rated as *moderate–high (medium confidence)*.

Climate change is having impacts in localised areas, affecting the production capacity of communities in some regions. Australia's cropping industry is sensitive to climate change, with rainfall declines and extreme heat reducing soil moisture and potential crop yields in parts of southwest Western Australia. Horticulture faces challenges from increased extreme heat which affects the quality and marketability of produce; however, these challenges are largely being managed in the current climate.

Forestry is under threat from hotter climates, increased fire weather risk, and changes in rainfall and drought patterns, impacting tree growth and increasing susceptibility to pests. Fisheries and aquaculture are experiencing changed productivity due to increased marine temperatures, ocean acidity and storm activity.

Livestock are experiencing higher heat stress, threatening productivity. This is exacerbated by changes to pasture productivity due to changing temperatures and rainfall.

Biosecurity pressures are rising, with higher temperatures, changing precipitation patterns, extreme events, and responses to these events contributing to the spread of pests and diseases.

Changes in the frequency and severity of extreme climate events affect production of primary industries, with farming communities at the frontline of these impacts. Water security is becoming a major concern for some regional communities, affecting agricultural productivity and community livelihoods.

Most primary industries are managed systems and are maintaining productivity despite climate change through uptake of technological advancements. In addition, Australia is one of the most food-secure nations in the world, producing more than it consumes. However, it remains uncertain whether current technological improvements and uptake will be adequate to address the risks posed by future climate changes.

Assessment of future risk

By 2050, the climate risk to the Primary industries and food system is expected to increase to *high–very high (medium confidence)*.

The sustainability and prosperity of the system will be challenged in many areas, with additional risks cascading from impacts in the Natural environment system, including potential ecosystem collapse and the loss of associated ecosystem services.

Increasing impacts across primary industries will cascade and increase risks to other systems, such as the Economy, trade and finance and Health and social support systems. For example, impacts may be felt in public health and safety, including in reduced food security in some areas, and in the mental health of producers and associated communities.

Dryland agriculture will continue to be challenged by rainfall variability and extreme heat, reducing soil moisture and crop yields. Horticulture will face ongoing severe challenges from increased extreme heat, affecting produce quality and marketability, as well as challenges from insecure irrigation water.

Forestry faces risks from hotter climates, increased fire weather risk, and changes in rainfall and drought patterns. Extreme events such as intense bushfires may result in complete ecosystem transition. Fisheries and aquaculture will likely experience significant changes in range and further declines in productivity due to increased marine temperatures, ocean acidity and storm activity.

The livestock sector will face increased heat stress with more areas exposed, leading to reduced productivity and potentially poor animal health outcomes.

Biosecurity pressures will increase, with higher temperatures and changing precipitation patterns leading to increased pressure and potentially greater spread of pests and diseases.

Farming communities will face heightened water security concerns, affecting agricultural productivity and community livelihoods and potentially reducing the ability to respond to bushfires. Economic impacts, migration away from high risk communities, loss of social cohesion and reduced workforce availability may challenge the viability of some communities.

Global climate change impacts may reduce the productivity of other international regions, which has the potential to present new markets and opportunities for Australian primary production and food products and services, although regulatory and governance barriers may limit these opportunities.

Places such as southwest Western Australia have demonstrated the immense capacity of the agriculture sector to adapt, and therefore the risk to productivity, especially at producer scale, is difficult to estimate. Incremental adaptation may mean that agriculture practices (e.g. crop selection and farming approaches) may look very different by 2050.

Summary of exposures, vulnerabilities, impacts and risks

Cropping

Climate change is significantly impacting Australia's cropping sector. Rainfall variability and extreme heat are major concerns, as they influence soil moisture and crop yields. In regions such as the southwest and southern Australia, changes in rainfall patterns and higher evapotranspiration rates are leading to lower soil moisture, which in turn can reduce crop productivity. Extreme heat events further exacerbate these challenges, stressing crops and decreasing yields. While a lower risk of frost might benefit some areas, the overall pressure from climate change remains high.

The changing climate may also create new production opportunities in some areas.

Horticulture

Horticulture is facing severe challenges due to climate change, particularly from increased extreme heat. High temperatures can cause fruit sunburn, reducing the quality and marketability of produce. Additionally, higher cool season temperatures can negatively affect flowering and yields in temperate perennial nuts and fruits, such as walnuts and apples, as well as in some tropical cropssuch as mangoes and avocados. Although reduced frost risk might offer some benefits, the overall impact of rising temperatures is likely to be detrimental.

Forestry

Forestry is challenged by hotter climates, increased fire weather risk, and changes in rainfall and drought patterns. These factors collectively impact tree establishment, growth rates and mortality. Higher temperatures stress trees, increasing their water requirements and making them more susceptible to heat-induced mortality and pest infestations. Increased bushfire frequency is a significant risk for forestry, with impacts including loss of timber stocks as well as increased costs to prevent and remediate fire damage. While some cooler areas might benefit from reduced frost damage and increased growth rates, the overall outlook for forestry is challenging.

Fisheries and aquaculture

Fisheries and aquaculture are expected to experience declining productivity due to climate change. Increased marine temperatures, ocean acidity and storm activity negatively affect marine environments, with varying impacts across regions. Wild-catch fisheries and aquaculture are particularly vulnerable, although some aquaculture systems might be less affected depending on management practices.

The poleward migration of the East Australian Current may result in new opportunities or fishing areas.

Livestock

The livestock sector is facing significant challenges from climate change, particularly due to changes in temperature and rainfall. Heat stress in cattle and sheep, driven by increasing temperatures and more frequent hot spells, is likely to reduce productivity and animal welfare. Additionally, the availability of feed is likely to be impacted by climatic changes, further stressing livestock operations.

Biosecurity

Biosecurity pressures are increasing as climate change influences the complex interactions between primary industries, the environment, transport, trade and other activities. Higher temperatures and changing precipitation patterns can lead to the spread of pests and diseases and lower resistance, threatening crops, livestock and ecosystems.

Farming communities

Farming communities are at the frontline of climate change impacts. Water security is a major concern, with increased drought, variable rainfall and aridity affecting regions such as Tasmania, the Murray–Darling Basin and NSW. These changes increase competition for water, impacting agricultural productivity and community livelihoods. In addition, supply chains face significant disruptions from extreme weather events, affecting jobs and the movement of goods, leading to food shortages and spoilage. Building resilience in farming communities through adaptation and support is critical to ensure their sustainability and wellbeing in a changing climate.

Future agriculture opportunities should consider diversifying crops and livestock to include species well-suited to the specific conditions of Country. Aboriginal and Torres Strait Islander knowledge and participation would be valuable across all sectors from land and sea, particularly forestry and fishing.

Introduction

This chapter provides a synthesis of the Primary industries and food system. It draws on a wide range of technical assessments to provide observations that can enable effective adaptation.

It includes:

- System overview
- Priority risk snapshot
- Key climate hazards for the system
- Exposures, vulnerabilities, impacts and risks relevant to the system
- Adaptation observations and considerations
- Case study

The chapter highlights one priority risk snapshot and draws on the analysis from across all the priority risk technical assessments. It is important to note for this first National Assessment that all 63 nationally significant risks have not been fully assessed. The chapter provides a useful national understanding of climate risks and information that can support adaptation. Climate risks are not static – this work is a sound foundation that should be built on over time.

System overview

Australia's Primary industries and food system refers to a wide range of land, marine and estuarine activities dedicated to producing food, fibre, wood, fuel and other essential products.

This system includes agriculture, aquaculture, fisheries and forestry sectors, spanning both large-scale and smallholder operations. It covers the entire chain from production to the consumer, ensuring that the diverse needs of the population are met.

Australia's primary industries are spread across the country and its surrounding seas, involving activities related to livestock, tropical and temperate horticulture, broadacre cropping, native and plantation forestry, and various coastal-marine resources. These industries are economically significant, with an estimated gross value of production for 2024–25 of around $94 billion (Australian Bureau of Agricultural and Resource Economics and Sciences, 2024). The economic importance of these sectors underscores their critical role in the national economy.

Primary industries are reliant on access to natural capital, more so than almost any other sector. The type and concentration of primary industry production depend on several factors, including climate, soils, water, vegetation and the surrounding environment. Additionally, the availability of suitable infrastructure, such as energy sources and transport, and proximity to services, a suitable workforce, appropriate markets and local communities, are crucial for the efficient functioning of these industries.

The Primary industries and food system is not only about production but also about maintaining the balance between economic activities and environmental sustainability. This system must adapt to the changing climate, which poses significant risks to productivity, quality and profitability. The impacts of climate change, such as increased rainfall variability, extreme heat and more frequent extreme events such as fires, droughts and floods are challenging the resilience of these industries. Effective management and adaptation strategies are essential to mitigate these risks and ensure the long-term sustainability of Australia's Primary industries and food system.

Projected changes to productivity under climate change scenarios depend on multiple factors, including changes to technology and decisions made by individual businesses. Productivity is also affected by a range of external factors (e.g. markets, technology, workforce), not solely climate. Presenting productivity as a result of climate change projections without context is inappropriate and could result in unintended market distortion.

Priority risk snapshot: Primary industries

Risks to primary industries that decrease productivity, quality and profitability and increase biosecurity pressures.

Rationale

The risk to primary industries is currently rated as **Moderate**. This risk is expected to rise to **Moderate–High** by 2050 and to become **High–Very High** by 2090 (Figure 87). At present, primary industries are adapting to climate risks through technology and active management. However, in the longer term, there will be significant risks to supply chains and outdoor workers as well as to productivity. It is also expected that limits to adaptation will be rapidly reached – for example, with regions becoming too hot, even for heat-adapted cattle. There are opportunities as global breadbaskets are impacted, which may open new markets and opportunities for Australian produce. This system has a strong history of improved management and incremental adaptation. However, despite the highly adaptive nature of this system, the limits of incremental adaptation will be reached in some areas, necessitating transformational adaptation.

Key hazards

- Rainfall is critically important to primary industries, influencing productivity, soil moisture, water storage, irrigation, river discharge and biosecurity threats. It is projected that annual rainfall will decrease in southwest Western Australia and parts of southeast Australia *(medium confidence)*. For the remainder of the country, it is uncertain whether rainfall will increase or decrease in the future due to climate change; continuing to manage year-to-year rainfall variability will be important, as well as planning for potential wetter or drier future conditions.
- Extreme heat days are expected to increase in all areas of the country *(very high confidence*) and will negatively impact primary industries by reducing crop yields, stressing livestock, reducing fisheries and aquaculture productivity, increasing costs for biosecurity measures, and impacting outdoor workers. Heat impacts vary by crop and industry, with timing of heat events playing an important role.
- The intensity and frequency of extreme climate events are changing *(high confidence)*. A detailed case study highlights the potential impacts of these events on livestock production, using the Monsoon Trough in northern Queensland in early 2019 as an example. The combination of drought and flooding resulted in large losses of livestock and infrastructure, and the degradation of pastures and landscapes. Extreme events like this are challenging to prepare for because they are difficult to predict at a local scale (temporally and spatially) and there are limited viable anticipatory responses available to producers.

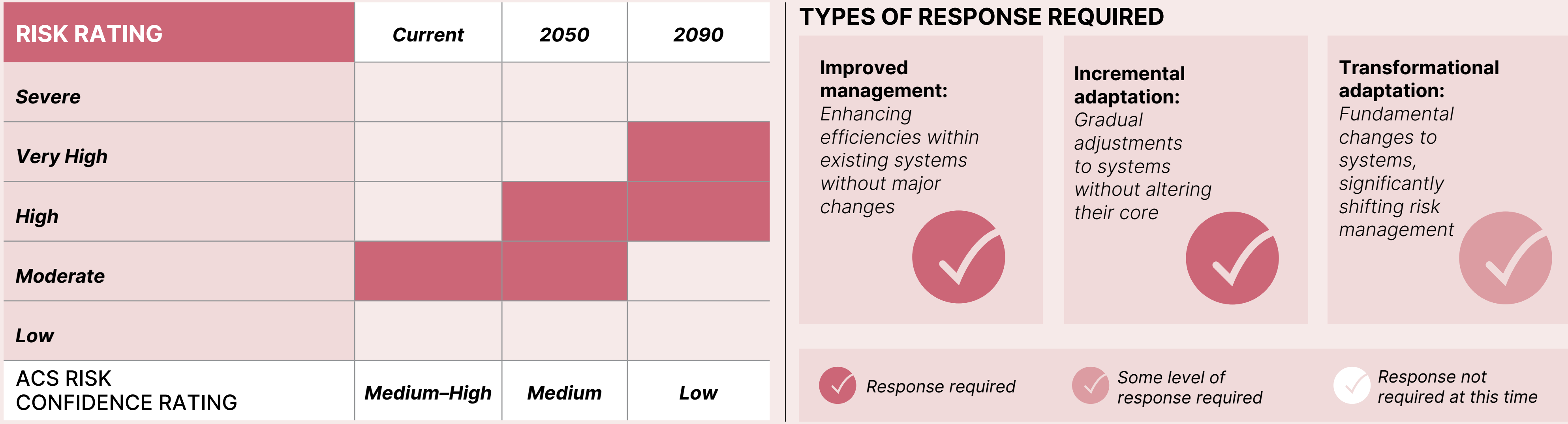


Figure 87: Rating for the Primary industries priority risk for current, 2050 and 2090, and the types of responses required to address the risk. For definitions of risk ratings, please see Figure 9.

Exposure and vulnerability

- Australia's diverse primary industries operate across the country and surrounding seas, and are both economically important and exposed to climate change. They include activities relating to livestock, tropical and temperate horticulture, broadacre cropping, native and plantation forests, and a variety of coastal-marine resources.
- The type of production of primary industries is dependent on climate conditions and local environmental characteristics (e.g. soils, coastal waters) along with other non-environmental factors (e.g. workforce, infrastructure, markets). These factors and characteristics can influence exposure and vulnerability.
- Outdoor workers, particularly across the north, will be increasingly exposed to extreme heat, which is likely to require additional management measures and may reduce productivity.
- Biosecurity pressures are rising with climate change and increasing the vulnerability of primary industries. As favourable climatic conditions for pests and diseases increase, and crops and livestock become stressed, resistance to disease may be reduced.
- In the long term, domestic food security is a vulnerability.

Impacts and risks

- **Cropping:** Growing season rainfall for cropping will likely reduce in southwest Western Australia. Dry years can reduce yields by 40% compared to average rainfall conditions; similarly, wet years can increase yield by approximately 40% (Hughes et al., 2017). All cropping regions are expected to see temperature increases with increased risk of crop heat stress.
- **Horticulture:** Increased extreme heat can damage fruit (e.g. through fruit sunburn). While reduced frost will likely be a benefit, higher cool season temperatures may reduce fruit tree flowering and yields.
- **Forestry:** Increases in the number of fire risk days are expected for most forested areas of Australia, with the largest increases expected in southwest Western Australia, areas in the Northern Territory and inland NSW. Impacts include loss of timber stocks as well as increased costs to prevent and remediate fire.
- **Fisheries and aquaculture:** Ocean warming can lead to severe ecosystem consequences and fishery impacts, including range shifts and resource depletion. Fisheries in shallow coastal and intertidal areas, such as the mud crab fishery and oyster farms, are very likely to become increasingly vulnerable to extreme warming.
- **Livestock:** Livestock animal health and the availability of feed will likely be impacted by changes in temperature and rainfall. Heat stress in cattle and sheep, driven by increasing temperatures and more frequent hot spells, is likely to reduce productivity and animal welfare. The area of heat stress conditions for tropically adapted beef cattle could more than double at a global warming level of +3.0°C. Time spent in drought is also expected to increase in the south of Australia, exposing farmers to major cropping and horticulture losses, livestock destocking, and resulting in mental health and wellbeing impacts.
- **Biosecurity:** Biosecurity threats are likely to increase with the changing climate, affecting survivability, dispersal pathways, increased reproduction rates, and susceptibility of host species and areas suitable. Climate change impacts are likely to produce conditions that become more suitable for exotic pests that are currently not present in Australia. At the same time, increases to plant and animal stress from climate change increase their susceptibility to pests and disease, increasing overall impacts. Emergency responses to climate hazards such as movement of machinery for flood and cyclone recovery/aid, or emergency shipping of livestock feed during drought events, can also present an indirect opportunity for the movement of biosecurity threats.
- **Ecosystem services:** Degradation of the natural environment threatens eco-services such as pollination and water security and quality, as well as environmental protection such as coastal protection and temperature regulation.

Adaptation

- Improvements for productivity and profitability may be derived from adoption of technology (e.g. new varieties, management options, new machinery), increased management skills, government policy (e.g. market reform) and market demand, and are currently successfully maintaining productivity (Australian Bureau of Agricultural and Resource Economics and Sciences, 2024). However, it is unclear whether current approaches to productivity improvements will be sufficient to adapt to the pace and challenges presented by future climate change.
- The native forestry and wild-catch fisheries industries are particularly dependent on the health of natural ecosystems, which are already stressed by the changing climate. Adaptation in the Natural environment system is therefore essential.
- It is necessary to enhance preparedness for new pests. Robust baseline biosecurity surveillance data, combined with monitoring data following an emergency response would assist with this.
- Key adaptation strategies for water-dependent agricultural industries include diversification, technological innovation, improved water use efficiency, and, utilisation of climate services. Technological innovations, such as plant-based water sensors and more efficient irrigation systems, can enhance resilience, but the rate of climate change is putting pressure on the effectiveness of these innovations.
- Response to climate change in primary industries will largely be carried out by individual businesses. As such, including producer perceptions of the implications of climate change is important for industry adaptation planning.

Key climate hazards for the system

This section describes the changing climate hazards for the Primary industries and food system.

Rainfall is critically important to primary industries, influencing productivity, water storage, irrigation, and biosecurity threats. Primary industries, producers and management will need to continue to manage year-to-year rainfall variability and plan for potentially wetter or drier future conditions *(medium confidence).*

- There is considerable range in the climate projections of mean rainfall and uncertainty in the likely direction of change to rainfall across most of the country. However, it is projected that mean rainfall will decrease in southwest Western Australia and parts of southeast Australia, particularly in the agriculturally critical April–October crop and pasture growing season. For the remainder of the country, it is uncertain whether mean rainfall will increase or decrease in the future due to climate change. The range of projections in mean rainfall should not be interpreted as no impact, as time spent in drought increases in most areas and heavy rainfall at short timescales (e.g. 1-hour) is likely to exceed current extremes. Continuing to manage potentially increasingly large year-to-year rainfall variability will be important, as well as planning for both wetter and drier future mean conditions.
Evidence: Future Climate and Hazards Insight Report, Primary Industries Technical Report
- Research into attribution in southwest Western Australia (Figure 88) has demonstrated a significant cool- season (May–October) rainfall decline, with a 20.5% reduction during 2001–20 compared to the 1901–60 baseline (Rauniyar et al., 2023). Climate models project that few, if any, very wet years will occur through 2100 under high-emission scenarios. Even with substantial emissions reductions, the region will likely continue to experience predominantly drier conditions.
Evidence: Water Security Technical Report
- Rainfall directly influences productivity of rain-fed crops (e.g. cereals, pastures, tree stands), and is important for on-farm water storage, availability of irrigation water, river discharge (which impacts fisheries production and biosecurity), and threatens species' suitability and invasion opportunities.
Evidence: Primary Industries Technical Report

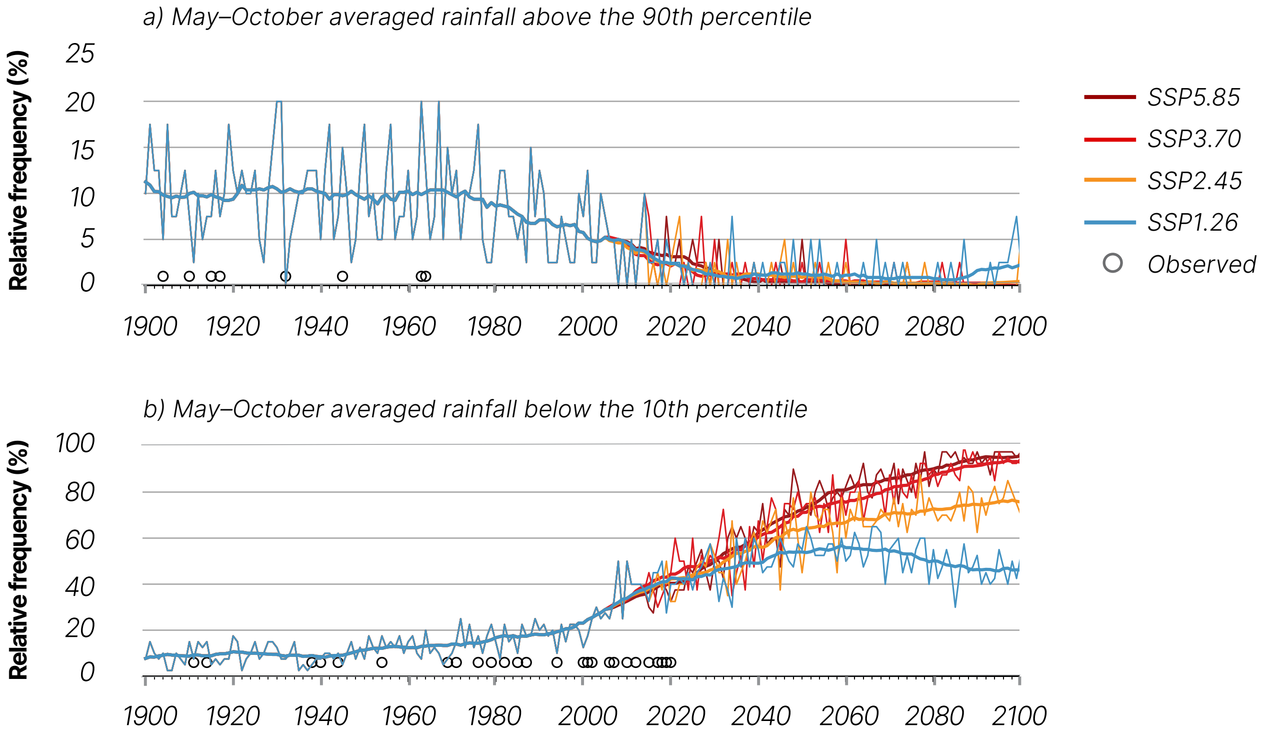


Figure 88: Southwest Western Australia rainfall analysis. The relative frequency of model runs reaching the cool season rainfall thresholds of a) above 90th percentile, representing very wet years, and b) below 10th percentile representing very dry years (Rauniyar et al., 2023). Shared socio-economic pathways are developed by the IPCC for use as climate change scenarios (IPCC, 2023).

- The dynamics of rainfall are important for primary industries. Changes to extremes (e.g. droughts, floods) can have significant and long-term impacts on productivity. Rainfall at particular times of year is more critical for some industries (e.g. April to October rainfall for winter cropping; wet season rainfall for fisheries production in northern Australia), and interactions of rainfall with other climate conditions (e.g. high temperatures) also influence productivity.
Evidence: Primary Industries Technical Report

Extreme heat will negatively impact primary industries by reducing crop yields, stressing livestock, fisheries and aquaculture, increasing costs for biosecurity measures and impacting outdoor workers. Heat impacts vary by crop and industry, with timing of heat events playing an important role *(high confidence).*

- Extreme heat days are expected to increase in all areas of the country. The greatest increases are projected for northern Australia, while the coastal areas are expected to see smaller increases.
Evidence: Australia's Future Climate and Hazards Report
- An increase in the number of extreme heat days will likely have adverse effects on crop and animal production. Timing of heat events is important – for example, during flowering for crops or around mating for sheep. The threshold value also varies by industry and crop; for example, wheat heat damage can occur at or above 32°C (Farooq et al., 2011) while heat stress for cotton can occur between approximately 37°C and 42°C (Iqbal et al., 2017). Additionally, species important to fisheries and aquaculture have individual thermal limits, and exceedance of these limits can lead to decreased catch, mortality and species range shifts.
Evidence: Primary Industries Technical Report
- Higher temperatures may lower biosecurity pressure from heat-intolerant species; however, it is likely that different biosecurity threat species adapted to the changed climate would replace those that cannot survive. Increases in minimum temperatures could result in a greater ability of insect pests to survive over winter (where this is currently not possible), leading to shifts of pest presence and intensity (Srinivasa Rao et al., 2022). Higher temperatures may also increase susceptibility to pests and diseases.
Evidence: Primary Industries Technical Report
- Compounding impacts associated with high temperatures, such as interaction with humidity, wind, rainfall and minimum temperatures, as well as the impact of multi-day events, could dampen or amplify the effect of high heat days. These combinations are not currently available in the climate-hazard projections with any confidence.
Evidence: Primary Industries Technical Report

Extreme events including fires, droughts, floods, tropical cyclones and marine heatwaves cause significant, lasting damage to primary industries *(high confidence).*

- Bushfire risk is expected to increase across parts of Australia under future warming, with increases in the number of dangerous fire weather days and an extended fire season projected for southern and eastern Australia, with a potential for more megafires (fire complexes over 10,000 hectares). Direct fire damage is a significant risk to forestry, with specific impacts including loss of forestry stands (Stephens et al., 2012). For example, the 2019–20 Black Summer fires burnt 8.3 million hectares of native forests nationally and more than 130,000 hectares of plantations, resulting in long-term reductions in forest timber log supply.
Evidence: Australia's Future Climate and Hazards Report, Primary Industries Technical Report
- Time spent in drought (or extended dry periods) is projected to increase across large areas of the country, particularly in southern Australia. Projections indicate that Australia is likely to spend more time in drought and to experience an increase in aridity in the southwest of Western Australia for all future global warming scenarios (+1.5°C, +2.0°C and +3.0°C). Sustained losses across production types from drought will likely impact primary producers and the community. Severe and long droughts result in production losses, animal death and destocking, increased salinisation of water and soils, landscape degradation and a lack of flushing in estuaries. Increased severity of droughts is likely to impact the financial and emotional wellbeing of primary producers, with resulting mental health impacts (Seneviratne et al., 2021). During the Millenium Drought (1997–2009), the agriculture industry's contribution to GDP decreased by approximately 16% and approximately 6,000 jobs were lost (van Dijk et al., 2013).
Evidence: Australia's Future Climate and Hazards Report, Primary Industries Technical Report
- There is potentially greater risk of flooding in parts of the east coast and tropics, with an increase in annual severe run-off projected. More intense short-duration heavy rainfall events are also projected for a global warming level of +3.0°C, even in regions where the average rainfall decreases or stays the same. Floods can directly damage farm infrastructure and kill livestock but can also cause soil erosion and poor water quality, and impact ecosystem services underpinning farm health and productivity. The floods in northern Queensland in January–February 2019, compounded by rainfall, cold temperatures and high wind chill, resulted in livestock losses in excess of 500,000 animals along with damage to infrastructure and degradation of the landscape. Productivity losses lasted long after the event as producers re-built herds and flocks (Phelps, 2019). The cost of crop and livestock losses, fodder drops, carcase disposal and the replacement of on-farm infrastructure is estimated to be in excess of $400 million (Deloitte Access Economics, 2019).
Evidence: Australia's Future Climate and Hazards Report, Primary Industries Technical Report
- While overall tropical cyclone numbers may decline, a greater proportion of tropical cyclones will be of high intensity, with greater rainfall and higher storm surges due to rising sea levels. Increased

high-intensity tropical cyclones will impact marine ecosystems that support economically important fisheries (IPCC, 2022b). Tropical cyclones can damage habitat-forming species (mangroves and seagrass) leading to loss of habitat and subsequent impacts on fishery species, such as penaeid prawns and barramundi, which rely on these environments for their life cycle (Stokes & Howden, 2010). Aquaculture is affected by strong storms that break infrastructure and damage stock. Storms washing into aquaculture are very likely to lead to stock loss (Stokes & Howden, 2010). Cyclones and floods can directly spread biosecurity threats by increasing natural vectors but can also provide a productivity boost for land-based agriculture by delivering moisture and nutrients to floodplains.
Evidence: Australia's Future Climate and Hazards Report, NCRA Stage 1 Rapid Literature Scan Report

- Marine heatwaves are prolonged periods of abnormally high sea temperatures that can have severe impacts on both wild and farmed marine resources, including impacts on recruitment, altered migration paths, disease outbreaks and even wide-spread mortality of some species, particularly benthic species. Marine heatwaves have caused die-off of coral reefs, mangroves, seagrass and kelp – important habitats for numerous species, including those that contribute to fisheries. They can contribute to disease outbreaks and reduce productivity in farmed species.
Evidence: Primary Industries Technical Report
- Emergency responses to extreme climate events, such as the movement of machinery for flood and cyclone recovery/aid or emergency shipping of livestock feed during drought events, can present an indirect opportunity for the movement of biosecurity threats, compounding the impacts from the extreme event with long-lasting costs (see *Case study: Biosecurity risks from emergency response to drought*).
Evidence: Primary Industries Technical Report

Exposures, vulnerabilities, impacts and risks

This section provides a summary of impacts and risks associated with the Primary industries and food system.

These impacts and risks have been identified by understanding the changing climate hazards, as well as exposures and vulnerabilities that drive them.

Cropping

By a global warming level of +3.0°C, growing season rainfall for cropping will likely reduce in southwest Western Australia and parts of southeastern Australia, potentially reducing yields. Increased extreme heat will place further pressure on productivity. Lower risk of frost may be a benefit, but some risk will likely remain in many production areas *(high confidence).*

- Rainfall received over the relevant cropping growing season is a significant driver of crop yields, particularly in dryland systems. Hughes et al. (2017) found that dry years can reduce yields by 40% compared to average rainfall conditions; similarly, wet years can increase yield by approximately 40%. There is high agreement between climate models for drying for southwest Western Australia, some of southeast Australia and parts of the Eyre Peninsula, with a wide projected range in the amount and direction of change elsewhere (Figure 89).
Evidence: Primary Industries Technical Report, Australia's Future Climate and Hazards Report
- High temperatures can reduce yields (through changes to growth rates) and cause direct damage to plants (including flowers and grains). All cropping regions are expected to see temperature increases and an increased risk of crop heat stress.
Evidence: Primary Industries Technical Report, Australia's Future Climate and Hazards Report
- Frosts can damage or kill flowers and grains, which leads to yield losses. Greatest reductions in frost are projected for the eastern cropping regions, from the plains into the western slopes of the Great Dividing Range at a global warming level of +2.0°C and then up into the tablelands of the Great Dividing Range in NSW and Victoria, and for Tasmania at a global warming level of +3.0°C.
Evidence: Primary Industries Technical Report

Changes in water security could significantly impact agriculture due to increases in extended and severe dry periods, variable rainfall and aridity. Climate change will likely increase competition for water and decrease reliability of water resources, resulting in reduced allocations in some irrigated systems *(high confidence).*

- Tasmania, the Murray–Darling Basin and east coast of NSW, which rely on seasonal streamflows, are highly vulnerable to the impacts of multi-year dry. Other regions face water security risks associated with higher evapotranspiration, increasing crop demand, and hotter conditions, which may lead to high animal water intake. Water quality risks from salinity, algae and bushfires, and increased rainfall variability, could further challenge agricultural productivity.
Evidence: Water Security Technical Report
- Irrigated agriculture, while covering less than 1% of agricultural land, contributes over 25% of total agricultural value and consumes more than 60% of Australia's water resources. The Murray–Darling Basin and southwest Western Australia are among the most productive agricultural regions in the country. Projections indicate that both regions are likely to experience further declines in water availability, in addition to a historical drying trend.
Evidence: Water Security Technical Report

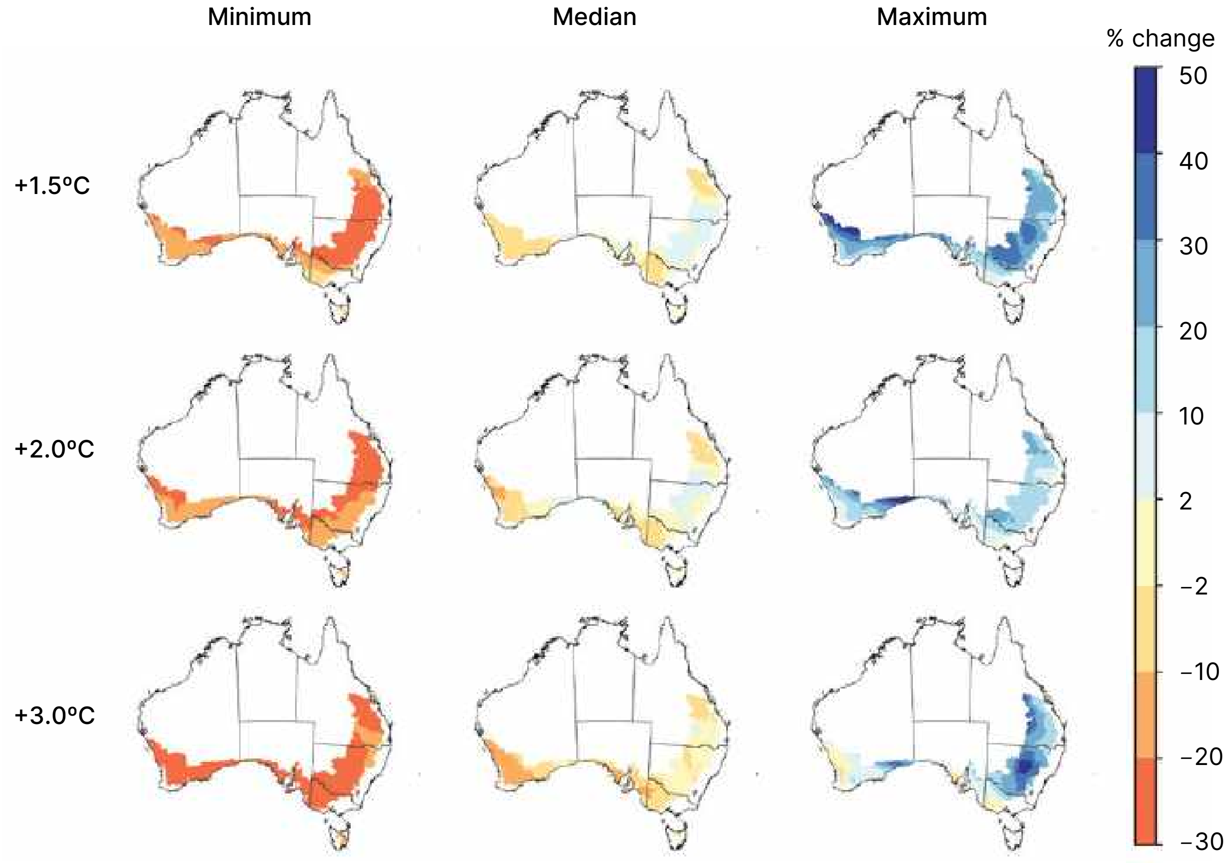


Figure 89: Projected change (%) in winter cropping growing season rainfall (April to October).

Rainfall calculated from the baseline period (2001–20). GWL: +1.5°C, GWL: +2.0°C and GWL: +3.0°C represent changes for global warming levels 1.5, 2.0 and +3.0°C, respectively. Minimum, median and maximum represent difference between climate model projections, using the statistics taken across the mean values of the models. (Source: Primary Industries Technical Report)

- The vulnerability of agricultural water security to climate hazards varies based on the water source, with regulated systems, natural flows, groundwater, farm storages, and irrigation system and management playing critical roles. Climate hazards such as drought, changing rainfall patterns and soil moisture decline are likely to impact regions and commodities differently, while factors such as crop type, irrigation system, alternative water sources and water market access shape the resilience of agricultural systems.
  Evidence: Water Security Technical Report
- Time spent in drought and associated water scarcity is likely to increase across most of the country, particularly in southern and eastern areas. When extended dry periods occur in the future there is high confidence they will be more severe than those experienced in the past. Regions such as Tasmania, the northern Murray–Darling Basin and the east coast of NSW have high portions of direct take from streamflow, making them vulnerable to extended periods of dry. Extended dry periods, including drought, present additional challenges to vulnerable remote communities and primary producers facing heightened mental health challenges.
  Evidence: Water Security Technical Report
- Future water quality risks to agriculture are almost certain to increase due to factors such as algae formation, increased salinity and acid sulphate soil exposure. More frequent bushfires are very likely to pose significant risks to water quality. Higher rainfall variability and an increase in extreme rain events are likely to increase risks of flooding, soil erosion, the addition of ‘excess’ nutrients (eutrophication) and contamination from chemical and sedimentary sources.
  Evidence: Water Security Technical Report
- Perennial crops, due to their long-term water needs, will be particularly vulnerable to future water scarcity, especially as demand grows for high-value crops requiring reliable water. In contrast, annual crops offer more flexibility and can be replaced with less water-dependent varieties, helping to mitigate impacts. The exposure level of crops can also be determined by water allocation security levels. Livestock systems, particularly dairy, are also vulnerable and sensitive to water shortages. These systems, however, can adapt by altering feed sources, adjusting stocking rates or relocating herds to areas with better water access, but this can be very expensive.
  Evidence: Water Security Technical Report

Horticulture

Horticulture is likely to face challenges due to increased extreme heat leading to fruit sunburn. While reduced frost will likely be a benefit, higher cool season temperatures can reduce flowering and yields in temperate perennial nuts and fruit (e.g. walnut, apple) and some tropical crops (e.g. mango, avocado) *(high confidence).*

- Heatwaves increase the risk and severity of the heat stress impacts and reduce the capacity of a horticultural producer to manage the impacts (Webb et al., 2010). Extreme heat events can reduce productivity and increase the risk of sunburn, collectively lowering quality and yield (Sukhvibul et al., 1999; Webb et al., 2010).
  Evidence: Primary Industries Technical Report
- A reduction in frost could be beneficial. Frosts, as well as exposure to low temperatures, can cause damage to fruit and plant tissue and lower yield and quality (Ayala Silva & Ledesma, 2014; Joshi et al., 2020). Reduced frost could increase the ability for direct seeding and reduce the need for frost protection measures, thus reducing operational costs (Stokes & Howden, 2010). The number of days with minimum temperatures less than 0°C is projected to reduce at global warming levels +2.0°C and +3.0°C, particularly in the southeast and southwest of the country.
  Evidence: Primary Industries Technical Report
- Many temperate fruit and nut crops, such as apples and cherries, rely on cold temperature exposure throughout winter for normal flowering. Insufficient chill accumulation can lead to poor flowering and reduced yield in many crops (Measham et al., 2017; Oukabli et al., 2003). For a global warming level of +2.0°C and of +3.0°C, reductions in winter chilling are likely across most temperate fruit-growing regions, with the greatest reductions in Queensland and coastal NSW.
  Evidence: Primary Industries Technical Report
- Many tropical crops, such as avocado and mango, need periods of cooler weather, often during the winter months, to support key flower bud functions and fruit set (Gazit & Degani, 2002). Increases to mean minimum winter (1 June to 31 August) temperatures are expected across the country with increasing amounts up to a global warming level of +3.0°C, with greater warming in northern Australia. This may affect fruit tree flowering and yields.
  Evidence: Primary Industries Technical Report

Forestry

Forestry is very likely to face challenges from hotter climates, increased fire weather risk and changes to rainfall and drought, collectively impacting tree establishment and growth rates. Increased temperatures stress trees, requiring more water and making them more susceptible to heat-induced mortality and pest infestations. Some cooler areas may benefit from increasing temperatures due to reduced frost damage and increasing growth rates *(high confidence).*

- Increased bushfire frequency in the future is a significant risk for forestry (IPCC, 2021). At a global warming level of +3.0°C, an increase in the number of days when the Forest Fire Danger Index exceeds 50 (severe rating) is projected across most forested areas in Australia. Higher risk of fire is expected across southwest Western Australia, Pilliga (NSW), the Northern Territory, the Mount Lofty Ranges, Kangaroo Island, the Green Triangle, Central Tablelands, Murray Valley and Central Victoria forestry areas. Likely impacts include loss of timber stocks, including loss of volume and quality of available timber for harvest, as well as increased costs to prevent and remediate fire damage.
  Evidence: Primary Industries Technical Report
- Climate change is expected to increase mean annual temperatures in most production forestry areas across Australia, with a greater number of multi-day heat events also projected to occur. Increased temperatures result in greater water demand and may slow tree growth in already-warm regions (IPCC, 2021). High heat and/or low water conditions cause stress to trees, increasing susceptibility to pests and diseases. These stressed conditions are likely to cause tree mortality, particularly during early growth/establishment, leading to an increasing risk of recruitment failure (a lack of understorey saplings becoming mature canopy trees).
  Evidence: Primary Industries Technical Report
- Regionally, changes in temperature may cause forestry production to decrease in more marginal regions (IPCC, 2021). However, changes in temperature in cooler areas may increase yields. Warmer conditions are likely to improve conditions for forestry in Tasmania and the Victorian highlands.
  Evidence: Primary Industries Technical Report
- Increased stress from elevated temperatures and lack of water is likely to impact forestry production through increased vulnerability to fire and pests and to reduce the operational window for tree establishment (IPCC, 2021). At a global warming level of +3.0°C, projections indicate significant drying for southwest Western Australia and parts of southeast Australia forestry areas.
  Evidence: Primary Industries Technical Report, Australia's Future Climate and Hazards Report

Fisheries and aquaculture

Fisheries and aquaculture are projected to face challenges due to climate-driven ocean warming, ocean acidification, longer and more intense marine heatwaves, and altered productivity. The resulting impacts of these climate hazards on fisheries and aquaculture are complex and spatially variable, influenced by the degree of exposure. Negative impacts are generally expected for fisheries and aquaculture production, although some species may be positively (or neutrally) impacted, depending on the sector and region *(medium confidence).*

- Increased ocean warming and extreme heat is occurring, and will continue to occur, in Australia's coastal and marine regions *(high confidence)*. Ocean warming can lead to severe ecosystem consequences and fishery impacts through changes to the distribution (range shift) and abundance of marine resources, changes to habitat that fish species rely on, and increased thermal stress leading to increased mortality of marine species, all of which impact productivity. The degree of warming and impacts is spatially variable, but at a global warming level of +3.0°C the Tasman Sea will approach a permanent marine heatwave state.
Evidence: Primary Industries Technical Report, Australia's Future Climate and Hazards Report
- Biomass available to fisheries is projected to decrease across most of Australia's Exclusive Economic Zone (Oceans), but the pattern varies spatially. Increases are expected in north western Australia and around Tasmania, while decreases are expected along eastern Australia and, to a lesser extent, southern Australia. This pattern is consistent across global warming levels and intensifies with increasing warming (Figure 90); however, there remains considerable uncertainty in the fish models.
Evidence: Primary Industries Technical Report
- Wild-catch fisheries and aquaculture are dependent on healthy marine and estuarine environments. Increasing ocean acidity and temperature is likely to affect these environments (Hobday & Cvitanovic, 2017; IPCC, 2021, 2022; Stokes & Howden, 2010). Fisheries in shallow coastal and intertidal areas (e.g. the mud crab fishery and oyster farms) are very likely to become increasingly vulnerable to extreme warming, with exposure of some areas to extreme heat in the summer likely to negatively impact habitat-forming species, such as mangroves, which many fish species rely on (Duke et al., 2021; Robins et al., 2020).
Evidence: NCRA Stage 1 Rapid Literature Scan Report, Primary Industries Technical Report
- Increased temperatures pose risks to aquaculture productivity, particularly species farmed in shallow enclosures such as pens, ponds and tanks (Partridge et al., 2008; Spillman et al., 2015; Stokes & Howden, 2010). Increasing temperatures already evident in Tasmania will likely result in Atlantic salmon being cultivated close to their upper thermal limits of optimal growth and may therefore result in decreased productivity (Hobday et al., 2008; Osburn et al., 2021).
Evidence: Primary Industries Technical Report
- Coral reefs support high biodiversity and serve as spawning and nursery grounds for numerous fish species important to commercial fishing (Great Barrier Reef Marine Park Authority, 2024). Overall, the condition of coral reefs nationally is assessed to be poor. The projected increasing intensity and duration of marine heatwaves is likely to leave insufficient time for the corals to recover between successive bleaching events, with potential impacts on commercial fishing dependent on reefs.
Evidence: Natural Ecosystems Technical Report

Livestock

Livestock animal health and the availability of feed will be impacted by changes in temperature and rainfall. Heat stress in cattle and sheep, driven by increasing temperatures and more frequent hot spells, is likely to reduce productivity and animal welfare *(high confidence).*

- Heat stress in both dairy and beef cattle can reduce livestock productivity and welfare through changes in feed intake, behaviour, fertility and metabolism; in extreme conditions, mortalities can also occur. Increasing temperatures will result in cattle requiring increased water intake (+13% per 2.7°C of warming), compounding water availability challenges, with increased temperature also increasing evaporation (Stokes & Howden, 2010).
Evidence: NCRA Stage 1 Rapid Literature Scan Report
- The number of cattle heat stress days is projected to increase in most regions of Australia. By a global warming level of +3.0°C, the area expected to experience at least 150 days per year of heat stress in dairy cows and European beef cattle is expected to increase by about 30%. The area of heat stress conditions for tropically adapted beef cattle could more than double at a global warming level of +3.0°C (Table 16).
Evidence: Primary Industries Technical Report
- The impacts of heat stress events in cattle are exacerbated when hot temperatures continue for several days in a row and nighttime temperatures do not decrease sufficiently for animals to shed heat accumulated during the day. Most regions of Australia are projected to experience more hot spells (Figure 91 and 92, Table 16).
Evidence: Primary Industries Technical Report

  In northern Australia, there is some evidence of changed hot spell dynamics with possibly fewer but longer hot spells (i.e. multiple shorter hot spells combining into single long ones), but the reduced number of hot spells creating the 'warming hole' in northern Australia could also be driven by changes in cloud and rainfall related to climate variability and aerosols (Grose et al., 2017).
Evidence: Primary Industries Technical Report
- Changes in temperature at critical times of the year are likely to impact sheep productivity. Heat stress in sheep during the week of mating can decrease lambing rates by 3.5% for each additional day greater or equal to 32.2°C (Kleemann & Walker, 2005; Lindsay et al., 1975). Heat exposure during joining months is projected to rise with increases in global warming levels (Table 16). Conversely, an increase in minimum temperatures will marginally decrease cold exposure at lambing, with the largest declines in cold environments in Tasmania, and in the highlands in Victoria and NSW.
Evidence: Primary Industries Technical Report

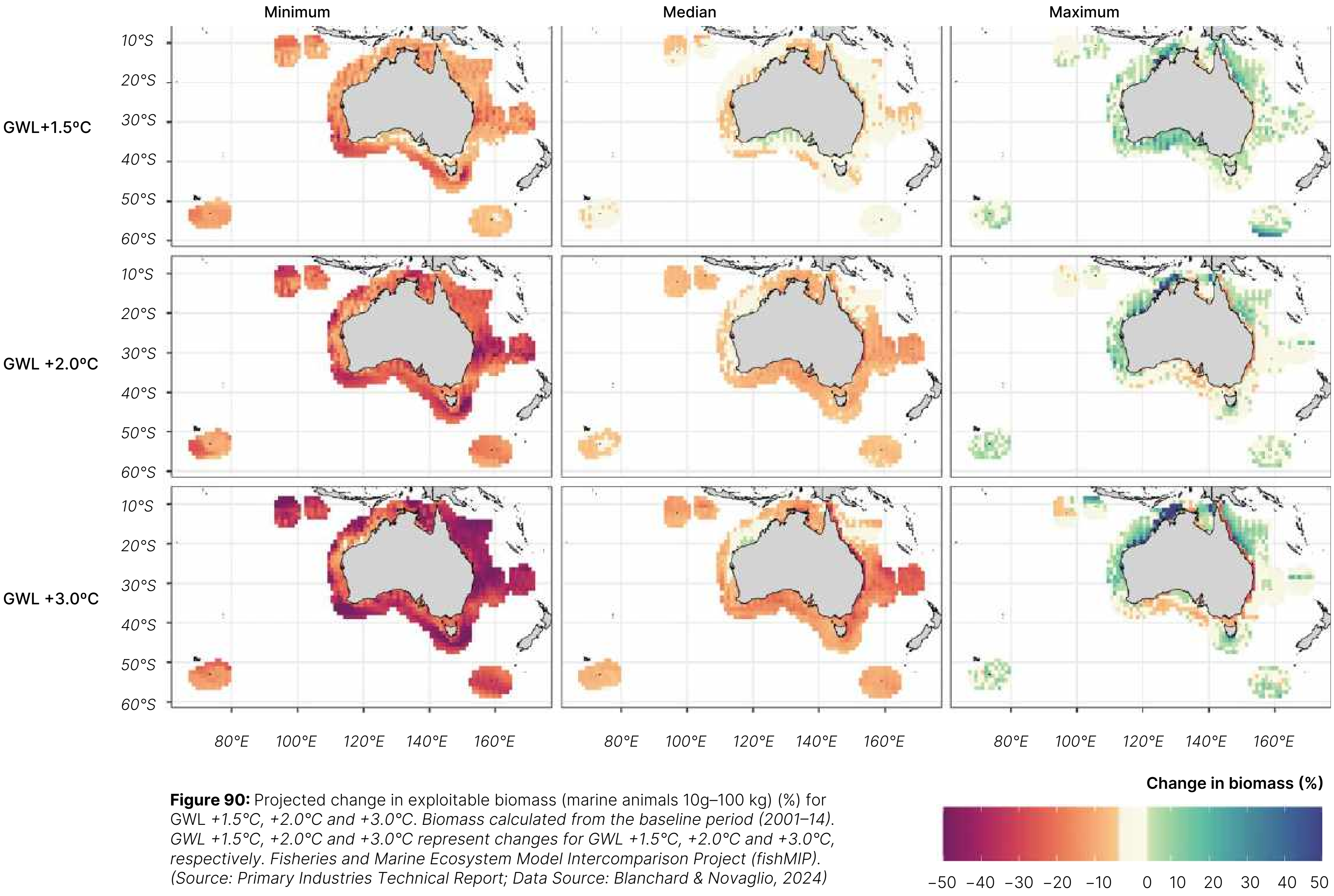


Figure 90: Projected change in exploitable biomass (marine animals 10g–100 kg) (%) for GWL *+1.5°C, +2.0°C and +3.0°C. Biomass calculated from the baseline period (2001–14). GWL +1.5°C, +2.0°C and +3.0°C represent changes for GWL +1.5°C, +2.0°C and +3.0°C, respectively. Fisheries and Marine Ecosystem Model Intercomparison Project (fishMIP). (Source: Primary Industries Technical Report; Data Source: Blanchard & Novaglio, 2024)*

Table 16: Projection results for livestock-relevant metrics. *(Source: Primary Industries Technical Report)*

Metric	Future changes relevant to current climate		
	GWL +1.5°C	GWL +2.0°C	GWL +3.0°C
Cattle heat stress – dairy cattle and European beef cattle breeds	There will be significant influence of year-to-year and decade-to-decade variability. Regions may experience fewer or greater number of days classified as heat stress conditions for European beef breed and dairy cattle, with 3.0 to 4.0 million km^2 of Australia experiencing this heat stress load for at least 150 days per year (baseline is 3.4 million km^2).	There will be an increase or similar in number of heat stress days expected for most of the country. There is some uncertainty in heat stress conditions (fewer or greater) along WA south and part of Qld coastal areas. The number of days classified as heat stress conditions for European beef breed and dairy cattle for at least 150 days per year is expected across 3.4 to 4.4 million km^2 of Australia.	All regions will experience a greater number of days classified as heat stress conditions for European beef breed and dairy cattle, with 4.1 to 5.4 million km^2 of Australia experiencing this heat stress load for at least 150 days per year.
Cattle heat stress – tropically adapted beef cattle	There will be significant influence of year-to-year and decade-to-decade variability. Regions may experience fewer or greater number of days classified as heat stress conditions for tropically adapted beef cattle, with 0.7 to 2.0 million km^2 of Australia experiencing this heat stress load for at least 50 days per year (baseline is 1.5 million km^2).	There will be an increase or similar in number of heat stress days expected for most of the country. There is some uncertainty in heat stress conditions (fewer or greater) along WA south and part of Qld coastal areas. Heat stress conditions for tropically adapted beef cattle of at least 50 days per year is expected across 1.1 to 2.5 million km^2 of Australia.	The majority of regions will experience a greater number of days classified as heat stress conditions for tropically adapted beef cattle, with 1.9 to 3.7 million km^2 of Australia experiencing this heat stress load for at least 50 days per year. There is some uncertainty in direction of change WA north and southern coastal areas.
Cattle hot spells (≥ 3 consecutive days of Tmin ≥22°C AND Tmax ≥ 34°C)	There will be significant influence of year-to-year and decade-to-decade variability. Some regions may experience fewer or greater hot spells, with 1.6 to 3.5 million km^2 of Australia experiencing 10 or more hot spells per year (baseline is 2.2 million km^2).	Most regions are projected to experience more hot spells, with 1.8 to 4.0 million km^2 of Australia experiencing 10 or more hot spells per year.	The majority of regions will experience more hot spells, with 2.1 to 4.8 million km^2 experiencing 10 or more hot spells per year. Some changes to hot spell dynamics in the north may be occurring (e.g. longer but fewer hot spells) but requires further work to confirm.
Sheep heat exposure during mating	There will be significant influence of year-to-year and decade-to-decade variability. Most regions will experience greater heat exposure at joining, with 5.0 to 6.7 million km^2 experiencing at least 80 days of heat exposure during the mating period (baseline is 5.6 million km^2).	Most regions will experience greater heat exposure at joining, with 5.2 to 7.0 million km^2 experiencing at least 80 days of heat exposure during the mating period.	Most regions will experience greater heat exposure at joining, with 5.6 to 7.4 million km^2 experiencing at least 80 days of heat exposure during mating period.
Cold exposure at lambing	There will be significant influence of year-to-year and decade-to-decade variability. Limited change is projected, with 0.12 to 0.20 million km^2 experiencing 10 or more cold chill days per year (baseline is 0.17 million km^2).	There will be marginal decrease in cold exposure at lambing, with 0.11 to 0.17 million km^2 experiencing 10 or more cold chill days per year.	There will be a further decrease in projected cold exposure at lambing, with 0.09 to 0.16 million km^2 experiencing 10 or more cold chill days per year. Largest declines are in currently cold environments (Tasmania highlands through Victoria and NSW).

- Changes in temperature and water availability can impact the volume and quality of pasture for livestock. An increase in days above 35°C is expected across most of the country and may alter pasture mix options in some areas. Pasture availability in northern Australian regions relies on wet season growth, which is heavily dependent on rainfall. Climate models show potential for both increase or decrease in wet season rainfall in northern Australia (October to April), but there is some indication that inland regions of northern Australia are likely to experience greater inter-annual variation in wet season rainfall (all warming levels and both wet and dry season rainfall).
Evidence: Primary Industries Technical Report, Australia's Future Climate and Hazards Report

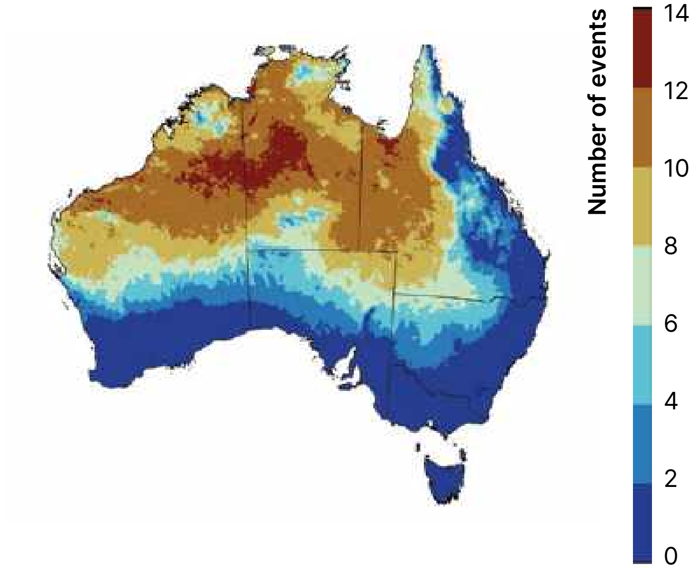


Figure 91: Current number of cattle hot spells.

Cattle hot spells occur when hot temperatures continue for several days in a row and nighttime temperatures do not decrease sufficiently for animals to shed heat accumulated during the day (Hot spell: ≥ 3 consecutive days of Tmin ≥22°C AND Tmax ≥ 34°C). (Source: Primary Industries Technical Report)

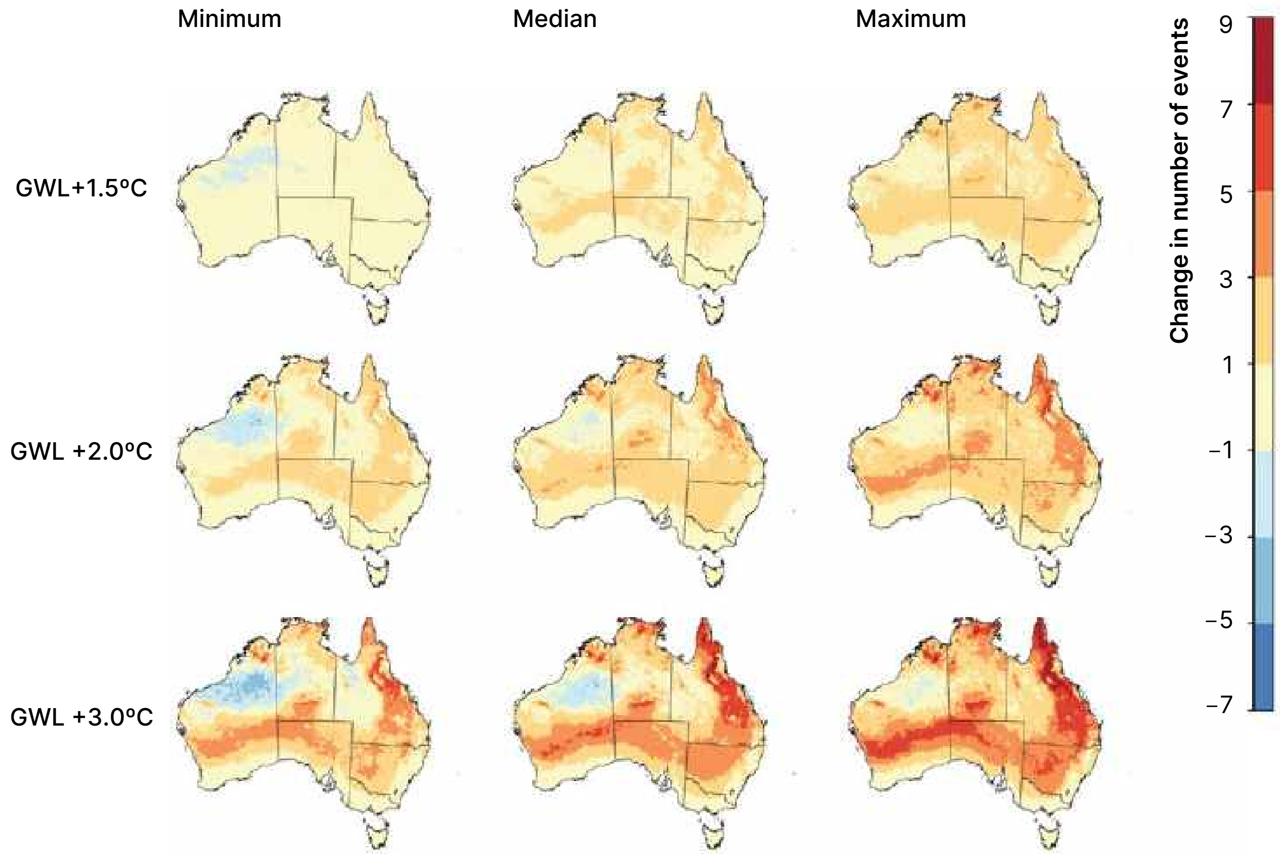


Figure 92: Projected change (%) in annual number of cattle hot spells.

Hot spells calculated from the baseline period (2001–20). Representing changes for global warming levels +1.5°C, +2.0°C and +3.0°C, respectively. Minimum, median and maximum represent difference between Global Climate Model (GCM) projections, using the statistics taken across the mean values of the GCMs. Cattle hot spells occur when hot temperatures continue for several days in a row and nighttime temperatures do not decrease sufficiently for animals to shed heat accumulated during the day. (Hot spell: ≥ 3 consecutive days of Tmin ≥ 22°C AND Tmax ≥ 34°C). (Source: Primary Industries Technical Report)

Biosecurity

Biosecurity threats are likely to increase with climate change, with changes in rainfall, temperature, ocean currents, and extreme events affecting survivability, dispersal pathways, increased reproduction rates, susceptibility of host species and areas suitable *(medium confidence).*

- For current endemic pest species, climate change can alter regions that are suitable for pest growth and survival (in particular, range expansion, contraction or shifts). It is likely that new threats will emerge and may become established. Climate change impacts may increase the stress on plant and animal host species (e.g. through hotter conditions), increasing their susceptibility to pests and diseases, in turn leading to decreases in yield (Carnegie et al., 2022).
Evidence: Primary Industries Technical Report, NCRA Stage 1 Rapid Literature Scan Report
- Higher temperatures reduce the effectiveness of herbicides and pesticides, meaning current management approaches may not remain suitable. Increased temperatures can also shorten the life cycles of certain pests, which can increase the number of generations produced in a crop growth season and reduce the influence of cold stress on pest growth rates (Sutherst et al., 2011). This is likely to lead to an overall increase in biosecurity pressure.
Evidence: Primary Industries Technical Report, NCRA Stage 1 Rapid Literature Scan Report
- Climate change impacts are likely to produce conditions that become more suitable for exotic pests that are currently not present in Australia due to unfavourable growing conditions. An example is the Southern Armyworm *(Spodoptera eridania)* (on Australia's national priority plant pest list). Climate change will increasingly provide suitable conditions for this pest to invade and become established in Australia, with areas of moderate suitability developing along the east coast of Australia by 2050 (Zhang et al., 2023). A study of 32 weed species indicated that there will likely be increased suitability in southeastern Australia for many invasive weeds by the 2050s (Shabani et al., 2020).
Evidence: NCRA Stage 1 Rapid Literature Scan Report

Farming workforce and communities

Primary industries are susceptible to climate impacts due to exposure of their outdoor workers. This is likely to reduce productivity and have impacts on health and wellbeing, including mental health, and may challenge the viability of some communities *(medium confidence).*

- Risks from climate change to primary industry workers and communities that rely on primary industries include increasing exposure of people and places to extreme heat, supply chain and transport uncertainty, and water insecurity. These impacts are likely to result in localised food insecurity and migration away from high risk communities with impacts on social cohesion and community structures. Long-term climate change impacts on productivity and supply chain disruptions, and consequences including difficulty in attracting and retaining workers and increased costs from insurance and adaptation investments, are likely to reduce the attractiveness and sustainability of farm businesses and could lead to higher food insecurity at higher warming levels.
Evidence: Health and Wellbeing Technical Report, Communities Technical Report, Governance Technical Report, Primary Industries Technical Report
- Outdoor workers, including primary producers, may be particularly exposed to extreme heat risks with increases in temperature that make working outdoors unsafe, reducing productivity and potentially resulting in heat-health impacts. Projections indicate that in the long term (by 2070), manual labour in Perth will be dangerous to perform 15–26 days per year for agricultural or labour-based work, reducing productivity and employment opportunities (Zhang et al., 2018). Many workers employed in the sector, such as Aboriginal and Torres Strait Islander peoples and migrant seasonal workers, are already in vulnerable circumstances and may become more vulnerable if there are not adequate protections in place.
Evidence: Real Economy Technical Report
- Increasing heat is perceived to lead to significant risks to the future agriculture and construction industries. Heatwaves are estimated to reduce annual productivity by $616 per worker, $5.8 billion, or 0.33–0.47% of GDP, and to add pressure to the grid (Australian Energy Market Operator, 2020; Zhang et al., 2011), potentially causing increased power outages. Unpleasant working conditions may push workers into other industries or to leave communities and regions, creating labour shortages and the shutdown of businesses.

Supply chains and critical infrastructure will face significant disruptions from increased frequency and intensity of extreme weather, causing uncertainty and implications for on-farm inputs and market access. These disruptions affect jobs and the movement of goods, and can lead to food shortages and spoilage, with risks from climate change making future planning difficult *(high confidence).*

- Damage to critical supply chain infrastructure increases the cost of inputs, causing spoilage, food shortages and reduced income for primary producers (Hughes et al., 2022; Lim-Camacho et al., 2017; Murphy et al., 2023; Stokes & Howden, 2010). Flooding in southeast Queensland in early 2022 caused damage to roads that meant milk tankers could not access properties, and large volumes of milk were discarded (Jurss-Lewis & Burt, 2022). Extreme weather events, such as drought, fires, floods and heatwaves, are projected to increase with climate change, resulting in almost certain increased disruption to supply chains.
Evidence: NCRA Stage 1 Rapid Literature Scan Report, Primary Industries Technical Report

- Increased population changes at 2050 and 2090 significantly impact freight and supply chains, from the point of production through to communities and market, as the rate of growth differs by state and territory. This is compounded by climate change impacts on primary production. Modelling of livestock and cropping commodities, combined with projected population change, resulted in significant changes in supply chain paths for both 2050 and 2090 compared to 2024, with large changes in both the number of supply chains and the tonnages between origins and destinations.
  Evidence: Supply Chains Technical Report
- Agricultural impacts are made worse by elevated risks to critical infrastructure. Maranoa is an LGA in southwest Queensland with an estimated population of 13,255. Due to climate change, Maranoa is expected to experience heightened extreme rainfall periods and an increased number of hot days. These extremes are expected to lead to elevated risks to all 3 categories of critical infrastructure: transport, telecommunications and energy. Such events are expected to increase in the future, resulting in significant impact on a range of infrastructure facilities that will have consequences for both key economic drivers for this LGA – namely, mining and agriculture.
  Evidence: Critical Infrastructure Technical Report

Aboriginal and Torres Strait Islander peoples have historically been excluded from the agriculture industry. Climate impacts will further challenge practices and opportunities for Aboriginal and Torres Strait Islander peoples in this system *(medium confidence).*

- Aboriginal and Torres Strait Islander consultations highlighted that climate change impacts the current practices and future opportunities for Aboriginal and Torres Strait Islander peoples in bush foods, aquaculture and mariculture, such as kelp farming.
  Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering
- Buffel grass, introduced in the 1970s for its drought tolerance and resilience to heavy grazing, has caused significant ecosystem degradation, including habitat loss, biodiversity decline and altered fire regimes. Buffel grass has also caused a reduction in the availability of natural resources (bush tucker) and water for Indigenous communities.
  Evidence: Natural Ecosystems Technical Report, Communities Technical Report
- Total clearing of large areas of mallee has occurred in southern Western Australia and South Australia, and in northern Victoria. A catastrophic extent of clearing open mallee has occurred in central Tasmania. Mallee woodlands and shrublands hold significant cultural and practical importance for Indigenous communities. Aboriginal and Torres Strait Islander peoples have lived in mallee for as long as they have occupied these regions, with the term 'mallee' originating from the Koori people. The mallee provides traditional food resources, including possums, macropods, mallee fowl, emu eggs, reptiles and various plant foods.
  Evidence: Natural Ecosystems Technical Report
- Aboriginal and Torres Strait Islander consultations also highlighted that the agriculture industry has historically been exclusionary towards Aboriginal and Torres Strait Islander people, and the onerous requirements to establish Native Title can pose additional barriers to their participation. Aboriginal and Torres Strait Islander peoples participation must be encouraged in all sectors from land and sea, particularly forestry and fishing.
  Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering

Impacts to and from the Primary industries and food system can cascade through multiple pathways to compound risks in other systems that shape Australian society. The system is also heavily influenced by decisions made in other systems, particularly the Natural environment and Economy, trade and finance systems *(low confidence).*

- Stakeholder consultation as part of the National Assessment highlighted that impacts in the Natural environment and Economy, trade and finance systems are likely to compound risks in the Primary industries and food system. Impacts to the Primary industries and food system are likely to cascade and compound risks in the Health and social support and Natural environment systems.
- The Primary industries and food system experiences impacts from decisions made in other systems – in particular, the Natural environment and Economy, trade and finance systems (Figure 93).
  Evidence: Governance Technical Report
- The primary industries are a key source of livelihood in regional and remote areas. In rural communities, impacts from hazards on key sectors such as businesses reliant on natural resources

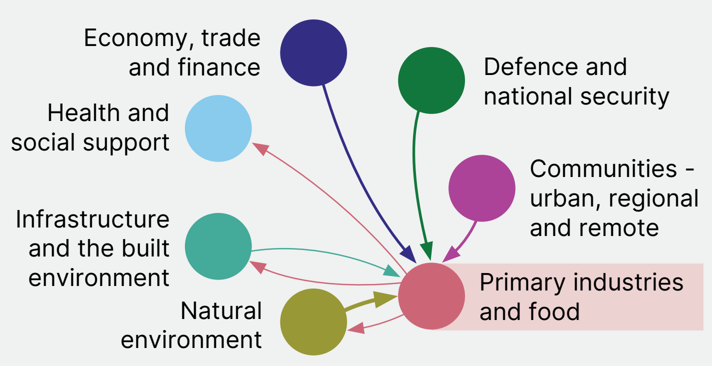


Figure 93: The flow of adverse impacts from decisions between the Primary industries and food system and other National Assessment systems. (Source: Governance Technical Report)

Each arrow originates at the system where the decision is made and points towards the system that is adversely impacted. The weight of each arrow represents the number of interactions identified. This data reflects stakeholder engagement workshops. The Aboriginal and Torres Strait Islander Peoples system followed a different approach and is not represented in this data.

are reducing employment opportunities for residents and impacting mental health (Hanigan & Chaston, 2022; Nicholls et al., 2006; Steffen et al., 2019). For example, the increased severity of droughts can impact the financial and emotional wellbeing of farmers, with resulting mental health impacts (Seneviratne et al., 2021).
Evidence: Real Economy Technical Report, Primary Industries Technical Report

- Long-term landscape drying will hit regional economies reliant on agriculture. Communities lacking alternative water supplies or reliant on annual surface inflows are most vulnerable to future climate water security risks.
Evidence: Water Security Technical Report

Adaptation observations and considerations

This section provides information that can support adaptation planning and approaches.

Adaptation is a feature of the sector, but it is unclear whether current approaches will be sufficient to keep pace with the risks of future climate change, including declining ecosystem health and increasing biosecurity threats. Most primary industries are managed systems. The management decisions can influence climate exposure, differ between businesses and can differ within a business season-to-season. As climate impacts become more pronounced, adaptive capacity will vary across sectors and businesses, necessitating coordinated management at multiple jurisdictional levels to maximise flexibility and minimise the cumulative risks *(high confidence).*

Global climate change impacts may reduce the productivity of other regions, which may present new markets and opportunities for Australian products, although increasing protectionism globally, and other technical restrictions, could restrict our ability to access markets.

- There are many management strategies and options available to most primary producers. For example, in broadacre cropping farmers have choices regarding crop rotation, soil and fallow management, incorporation of livestock, nutrient use, and sowing and harvesting timing. How producers choose to manage their businesses varies across the country, with decisions being influenced by a variety of drivers (e.g. markets, labour availability, financial position, education) and not necessarily being static, with some decisions changing season-to-season. These management choices intersect with climate change and impact productivity and future potential vulnerability.
Evidence: Primary Industries Technical Report
- The Primary industries and food system includes elements that are strongly shaped by governance, such as decisions on workforce and service delivery, domestic disaster response and recovery, and biosecurity. The Primary industries and food system experiences the greatest number of governance challenges in relation to dealing with the complexity of knowledge about climate change risks facing the system.
Evidence: Governance Technical Report
- Historically, Australia's primary industries have continually changed to improve productivity or profitability. Improvements may be derived from adoption of technology (e.g. new varieties, management options, new machinery), increased management skills, government policy (e.g. market reform) and market demand. The motivation to improve productivity may be varied and not related to climate change. This ongoing improvement across the sector demonstrates a willingness and capability to respond to change. To date, sector-wide actions to increase productivity have offset negative climate impacts with, for example, a plateauing of wheat yields despite declining climate conditions (Hochman et al., 2017). However, it is unclear whether current approaches to productivity improvements will be sufficient to keep pace with future challenges and opportunities presented by climate change (Hochman et al., 2017).
Evidence: Primary Industries Technical Report
- Although global markets may present new opportunities for Australian agriculture, these opportunities need to be tempered with the fact that increasing protectionism globally and the proliferation of new technical market access requirements, such as those based on sustainability or climate grounds, could restrict Australian producers ability to access markets (Department of Agriculture, Fisheries and Forestry, 2024b).
- Native forestry and wild-catch fisheries industries are particularly dependent on the health of natural ecosystems, which are already stressed by changing climate and are less resilient to increases in temperature. Adaptation in the Natural environment system is therefore essential to maintain opportunities.
Evidence: Primary Industries Technical Report, Natural Ecosystems Technical Report
- Climate change can expand or shift regions that are suitable for pest growth and survival. It is necessary to enhance preparedness for new pests. Robust baseline biosecurity surveillance data, combined with monitoring data following an emergency response, would assist in adaptive management of future biosecurity threats.
Evidence: Primary Industries Technical Report

The adaptability of agriculture to future risks from climate change varies by region, commodity and water source. Annual crops offer more flexibility, while perennial crops and livestock are highly vulnerable to prolonged droughts *(high confidence).*

- Key adaptation strategies include diversification, technological innovation, improved water-use efficiency and utilisation climate services. Technological innovations, such as plant-based water sensors and more efficient irrigation systems, can enhance resilience, but the rate of climate change is putting more pressure on these innovations.
Evidence: Water Security Technical Report

- Crops such as wheat can be managed seasonally, allowing for more flexible responses to changing conditions. Perennial crops such as stone fruit, nuts, citrus and winegrapes have limited adaptability due to their reliance on stable water supplies over their decadal life spans. Agricultural areas reliant on such crops may need to further diversify their economies to reduce vulnerability to future water security risks.
Evidence: Water Security Technical Report

Aboriginal and Torres Strait Islander engagement can support innovation and adaptation in the Primary industries and food system, helping it to adapt to increasing risks from climate change while valuing and protecting cultural knowledge. This can also improve economic participation for Aboriginal and Torres Strait Islander peoples.

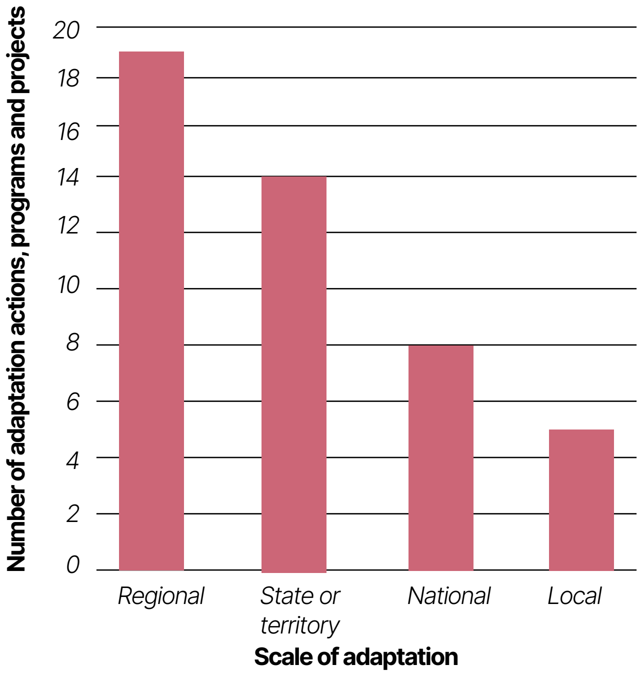


Figure 94: Distribution of adaptation actions, programs and projects by scale in the Primary industries and food system. *(Source: Insights from the Adaptation Stocktake)*

- Aboriginal and Torres Strait Islander consultations highlighted that sustaining Country should be the primary focus for primary industries adapting to climate change and that Aboriginal and Torres Strait Islander participation should be encouraged in all sectors from land and sea, particularly forestry and fishing, as they have significant knowledge of successful land management.
Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering
- Aboriginal and Torres Strait Islander consultations highlighted that future agricultural opportunities should consider diversifying crops and livestock to include species well-suited to the specific conditions of Country.
Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering
- Aboriginal and Torres Strait Islander consultations highlighted that there are opportunities to explore the potential of bush foods and medicinal plants to improve economic participation for Aboriginal and Torres Strait Islander peoples in primary industries. This would require acknowledging, valuing and protecting cultural knowledge and implementing appropriate decision-making models to support these initiatives.
Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering
- Aboriginal and Torres Strait Islander consultations highlighted that there are opportunities to increase economic participation for Aboriginal and Torres Strait Islander peoples through aquaculture and mariculture, such as kelp farming.
Evidence: Aboriginal and Torres Strait Islander Peoples Second Gathering

The Insights from the Adaptation Stocktake found that fewer plans and policies are identified as adaptation to climate change for the Primary industries and food system compared to some other systems; however, there are long-standing and well-funded policies (e.g. for drought) that do contribute to adaptation to climate change. There are opportunities to further integrate climate change adaptation within plans and policies, and to improve governance within this system to address gaps in adaptation action, particularly at the regional level and local scale, reflecting the scale at which many risks occur *(high confidence).*

- Adaptation in the Primary industries and food system makes up 10% of total policies, plans and laws, and 13% of the coded adaptation actions in the adaptation stocktake. This is not as extensive as in other systems; however, many actions that make agriculture more resilient or adaptive to a changing climate are not labelled as climate change adaptation. Management actions that adapt to a changing climate are proving effective so far, as the gross value of agricultural production continues to be maintained and has risen by 7% to $88.4 billion in 2024–25 (Australian Bureau of Agricultural and Resource Economics and Sciences, 2024).
Evidence: Insights from the Adaptation Stocktake
- Adaptation in the Primary industries and food system mostly occurs at a regional scale (Figure 94). It is important to note that because the stocktake is limited to publicly available adaptation actions and projects with published information, this is likely to significantly underrepresent the adaptation that is occurring at farm/business scales. Addressing local-level data gaps and sharing adaptation skills and knowledge (e.g. through local adaptation networks) is an important opportunity for adaptation governance within this system.
Evidence: Insights from the Adaptation Stocktake
- Drought and changes in precipitation are the most common specific hazards addressed through adaptation in this system (Figure 95) with large funding regimes related to the National Water Initiative and the Future Drought Fund. This points to a significant cross-over with the Water security priority risk, with many of the examples of adaptation included in this system, such as drought monitoring and modelling, also relating to this.
Evidence: Insights from the Adaptation Stocktake

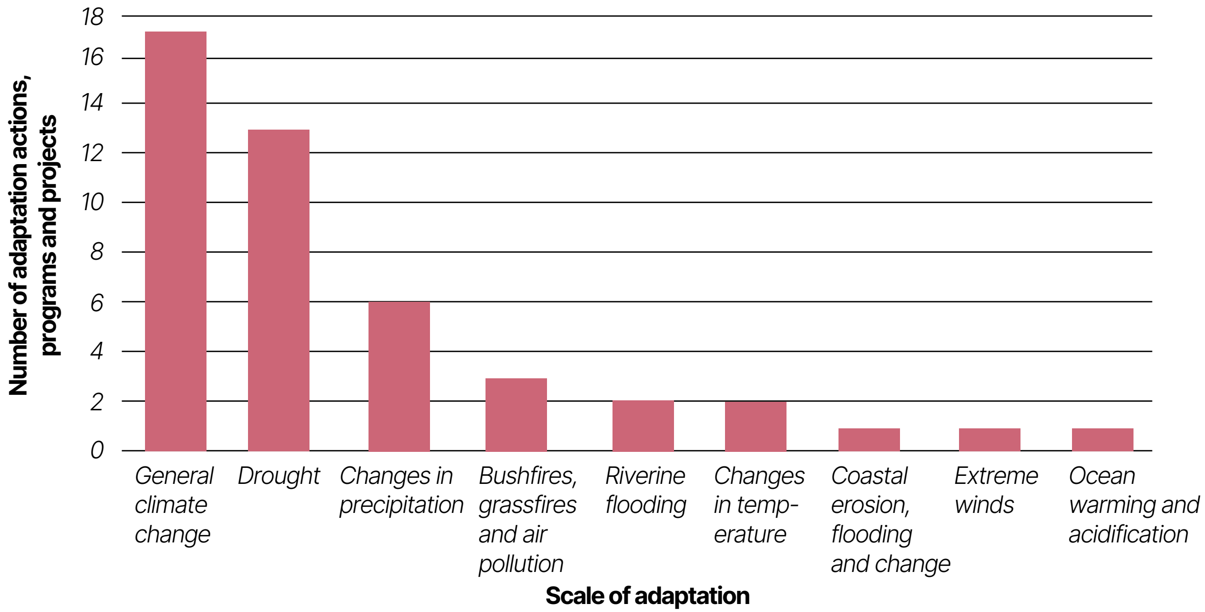


Figure 95: Distribution of adaptation actions, programs and projects by hazard in the Primary industries and food system. *(Source: Insights from the Adaptation Stocktake)*

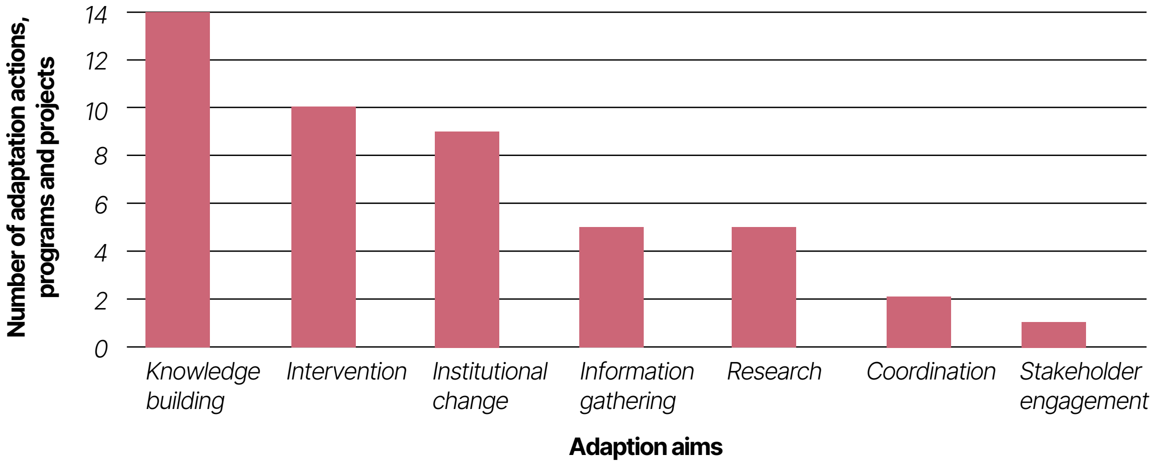


Figure 96: Distribution of adaptation programs, projects and actions across adaptation aims in the Primary industries and food system. *(Source: Insights from the Adaptation Stocktake)*

Many of the adaptation programs and projects within the Primary industries and food system aim to provide knowledge about current and future risks from climate change to primary producers to support their risk decisions *(high confidence).*

- The Primary industries and food system has the most balance and diversity across adaptation aims compared to other systems and a high proportion of tangible interventions, indicating progress in this system (Figure 96).
Evidence: Insights from the Adaptation Stocktake
- It is important to note, however, that the data from the *Australian Adaptation Stocktake* cannot evaluate how effective those adaptation actions are in achieving their stated aims.
Evidence: Insights from the Adaptation Stocktake
- Adaptations in the Primary industries and food system that target intervention include funding to support on-farm adaptation initiatives and community-based programs such as food hubs, as well as regional-scale adaptations, such as changes to water infrastructure and landscape regeneration in key primary production regions. As with other systems, the knowledge-building projects in this system include vulnerability assessments and research projects that seek to provide primary industries and food producers with information to make decisions about risks. Institutional adaptations primarily focus on altering how producers access funding, support and outreach.
Evidence: Insights from the Adaptation Stocktake
- Response to climate change in primary industries will largely be carried out by individual businesses, and so including producer perceptions of the implications of climate change is important for industry adaptation planning. Perceptions of climate change implications were gathered from growers operating in the low-rainfall cropping regions of South Australia. These growing regions are at or close to the biophysical limits of economically sustainable cropping. Adaptation, such as transitioning out of cropping, due to climate change alone was not considered likely; such decisions were considered irreversible, and drivers of this degree of change were thought to be more likely the result of policies associated with climate change rather than arising directly from climate changes.
Evidence: Primary Industries Technical Report

Case study: Biosecurity risks from emergency response to drought

Emergency responses to climate hazards, such as movement of machinery for flood and cyclone recovery/aid, or emergency shipping of livestock feed during drought events, can present a risk for the movement of biosecurity threats.

This case study examines biosecurity implications of emergency shipping of livestock feed into NSW to provide relief during the 2018–20 drought.

Between January 2017 and December 2019, eastern Australia experienced a record-breaking drought with the warmest temperatures and lowest rainfall on record for NSW (NSW Department of Planning, Industry and Environment, 2021). Between mid-2018 and early 2020, there was no significant natural inflow into the Barwon–Darling River, and by June 2019 there were 364 days of no flows recorded at Walgett, which represented the longest no-flow period on record for the Barwon-Darling (NSW Department of Planning, Industry and Environment, 2021). With the prolonged drought, hay and fodder within the state became scarce and led NSW farmers to 'desperately seek feed from all over Australia' (Bryant et al., 2018). Feed was purchased largely from interstate, but as the drought intensified, fodder donations were also organised (Figure 97).

The introduction of contaminated hay and grain from Queensland during the 2018–19 drought in NSW (via purchases and donations) caused a significant expansion in the range of parthenium weed (*Parthenium hysterophorus*) in that state (Dixon, 2024). Parthenium weed is an aggressive invader of disturbed land, roadsides, perennial pastures, grazing land and summer cropping areas (Department of Primary Industries and Regional Development, 2019). This is a Weed of National Significance in Australia and has been listed in the top 100 weeds in the world (Weyl, 2019). It was calculated to cost Queensland pastoralists over $16 million for 1990–91 in reduced production and increased management costs (Chippendale & Panetta, 1994) and up to $68 million each year currently (NSW Department of Primary Industries, 2024).

Following the fodder donations, 30 large infestations of parthenium were detected on private properties in 2020 and 2021 in the North Coast, Hunter, Greater Sydney and southeast regions of NSW (Dixon, 2024). These areas are now under continuous surveillance and are eradication targets, requiring increased investment of state government resources. In cases where eradication is no longer deemed feasible, the weed could be designated as 'established', in which case an expansion of its distribution would be seen and impacts would be incurred by the farmers in control costs, livestock and human health risks, and production losses.

This is one case study where an invasive species threat arising from an emergency response has increased costs of biosecurity management and will have a long legacy. Each location where a parthenium weed was found must be under surveillance for at least 8 years from the last seeding event recorded, to ensure that the seedbank is depleted (estimated at 6 years of longevity plus 2 years of no records) to cease surveillance of that area. Multiple other threats are potentially transported during emergency responses, but with no data collected before or after the events, traceability is not feasible, and it is not possible to calculate the cost or the duration of the impact of such responses where biosecurity is not pre-emptively considered.

For more information on this case study, see the Primary Industries Technical Report.

Figure 97: Twenty-three road trains arrive in Condobolin, NSW, with more than 2,000 hay bales (Sheil, 2018).

Governance and adaptation

Summary

The National Assessment has undertaken quantitative and qualitative analysis for priority risks. The first pass assessment identified governance as a cross-system risk.

Governance is about how society is organised to make decisions, pursue shared goals and manage risk. Understanding who makes decisions, how these decisions influence risks, and our responses to them is an important part of a risk assessment.

Adaptation is the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or to exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects (IPCC, 2022a).

Adaptation plays a crucial role in reducing risks and cascading impacts. It is likely that adaptation in Australia is not currently keeping pace with climate change. Adaptation responses can inadvertently lead to maladaptive outcomes, especially in the absence of collaboration, and thus careful planning and action is required.

Priority risk

One priority risk has been analysed as part of the second pass assessment:

- Risks to adaptation from maladaptation and inaction from governance structures not fit to address changing climate risks.

Impacts, risks and adaptation summary

The role and challenges of governance in adaptation

Governance is a crucial enabler of positive climate change adaptation processes and outcomes (IPCC, 2022c). It needs to be harnessed to accelerate, guide, assess and improve adaptation. Yet, the complex, uncertain and long-term nature of climate change risks often conflicts with traditional governance cycles and established roles, which can hamper accurate risk assessment and lead to uneven and unhelpful adaptation efforts and outcomes.

Governance also contributes to climate change impacts and risks and can propagate them across systems. Evidence assessed in this National Assessment suggests that 2 out of 5 climate change risks are triggered by decisions rather than by climate hazards themselves, with the Natural environment and Primary industries and food systems the most affected by decisions in other systems.

Governance in Australia will need to overcome several challenges, including resource shortfalls, ambiguous roles, limited engagement and lack of coordination. Addressing these issues at all levels will better support climate change adaptation and resilience.

Climate change poses additional risks to the self-determination of Aboriginal and Torres Strait Islander peoples. Aboriginal and Torres Strait Islander peoples' right to freely pursue their economic, social and cultural development is at risk due to the effects of climate change on the health of and access to Country for social and emotional wellbeing. The lack of inclusion in decision-making in connection to caring for Country and developing climate adaptation strategies is also affecting the ability of Aboriginal and Torres Strait Islander people to freely pursue their economic, social and cultural development.

Adaptation in Australia

The National Assessment has identified that overall, there is an adaptation action shortfall across all systems, risks, jurisdictions and geographies in Australia.

Different approaches to adaptation in Australia make cross-jurisdictional comparisons challenging. Policies and plans indicate progress towards adaptation and institutional preparedness, and adaptation programs and projects focus on knowledge building (40%) and institutional (27%) adaptations. However, planning and policy do not always translate into adequate adaptation action, and tracking of the effectiveness of adaptation actions is limited.

The risk of maladaptation and negative social tipping points

A lack of data on adaptation outcomes and other characteristics of current governance systems increases the risk of maladaptation. Maladaptation refers to the negative outcomes for those adapting, specific others and society as a whole.

Extreme climatic events stress governance structures and processes and the perception of a slow or inadequate response could undermine public confidence in government.

Climate change may drive significant social changes, which governance systems may not be prepared to manage. Social fragmentation, declining trust in authority/institutions and rising inequality are already being seen in Australia and have the potential to trigger social tipping points, which can result in either positive or negative outcomes. Signs of negative social tipping points are emerging, which could undermine adaptation and wider governance.

Overall, adaptation within the governance system itself is needed to enable faster and better adaptation and potentially drive positive social tipping points.

Opportunities for intervention

Effective adaptation requires governance structures, functions and processes that can deliver proportional, timely and just responses to escalating climate risks.

1. *Improved management:* improvements to the management of the risk, including to enhanced efficiencies, within existing systems and processes without significant changes.
2. *Incremental adaptation:* gradual adjustments and modifications to existing systems and practices without changing their fundamental characteristics.
3. *Transformational adaptation:* fundamental changes to systems and structures, leading to a significant shift in how risks are managed.

Successful response requires adapting governance itself to better recognise and manage systemic risks. Collaborative governance is key for transformational adaptation.

Importantly, working with and learning from Aboriginal and Torres Strait Islander peoples can guide adaptation towards positive social outcomes. Among many opportunities in this space, traditional ecological knowledge, passed down through generations, has enabled a sustainable relationship with the land and water. Embracing this knowledge can drive systemic changes that enhance resilience and adaptation efforts.

Introduction

This chapter provides a synthesis of Governance and adaptation. It draws on multiple technical assessments to provide observations that can enable effective adaptation.

It includes:

- Chapter overview
- Priority risk snapshot
- Key insights
- Case study

Overview

Fit-for-purpose governance is needed to define, drive and guide successful adaptation, and to track adaptation outcomes and adjust efforts as needed.

There is a risk that governance fails to achieve this ambition, hampering adaptation elsewhere or enabling adaptation efforts that unjustly externalise costs and risks, making things worse for others. Contributing to this risk are not only current governance weaknesses but also the escalating pressures that climate change disruptions and stresses are placing on governance structures, processes and functions, which means that governance itself needs to adapt.

This chapter considers governance broadly and includes both formal and informal entities and stakeholders, each with distinct interests and mandates, but also a need to interact and generate collective outcomes. These entities engage through various processes and relationships to negotiate and implement decisions. For complex problems such as climate change, no single entity can govern alone. Effective governance depends on balancing competing priorities and interests and negotiating trade-offs between values.

The National Assessment recognises the multifaceted relationships and feedback between governance, climate change risks, and adaptation. In doing so, the National Assessment's approach to governance risk is broader than other priority risks. It is focused specifically on the inadvertent ways governance can slow or distort adaptation, and on the need for governance to manage the resultant tension between inaction and maladaptation.

As climate change risks escalate, governments are under increasing pressure to invest in adaptation. Complexities such as jurisdictional boundaries, uncertainty, dynamism, complex risk ownership and long-term effects pose significant challenges for decision-making. Many of these transfers arise from decision-making and cross-system interactions, underscoring the need to examine governance as a system itself, rather than as governance of individual entities or their interactions. There is also a need for risk assessments to consider governance as a risk alongside direct climate impacts.

Good risk governance requires reliable information about not only risks but also risk management. To this end, the Australian Adaptation Stocktake was developed in partnership with the National Environmental Science Program (NESP) Climate Systems Hub to investigate adaptation activities across Australia. This Adaptation Stocktake aims to understand whether Australia has progressed from planning to implementing adaptation, the levels of government involvement, the distribution of efforts across different scales and sectors, and the climate hazards being addressed. The Adaptation Stocktake has 2 main components: a repository of policies, plans, strategies and laws that respond to risks from climate change at state, territory and national levels; and publicly accessible examples of adaptation actions, programs and projects from local to national levels.

Adaptation is diverse and is approached differently in different contexts. Progress is evident, but more adaptation is required given the pace of climate change. There is also a real need to identify, track and respond to adaptation outcomes to allow learning, improvement and, ultimately, more just and sustainable adaptation.

Priority risk snapshot: Governance

The risk of maladaptation and inaction from governance structures not fit to address changing climate risks.

Rationale

The risk of maladaptation and inaction on adaptation due to governance structures that are not equipped to address changing climate risks is currently rated as **Moderate**. This risk is expected to increase to **Very High** by 2050 as there is a significant risk of inaction and adaptive inertia in governance structures (Figure 98).

While some governance structures have mechanisms to monitor and evaluate the effectiveness of decision-making and resource allocation, additional adaptations are needed, particularly in new ways to consult and collaborate. These adaptations require deliberate and sustained efforts from governance structures to be effective. Some transformational adaptation may also be required to adapt to uncertainties in 2090; however, further analysis and understanding of this risk in Australia is needed. The potential for social tipping points, local and national transmission of international climate impacts and cascading economic impacts means that it is not possible to evaluate the risk of and to governance in 2090.

Impacts and risks

The uncertain, dynamic, transboundary and long-term nature of risks from climate change are difficult to manage, and accelerating impacts will add pressure.

Governance mechanisms can transfer these impacts, risks and opportunities across the 8 National Assessment systems that underpin the functioning of Australian society. One of the challenges that governance must negotiate is how interactions between systems can generate and transfer risks to other systems, indicating the need for cross-system collaboration for positive adaptation outcomes.

RISK RATING	*Current*	*2050*	*2090*
Severe			Uncertain
Very High		■	
High			
Moderate	■		
Low			
ACS RISK CONFIDENCE RATING	***High***	***Medium***	

TYPES OF RESPONSE REQUIRED

Improved management: *Enhancing efficiencies within existing systems without major changes* — Response required

Incremental adaptation: *Gradual adjustments to systems without altering their core* — Response required

Transformational adaptation: *Fundamental changes to systems, significantly shifting risk management* — Some level of response required

Response required | *Some level of response required* | *Response not required at this time*

Figure 98: Rating for the Governance priority risk for current, 2050 and 2090, and the types of responses required to address the risk. For definitions of risk ratings, please see Figure 9.

Governance risk in Australia

This section provides an overview of key elements where there is evidence of governance risk in Australia.

- **Resource allocation:** Inadequate volume, duration and distribution of resources to manage emerging climate impacts and risks effectively.
- **Coordination and collaboration:** Inadequate coordination and collaboration across levels of government, sectors and with communities, leading to fragmented efforts. For example, the Select Committee on Australia's Disaster Resilience concluded that a coordinated effort across and within many areas, including land-use planning, infrastructure, emergency management, social policy, agriculture, education, health, community development, energy and the environment, is required to reduce future climate change impacts (Select Committee on Australia's Disaster Resilience, 2024).
- **Role ambiguity:** In the context of climate risk management, there are unclear roles and responsibilities among various government levels and agencies. For example, the 2024 Australian Local Government Climate Review found that local governments' ability to adapt is hindered by existing state, territory and federal legal and institutional frameworks (Ironbark Sustainability, 2024).
- **Engagement and participation:** Insufficient engagement with and participation by diverse stakeholders, leading to inequitable and ineffective governance. For example, the 2024 Australian Local Government Climate Review found that while councils may strive to engage vulnerable groups, they may lack the necessary relationships and resources to do so effectively, hindering their ability to meet the unique needs of those most affected (Ironbark Sustainability, 2024).
- **Knowledge and capacity:** Challenges in assessing and managing systemic climate-driven risks due to inadequate tools or inconsistent information and guidance. For example, the Climate Governance Initiative Australia and the Australian Institute of Company Directors Climate Governance Study reports that many company directors are struggling with navigating available information and using this to inform decision-making (Climate Governance Initiative Australia & Australian Institute of Company Directors, 2024).
- **Pace of change:** Governance systems and structures unable to adapt quickly allow climate change impacts to escalate, thereby undermining adaptive capacity and risking systems approaching adaptation limits. Climate change threatens all of the collective goals that the governance system currently explicitly or implicitly directs society towards, including those aiming for clear improvements (e.g. improving Aboriginal and Torres Strait Islander peoples' health outcomes), those aiming to avoid losses (e.g. reducing species losses), and those aiming to merely slow presumed inevitabilities (e.g. extending the life of infrastructure by reducing its rate of degradation). By altering the direction and/or pace of change along these trajectories (stalling improvements or worsening and accelerating problems), climate change presents severe, concurrent challenges for the governance system.
- **Social tipping points:** Climate changes can drive significant social changes, which governance systems may not be prepared to manage. In the context of climate change, core themes of social tipping are already being articulated in relation to national risks to Australia. Social fragmentation, declining trust in authority/institutions and rising inequality are major concerns.
- **Governance structures:** These are already under strain and may not be equipped to handle the dynamic and complex risks posed by climate change. Decadal timeframes for the realisation of some of the impacts are potentially at odds with short election cycles and decision-maker appointments.

Evidence: Governance Technical Report

Adaptation

- Successful adaptation relies on governance structures and processes that help to identify and validate complex climate change risks, generate innovative adaptation options, anticipate and avoid response risks, accelerate positive adaptation action, and track and adjust to outcomes. Governance needs to balance adaptation that is rapid enough to effectively reduce climate change risks and careful enough to achieve broader outcomes and avoid maladaptation (Figure 99).

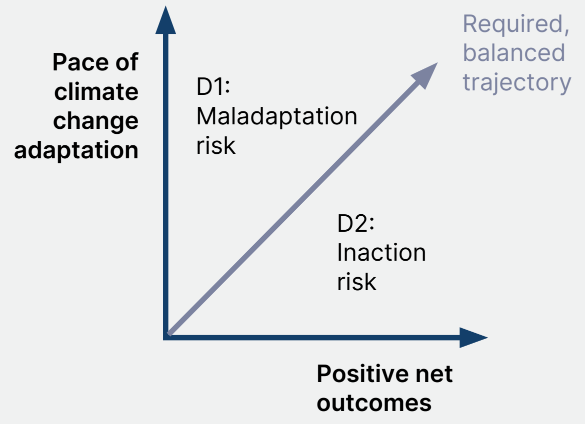


Figure 99: The balance between the pace and outcomes of adaptation that governance needs to negotiate. D1 (Deviation 1) is the risk of too much maladaptation, while D2 (Deviation 2) is the risk of inadequate adaptation stemming from an approach that is too careful and slow. *(Source: Governance Technical Report)*

Governance functions that support adaptation include (IPCC, 2022b):

- Legal, policy and regulatory instruments:
  - climate change legislation
  - climate change policies, strategies and plans, including articulation of clear roles and responsibilities
  - regulations and standards
  - environmental and social governance – voluntary or non-legally required actions taken by participating parties.
- Finance – including emerging public and private climate finance architecture.
- Knowledge and capacity, including:
  - co-production of knowledge and climate services and access to authoritative information
  - financial or corporate disclosure of climate risk
  - community-led networks
  - mechanisms for adaptive management, including forums for resolving issues.

Climate change adaptation actions and arrangements are currently assessed as inadequate to address the identified risks from climate change across all systems.

Key insights

This section provides key insights on risks and impacts to and from governance structures and information that can enable adaptation.

The role and challenges to governance in a changing climate

The nature and timeframe of climate-driven risks are difficult for many existing governance processes and structures to handle, and proliferating impacts are adding pressure. These difficulties worsen climate change risks, hamper climate change adaptation, and exacerbate outcomes. Governance is involved in, and ultimately required to manage, all aspects of this challenge *(medium confidence).*

- Governance can create, exacerbate or alleviate climate change risks through influencing vulnerability, exposure, hazards and adaptation efforts. Climate change itself can influence governance by straining existing systems, requiring new systems or exacerbating potential social tipping points (Figure 100).
  Evidence: Governance Technical Report
- The uncertain, urgent, dynamic and long-term nature of climate-driven risks is counter to many aspects of Australia's established governance system, including its typical governance cycles and established roles and responsibilities. All decision-makers perceive and prioritise risks differently, and institutionalised approaches and goals may conflict with acceptance of the severity and scope of climate change risks, reducing climate change adaptation.
  Evidence: Governance Technical Report
- There is evidence that young people feel that the issue of climate change is not being addressed quickly enough. A national survey by Monash University found that only 34% of Australians aged 18 to 24 believe that it is likely that climate change will be combated in the future (Walsh et al., 2024). The national survey found that addressing climate change is in young people's top 3 areas requiring immediate government action.

Exposures, vulnerabilities, impacts and risks

Governance mechanisms can transfer impacts, risks and opportunities across systems that underpin Australian society. Analysis of stakeholder observations of system interactions suggests that 2 out of every 5 climate-driven risks are triggered by decisions rather than climate hazards *(low confidence).*

- Impacts in one system can propagate through cross-system connections to impact multiple other systems. Analysis of stakeholder observations of system interactions suggests that 42% of risks that flow across systems are driven by a decision rather than a physical hazard.
  Evidence: Governance Technical Report
- Decisions in the Economy, trade and finance system affect the most other systems (Figure 101). The Natural environment and Primary industries and food systems are most likely to experience compounding risk as a result of decisions made in other systems.
  Evidence: Governance Technical Report

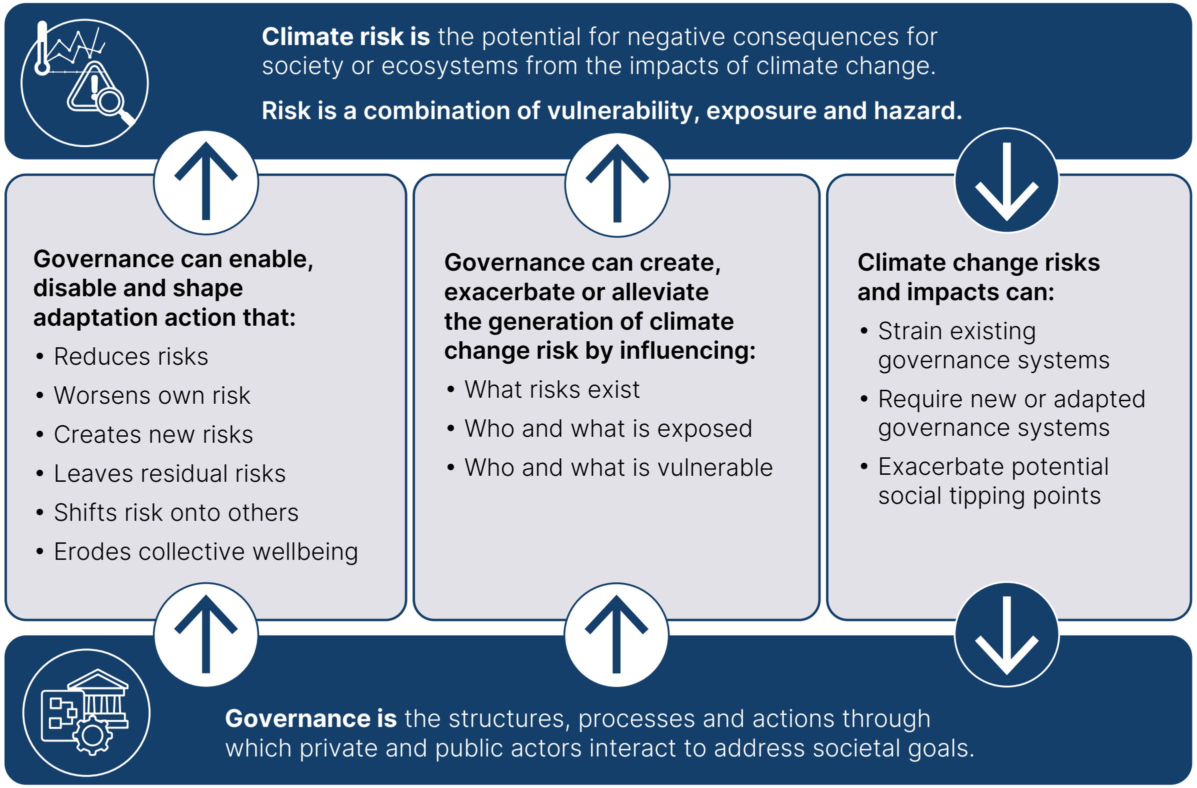


Figure 100: The interaction between climate change risks and governance. *(Source: Governance Technical Report)*

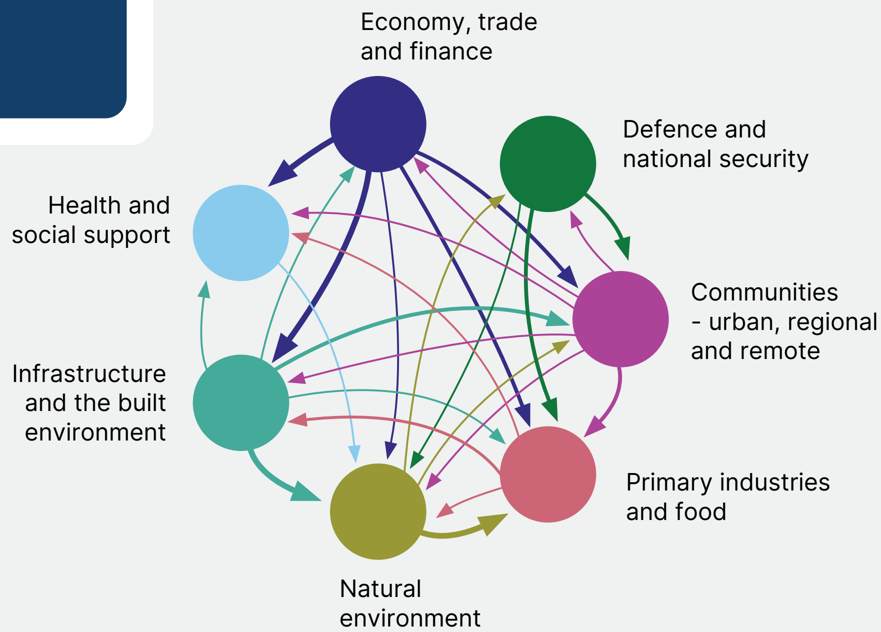


Figure 101: How decisions made in one National Assessment system can cause adverse impacts in another.

Each arrow originates at the system where the decision is made and points towards the system that is adversely impacted. The weight of each arrow represents the number of interactions identified. This data reflects stakeholder engagement workshops. The Aboriginal and Torres Strait Islander Peoples system followed a different approach and is not represented in this data. (Source: Governance Technical Report)

Risks and impacts from climate change are unequally distributed, reflecting and exacerbating pre-existing inequalities generated by past and present governance *(high confidence).*

- Many long-standing inequalities are being worsened by climate change as existing systemic vulnerabilities exacerbate the consequences of climate change hazards for some groups, entities and places, including the natural environment. Vulnerabilities include a lack of decision-making power or options around where to live, for example. Existing stresses on housing, cost of living, mental health and small towns are among the factors deepening climate change risks and impacts, including by hampering disaster response and recovery and worsening disaster effects (Australian Government & Department of Home Affairs, 2018; Future Earth Australia, 2022).
Evidence: Governance Technical Report
- Conversely, addressing existing vulnerabilities and inequalities will reduce climate change risks. Local governments and communities are under-resourced for the level of risk they are expected to address (Birch & Hanabeth, 2022; Ironbark Sustainability, 2024). There are growing calls for a governance system that invests in social welfare and protective measures to reduce vulnerability to climate change (Climate Planning, 2020b; Measham et al., 2020a), including community service organisations and their adaptation (Victorian Council of Social Services, 2024).
Evidence: Governance Technical Report
- Climate change will have unique and disproportionate impacts on Aboriginal and Torres Strait Islander communities, intensifying existing challenges including the need for self-determination. Examples include:
  - **Economic adaptation:** Limited access to resources and opportunities may restrict the ability to adapt economically to climate change. This could hinder investment in sustainable practices or infrastructure that align with Aboriginal and Torres Strait Islander peoples' self-determined development goals.
  - **Social disruption:** Climate change threatens community cohesion and health outcomes, impacting the ability of Aboriginal and Torres Strait Islander peoples to maintain cultural practices and remain on Country, therefore undermining their autonomy and self-determination.
  - **Cultural heritage and traditional practices:** The effects of climate change on land and water risk is endangering cultural sites, traditions and knowledges closely tied to the environment. Protecting these elements is essential for self-determination for Aboriginal and Torres Strait Islander peoples.
  - **Cultural governance and leadership:** Empowering Aboriginal and Torres Strait Islander leadership is vital to sustaining communities and supporting self-determined solutions and includes respect for existing governance mechanisms and cultural protocols. Without this involvement in governance and policy discussions addressing climate change and adaptation, there is a risk of further entrenchment of systemic inequities. Aboriginal and Torres Strait Islander peoples must be afforded the right to assert their cultural governance.

  Evidence: Aboriginal and Torres Strait Islander Peoples Technical Report

Risk factors that hamper good governance for climate adaptation include resource shortfalls, ambiguous roles and responsibilities, limited engagement and participation, lack of appropriate risk management guidance, and lack of coordination and collaboration across entities and scales *(medium confidence).*

- The level, distribution and reliability of resources is a fundamental outcome of governance, including in the context of climate change adaptation and disaster recovery. Effective decision-making requires adequate resources to manage immediate impacts and long-term risks. Investments in risk reduction can reduce future costs from damage and recovery; however, this is made more challenging because immediate climatic events demand short-term investments.
Evidence: Governance Technical Report
- Clear roles and responsibilities are particularly important in dynamic and complex environments. While adaptation is recognised as a shared responsibility across levels and entities, such entities do not equally control the intervention points to reduce or avoid climate change risks. Uncertainties include those around the roles of local government, unclear agency roles before and during disaster response periods, and ambiguity around ownership of systemic risks (Climate Planning, 2020; Measham et al., 2020; Productivity Commission, 2012).
Evidence: Governance Technical Report
- Sustained and comprehensive community engagement is critical for effective governance of climate risk (Biswas & Rahman, 2023; Wellstead & Biesbroek, 2022). Areas of challenge include the lack of ability to collect and reflect perspectives and experiences from diverse social groups. Factors such as gender and other intersectional characteristics can significantly affect individuals' decision-making influence and the impact of climate change on already vulnerable groups (Ironbark Sustainability, 2024; The Treasury, 2023b).
Evidence: Governance Technical Report
- Private and public entities report challenges with informed climate-driven risk decision-making and are calling for greater guidance, as company directors find this difficult (Aven, 2020; Climate Governance Initiative Australia & Australian Institute of Company Directors, 2024). State and territory governments report that existing risk management frameworks often lack guidance on conducting comprehensive climate change risk assessments, while local governments suggest the need for risk assessment and adaptation guidance at a national level (Ironbark Sustainability, 2024). A persistent

'business as usual' mentality to embedding climate-driven risk alongside other risks is also a barrier to effective responses (Climate Planning, 2020).
Evidence: Governance Technical Report

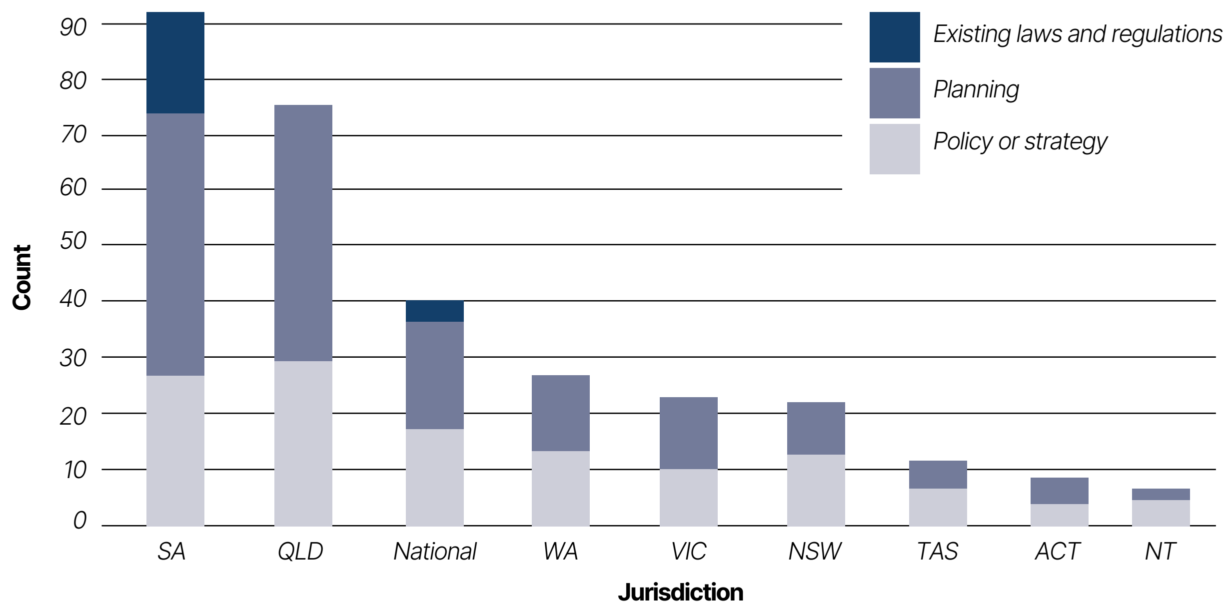
- Risk management is a core element of governance. Common challenges in climate risk management across the National Assessment systems are preparing and deciding on risk management strategies and policies, dealing with uncertainty, complexity and systemic issues, and gathering and interpreting information for adaptive learning. Risk management efforts by individual entities often involve a focus on the short-term outputs at the expense of long-term outcomes, with unintended side effects (McConnell & Hart, 2019).
Evidence: Governance Technical Report
- Strong relationships among public, private and civil society actors are essential for responding to emerging risks (Ansell & Gash, 2008; Bryson et al., 2015). However, a lack of coordination across various projects and government levels has led to siloed efforts, resulting in missed opportunities for more effective climate action and fragmented, insufficient policy outcomes (Ansell & Gash, 2008; Borgonovi et al., 2019; Howlett & Ramesh, 2014). Multiple inquiries into disaster resilience stress the need for not only structural coordination but also practical cooperation during disaster recovery action (Commonwealth, 2020; Government of South Australia, 2019; Measham et al., 2020). Local governments and communities have expressed a strong desire for improved cooperation and communication with other organisations to create a more strategic and long-term approach. These findings underline that no entity can tackle climate change risks and adaptation in isolation.
Evidence: Governance Technical Report

Adaptation in Australia

Despite current risks to governance in Australia, adaptation planning and policy is progressing across local, state, territory and federal levels. There are different approaches to mainstreaming and labelling adaptation, which makes comparison of adaptation action across jurisdictions difficult. Diversity in the processes of planning and regulating across regions reflects varying levels of readiness *(high confidence).*

- The *Australian Adaptation Stocktake* is the first of its kind in Australia and is currently the most comprehensive repository of information on adaptation policies, plans, projects and actions. Adaptation policies and plans have been identified across all scales and for most systems. However, the Stocktake does have limitations in that it relies solely on publicly available information. Therefore, it is unlikely that it captures all adaptation actions, and it does not assess adaptation effectiveness.
Evidence: Insights from the Adaptation Stocktake
- South Australia and Queensland have a larger proportion of entries for climate policies and plans than other jurisdictions, indicating progress in these 2 states (Figure 102). However, the number of policies does not necessarily reflect the level of impact in reducing risks and potentially masks the progress of other jurisdictions such as Victoria that have embedded climate change into broader policy agendas or portfolios.
Evidence: Insights from the Adaptation Stocktake

Figure 102: Number of climate change adaptation policies, plans and laws per state or territory. *(Source: Insights from the Adaptation Stocktake)*



Policies and plans to manage climate driven risks indicate progress towards adaptation and institutional preparedness for different systems. While all systems have evidence of planning for climate change, there are opportunities to increase planning efforts within some systems and for more coordination between systems in adaptation policy-making *(medium confidence).*

- Policies and plans can be understood both as progress towards adaptation and as a proxy for willingness to prepare for future adaptation. Climate change policies create mandates for change and enable environments for both government and non-government adaptation actors. Planning is essential to facilitate adaptation at all scales.
  Evidence: Insights from the Adaptation Stocktake
- Most climate change policies and plans are seeking to effect change across multiple systems (Figure 103). This indicates that adaptation planning is not always aligned to systems-based risk assessment but does recognise the integrated nature of risk.
  Evidence: Insights from the Adaptation Stocktake
- The Natural environment system is the largest single focus for policies, plans and laws addressing adaptation (22%) (Figure 103). This is likely due to the system's institutional history with managing climate-driven risks, as well as the higher likelihood of limits where we cannot avoid intolerable risks with any adaptation actions. While the data shows that adaptation is occurring within this system, the literature on adaptation shows that these actions are not sufficient to manage current or future risks.
  Evidence: Insights from the Adaptation Stocktake, Natural Ecosystems Technical Report

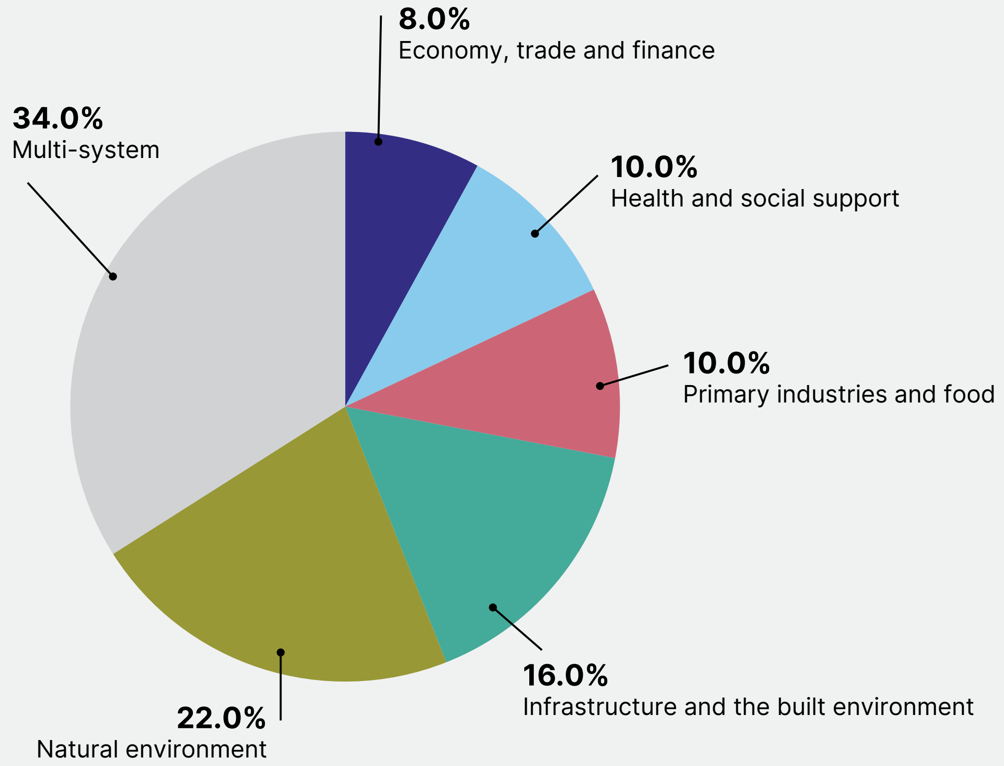


Figure 103: Percentage of total adaptation policies, plans and laws by system. *(Source: Insights from the Adaptation Stocktake)*

Adaptation action in the form of programs and projects, that seek to enact tangible change in response to climate-driven risks is also progressing at different paces across regions and systems *(high confidence).*

- There is variation in the number of adaptation actions undertaken in state, territory and national jurisdictions (Figure 104). The national jurisdiction has the greatest number of actions and they are focused primarily on the Infrastructure and the built environment system. South Australia, Victoria and Queensland have similar numbers and comparable balance between system focus.
  Evidence: Insights from the Adaptation Stocktake
- Across the systems, the Infrastructure and the built environment system has the largest proportion of identified adaptation actions, followed by the Natural environment system, the Health and social support system and then the Primary industries and food system (Figure 105).
  Evidence: Insights from the Adaptation Stocktake
- The overall numbers of projects and programs for each of these regions and systems are not high in comparison to the current and projected risks, and the low numbers in high-risk regions, such as in the Northern Territory, suggest significant adaptation shortfall at present.
  Evidence: Insights from the Adaptation Stocktake

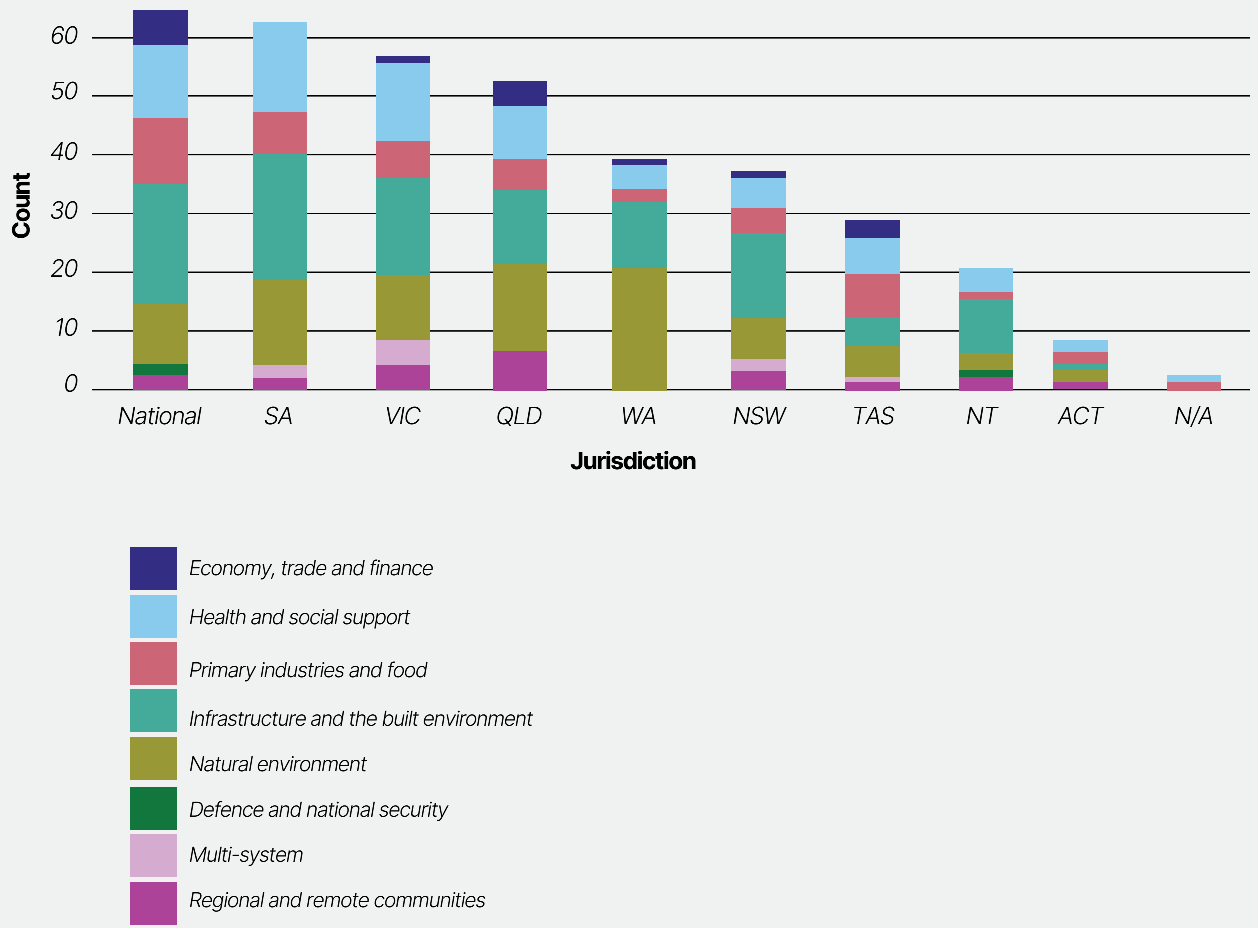


Figure 104: Number of adaptation actions, programs and projects identified as part of the Adaptation Stocktake for each system per state/territory.

At the time of data collection and analysis, the Adaptation Stocktake focused on communities identified as regional or remote. (Source: Insights from the Adaptation Stocktake)

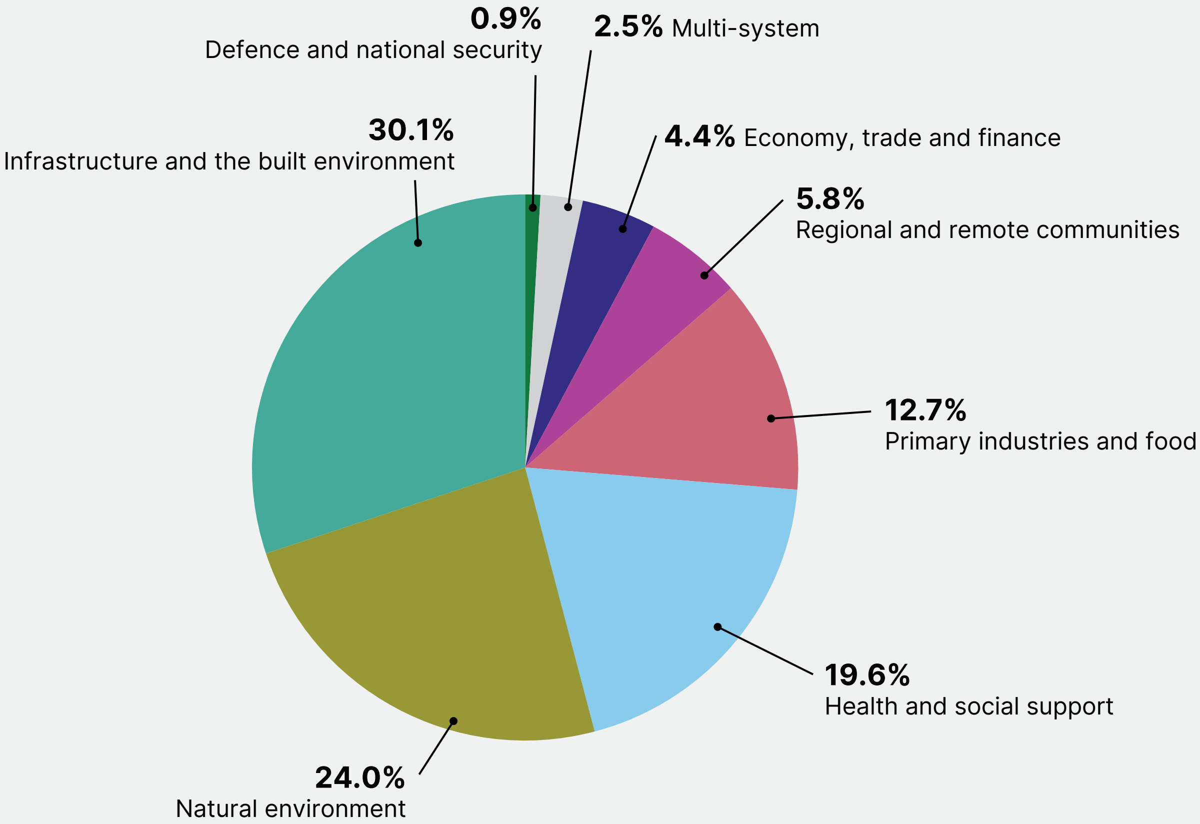


Figure 105: Percentage of total adaptation actions, programs and projects by system.

At the time of data collection and analysis, the Adaptation Stocktake focused on communities identified as regional or remote. (Source: Insights from the Adaptation Stocktake)

Adaptation actions primarily focus on knowledge building (40%) or institutional (27%) adaptation actions. Actions also commonly focus on non-specific climate change for particular systems. Effective adaptation requires balance between adaptation types and alignment with the priority hazards for each system. While these data show progress in addressing adaptation needs, significant gaps remain in both how and what adaptation is responding to *(medium confidence).*

- The most frequently identified adaptation types across systems are knowledge building (e.g. informing key stakeholders of risks) or institutional (e.g. conducting risk assessments) adaptation actions (Figure 106). This may be because these types are within scope for adaptation actors with more resources or a stronger mandate for adaptation, or are easier to enact, or are more aligned with current funding regimes. It may also reflect hesitancy to undertake deeper systemic change. It is important to note that these types do not necessarily reflect the most effective forms of adaptation.
  Evidence: Insights from the Adaptation Stocktake
- Most actions, projects and programs are broadly focused on non-specific 'climate change' (Figure 107). Focus on specific hazards may reflect funding opportunities for adaptation action (e.g. on drought) or other decision criteria, such as the perceived urgency (rather than long-term importance) of possible actions.
  Evidence: Insights from the Adaptation Stocktake

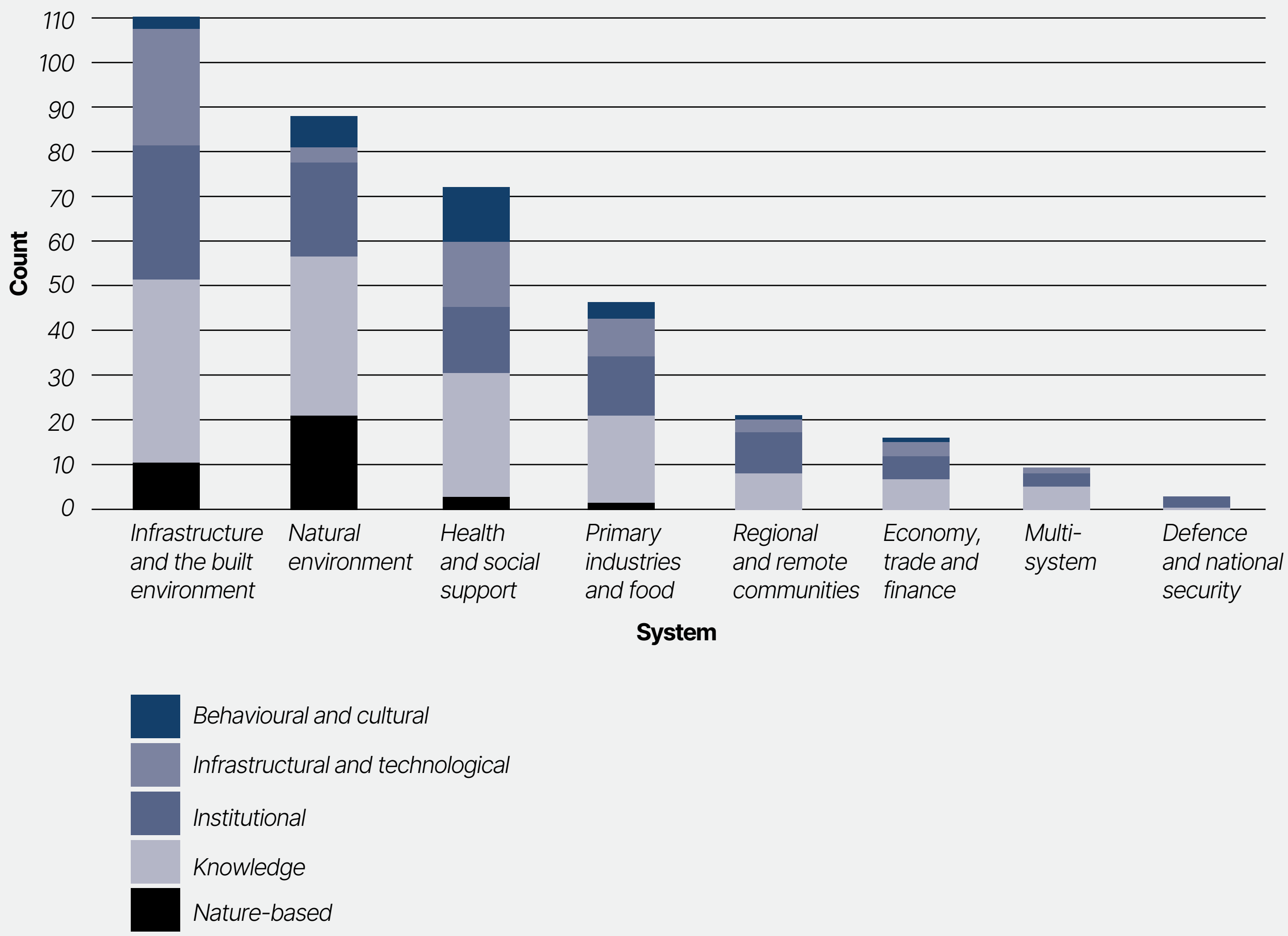


Figure 106: Comparison of primary system and IPCC adaptation type.

At the time of data collection and analysis, the Adaptation Stocktake focused on communities identified as regional or remote. (Source: Insights from the Adaptation Stocktake)

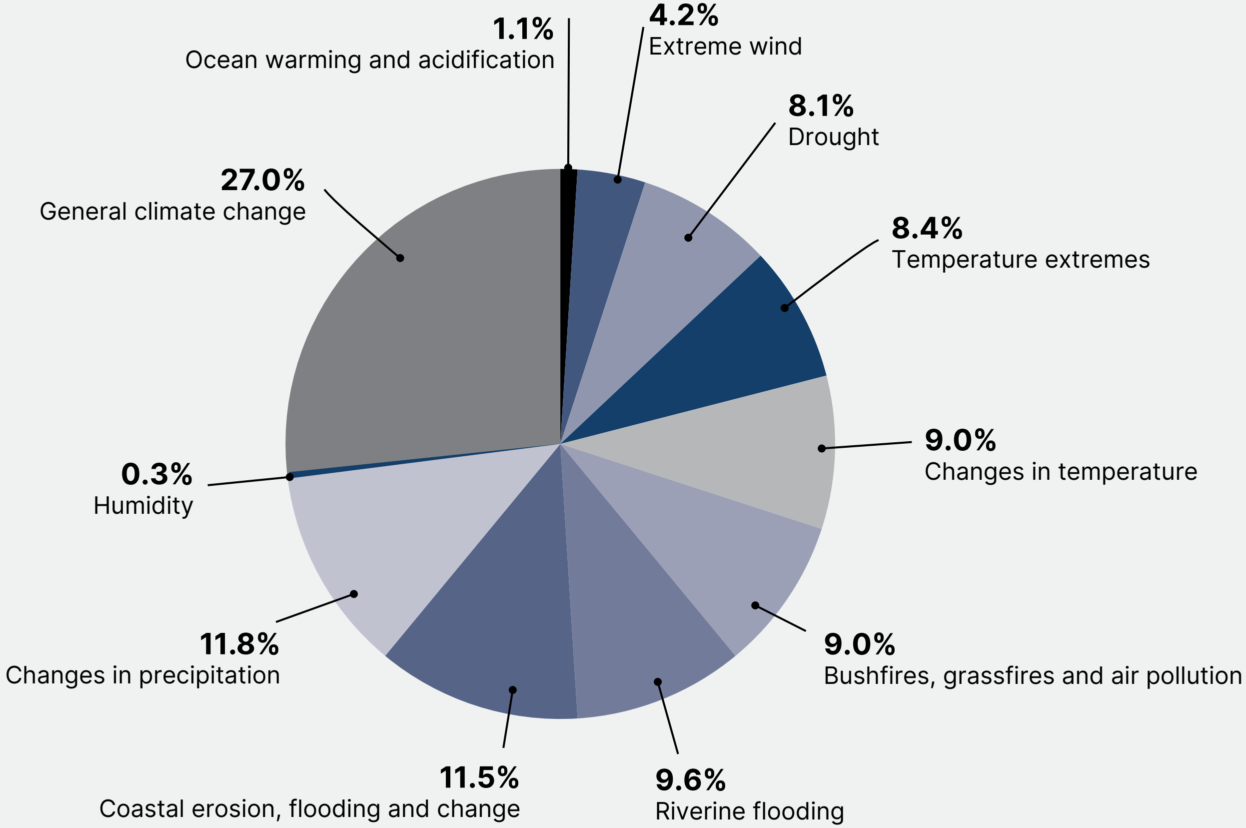


Figure 107: Percentage of total adaptation actions, programs and projects by hazard. *(Source: Insights from the Adaptation Stocktake)*

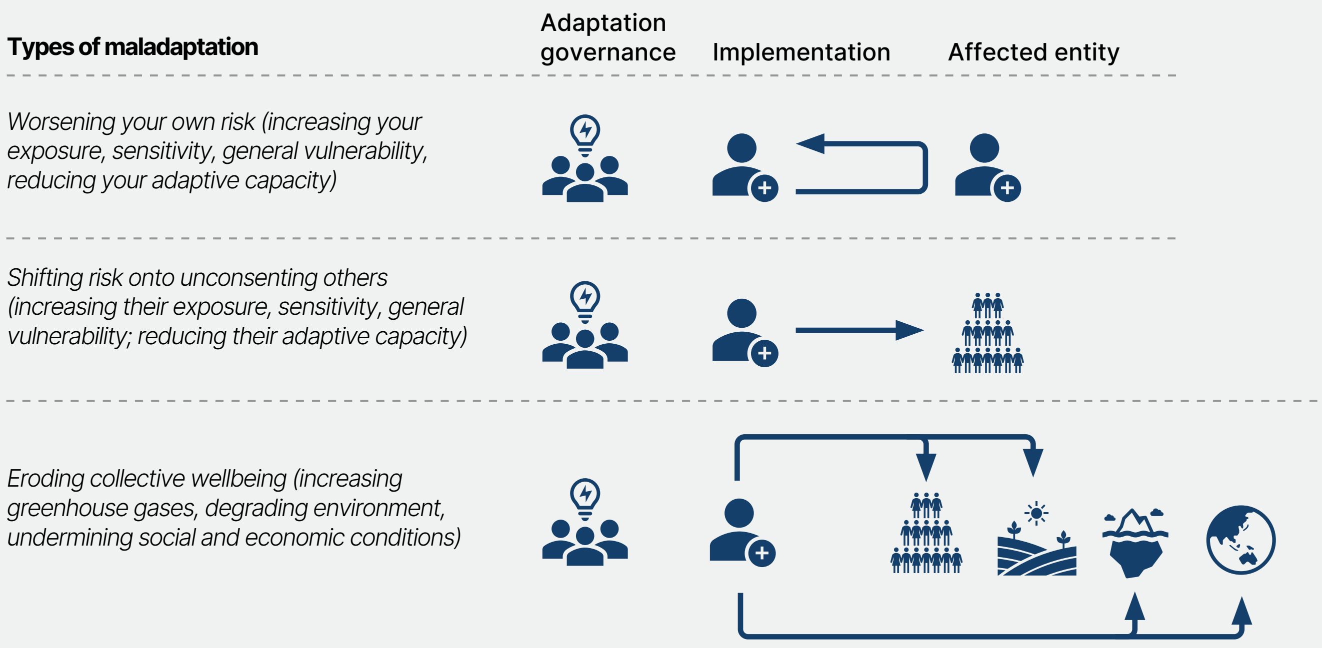
Climate change planning and policy do not necessarily translate to adequate adaptation action. Despite progress to date, there remains an adaptation action shortfall in every system, risk, jurisdiction and geography across Australia *(high confidence).*

- Planning for adaptation does not ensure that adaptation action will occur. Adaptation action is occurring in all systems; however, all systems have gaps in adaptation adequacy in terms of the currency of projects, the scale of action, the range of hazards being addressed, or the type of institutional response relative to governance responsibility and risks.
  Evidence: Governance Technical Report, Insights from the Adaptation Stocktake

Governance risk: Maladaptation and social tipping points

Governance influences whether adaptation occurs and how, and whether it successfully reduces risks from climate change and/or creates harms. Challenges to governance for existing adaptation efforts point to serious risks of maladaptation *(medium confidence).*

- Some adaptation actions are maladaptive in that they negatively impact those adapting, other people, jurisdictions or systems, or society as a whole (Figure 108). Comprehensive, systemic and future-oriented assessment of climate change risks and response risks is needed to avoid the likelihood of maladaptation and to expand the benefits of adaptation.
  Evidence: Governance Technical Report
- Maladaptive, fragmented and insufficient forms of adaptation are especially likely when entities or levels of governance use narrow reductive frameworks, focus on proximate concerns, neglect interactions with others, and do not actively engage in collaboration and coordinated action. A lack of information and understanding about emerging adaptation outcomes and their interactions worsens the risk of maladaptation.
  Evidence: Governance Technical Report



Note: Few adaptation efforts are perfect because we are learning as we go. The focus on maladaptation is primarily to try to avoid system harms (e.g. individualism).

Figure 108: Three types of maladaptation (Adapted from Juhola et al., 2016).

Governance structures and processes are being undermined by the pace, extent and intensity of climate change, and by their cascading, compounding and systemic effects *(medium confidence)*.

- Governance is being challenged by the pace, complexity and changeability of multiple climate change risks and others' emerging responses to them. This is forcing decision-makers to rapidly develop and implement adaptation initiatives while setting up new structures, incorporating new information and adapting to shifting circumstances.
  Evidence: Governance Technical Report
- Climate extremes and their intense, cascading effects are impacting governments and other entities, including not-for-profit organisations, reducing their capacity to deliver services. Direct impacts include harms to staff, damaged infrastructure, diversion of resources into disaster response and recovery, increased financial costs, lost income, legal liabilities and other complex flow-on effects (Gao, 2024; Steffen et al., 2019; Victorian Council of Social Services, 2024).
  Evidence: Governance Technical Report; Real Economy Technical Report; National Disasters and Emergency Management Technical Report
- Strains on government services, disaster response and recovery (Foote et al., 2024) can exacerbate impacts (O'Connor et al., 2023). This is combined with a perceived lack of transparency in some decision-making and planning (Climate Planning, 2020) which erodes trust and public confidence in government.
  Evidence: Governance Technical Report

Climate change has the potential to trigger social tipping points that result in positive and/or negative outcomes. There are signs of negative social tipping points emerging that could undermine adaptation and governance *(low confidence)*.

- Social tipping points are shifts in a system that trigger an abrupt, self-reinforcing change, with negative and/or positive outcomes. Social tipping elements push a system towards a tipping point. Undesirable social tipping elements include social inequalities that increase the likelihood of people being caught in a cycle of climate change impacts and risks. Desirable social tipping elements include social relations and interdependencies that generate chains of climate change adaptations.
  Evidence: Governance Technical Report
- Climate change can exacerbate cascading failures across different sectors, compounding social and environmental risks. A small change can result in a large consequence if there is strong reinforcing feedback within a system. Climate change can drive financial and physical cascades; for example, rapid-onset events (such as flood) and chronic changes (such as declines in surface water availability) can increase the cost of insurance or reduce business income. These events, combined with inadequate and poor adaptation, increase the likelihood that undesirable social tipping points are reached.
  Evidence: Governance Technical Report, Real Economy Technical Report
- There are signs of conditions associated with negative social tipping points starting to emerge in Australia. These include:
  - fatigue or overwhelm during recovery from extreme events (e.g. residents stating that they fear they could not cope during another repeat event) (Taylor et al., 2023); children experiencing heightened anxiety (NSW Government, 2022); and an increase in dependence on others for care (Kannan et al., 2021)
  - erosion of trust in governments (Australian Institute for Disaster Resilience, 2023)
  - increased inequality through the intersection of social disadvantage and disaster vulnerability, with under-resourced community service organisations bearing the brunt (van den Nouwelant & Cibin, 2022)
  - social fragmentation through displacement (Under2 Coalition, n.d.), trauma and disrupted livelihoods (NSW Government, 2022).
  Evidence: Governance Technical Report

Opportunities for intervention

The Australian governance system needs to enable better and faster adaptation. The governance system can achieve successful adaptation outcomes and co-benefits across various systems by recognising its role in generating risks and by deliberating on and designing governance for shared adaptation goals *(high confidence).*

- Stakeholder consultation identified that while decisions may be made in one system to reduce vulnerability, exposure or impacts, 92% of the time the impact of these decisions flow on to other systems. The greatest number of opportunities come from decisions in the Infrastructure and the built environment system (Figure 109). The Natural environment system is the recipient of most opportunities from decisions in other systems.
Evidence: Governance Technical Report

- For governance to protect and expand its role in generating successful adaptation outcomes, all types of governance need to adapt. A high-level process that reflects on current governance in the light of escalating systemic risks recognises the need for shared adaptation goals and positive collective outcomes, and collaboratively develops a plan for governing and supporting national adaptation. Building national-scale climate change impact assessments and adaptation pathways and outcomes into existing reporting such as the *Intergenerational Report*, the *State of the Environment Report* and *Measuring What Matters* frameworks would help to drive this process.
Evidence: Governance Technical Report

- A wide range of groups in Australia are using governance-based tools (e.g. developing new community-based entities or professional networks) and/or are trying to adjust governance settings to enable adaptation. Examples include the 2024 changes to the *Corporations Act 2001 (Cth)* that require large corporations to disclose climate change risks, and local government amendments to state- or territory-based planning schemes to better adapt to sea level rise in their jurisdiction (e.g. Mornington Peninsula Shire). The prevalence of 'institutional' climate change adaptation measures in the Adaptation Stocktake further indicates that people are actively engaging with governance structures and processes in their adaptation efforts.
Evidence: Governance Technical Report, Insights from the Adaptation Stocktake

- Developing a comprehensive understanding of the types of adaptation actions that are occurring currently is the first step in assessing adaptation progress. The next step is for governance institutions to collectively articulate the adaptation needs for systems and regions and to agree on measures of success for adaptation to build frameworks for evaluation and momentum for effective adaptation.
Evidence: Insights from the Adaptation Stocktake

Working with and learning from Aboriginal and Torres Strait Islander peoples would help guide adaptation towards more positive outcomes for all Australians *(high confidence).*

- Aboriginal and Torres Strait Islander traditional ecological knowledge has been passed down from generation to generation and continues until today. This has allowed Aboriginal and Torres Strait Islander peoples to live in symbiotic relationships with the land and water: 'We used it, we lived from it, we nurtured it' (quote from consultation participant, used with permission). As the world's oldest continuing culture and as custodians of the land and environment, Aboriginal and Torres Strait Islander peoples' use of Country was sustainable, continuing to today where it can be a model for more adapted living.
Evidence: Aboriginal and Torres Strait Islander Peoples Technical Report

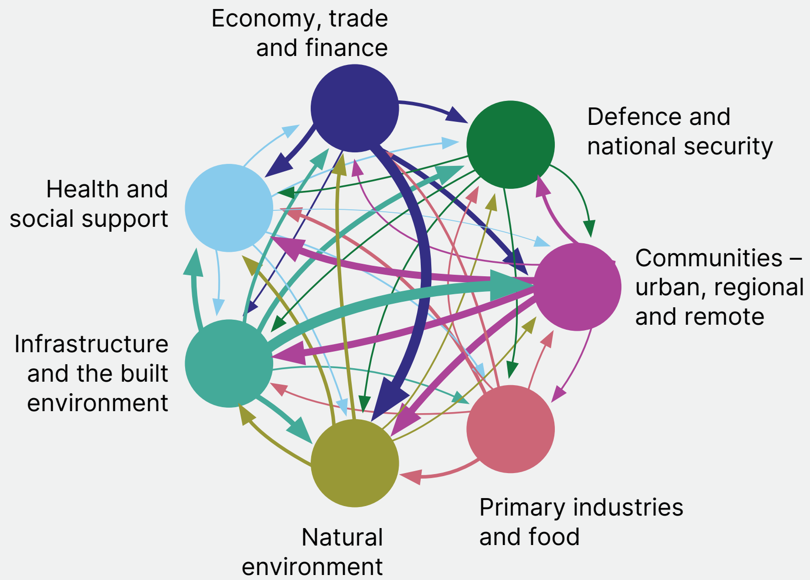


Figure 109: How decisions made in one National Assessment system can result in opportunities in another. *(Source: Governance Technical Report)*

Each arrow originates at the system where the decision is made and points towards the system that may benefit from opportunities. The weight of each arrow represents the number of interactions identified through stakeholder engagement workshops. The Aboriginal and Torres Strait Islander Peoples system engagement followed a different approach and is not represented in this data.

- Aboriginal and Torres Strait Islander communities and organisations across Australia deeply understand the rapid changes occurring on Country and the urgent need for adaptation and are already implementing numerous Caring for Country plans. Such efforts need to be amplified in order to continue this vital work of communities and organisations responding effectively to climate change. Resourcing is required to support the leading Aboriginal and Torres Strait Islander representative bodies, such as Local Aboriginal Land Councils, in developing climate change strategies. Representative bodies need support to engage members and develop localised, place-based strategies, including projection data on how their local Country could be affected.
  Evidence: Aboriginal and Torres Strait Islander Peoples Technical Report
- Robust decision-making mechanisms, such as the Aboriginal and Torres Strait Islander Peoples Clean Energy and Climate Change Advisory Committee, empower Aboriginal and Torres Strait Islander peoples' self-determination by ensuring they have a voice in critical decision-making processes. These mechanisms enable the integration of traditional and cultural knowledge into climate adaptation and mitigation strategies.
  Evidence: Aboriginal and Torres Strait Islander Peoples Technical Report
- The IPCC has identified that climate-resilient development is enabled when actors make inclusive development choices that prioritise risk reduction, equity and justice, and when decision-making processes are integrated (IPCC, 2022). Development is facilitated by working in partnership with traditionally marginalised groups such as Aboriginal and Torres Strait Islander peoples. These groups need to be supported by political leadership, resources and financing.
  Evidence: Aboriginal and Torres Strait Islander Peoples Technical Report

Governance structures, functions and processes need to enable adaptation that is proportional and timely relative to escalating climate-driven risks and carefully implemented to cultivate positive outcomes *(medium confidence).*

- Information and collaboration are needed to manage shared risks and to implement systemic adaptations. Climate change creates transboundary and systemic challenges that complicate governance. Enhancing clarity is crucial in order to identify conflicts and duplication of effort (Australian National Audit Office, 2024) and to improve the effectiveness and efficiency of adaptation.
  Evidence: Governance Technical Report
- Risk governance under climate change requires new approaches that better acknowledge complexity and uncertainty (Aven, 2011; Renn & Walker, 2008). Pathway approaches to climate change adaptation help to navigate the uncertainties, the interconnected, ongoing decisions, and the constant reappraisals and adjustments that climate change adaptation requires (Lawrence et al., 2020; Wise et al., 2014). This includes anticipating and planning for non-linear changes in circumstance and adaptation approach, such as a shift from trying to protect assets from hazards such as coastal erosion to relocating them to a less-exposed area (see *Case study: Managed retreat, Grantham*).
  Evidence: Governance Technical Report

Governance can help to accelerate, guide and innovate adaptation across Australia through tipping elements such as civic engagement, high-level direction and resolve, cascading adaptation decisions, and shared information and understanding *(medium confidence).*

- Governance responses to climate change can help drive positive social change. For example, the School Strike 4 Climate movement demonstrates how climate change awareness can mobilise communities, encourage youth leadership, heighten understanding of climate change threats, and generate proactive engagement with other governance tools such as holding decision-makers to account (Bright & Eames, 2022; O'Brien et al., 2018; Tattersall et al., 2022). Civic engagement in climate change responses (e.g. the Northern Rivers Community Resilience Alliance) helps to generate innovative and appropriate approaches, build more resilient and sustainable societies, cultivate hope and improve people's wellbeing (Otto et al., 2020).
  Evidence: Governance Technical Report
- Youth leadership in policy-making is important in climate adaptation as this has implications for current and future generations. This has mostly been quite limited in the past (Waite et al., 2024), although some forums exist to increase and encourage engagement (United Nations Climate Change, 2025).
- Embedding ambitious climate change adaptation goals into high-level governance frameworks is crucial for triggering effective adaptation efforts. However, the goals must be complemented by robust resource allocation, effective multi-level coordination and a commitment to ongoing learning.
  Evidence: Governance Technical Report
- Collaborative, transparent adaptation pathways informed by good-quality science can help to coordinate and drive adaptation by laying out a sequence and rationale for action, including tying certain responses to physical climate change indicators. Place-based adaptations such as managed retreat require negotiations of complex relationships between different entities and groups that can make adaptation difficult, but also trigger chains of cascading adaptation decisions as people respond to others' adaptations. Governance has a responsibility and an opportunity to steer these self-reinforcing processes in such a way that they generate positive transformational change.
  Evidence: Governance Technical Report

Case study:
Managed retreat, Grantham: A case of (partial) community relocation

Grantham is a small town in the Lockyer Valley of Queensland. In 2011, in the midst of wider tri-state floods, it suffered a devastating, unprecedented flash flood that killed 21 people and damaged nearly every house on the Lockyer Creek floodplain, 130 of them severely (ANU Institute for Climate, Energy & Disaster Solutions, 2023).

Combined with previous floods, the experience prompted the wholesale relocation of the town to nearby higher ground.

The move is frequently used to illustrate successful planned community relocation because of how swiftly and smoothly it occurred. Enabling this success was a combination of leadership, comradery and responsive institutions at multiple levels of government (Vermandé, 2021).

In the aftermath of the floods, the mayor of Grantham introduced an ambitious vision for relocation. The state government established the Queensland Reconstruction Authority which, among its wider work across the state, worked with the Lockyer Valley Regional Council to establish the Grantham Development Scheme and Grantham Reconstruction Area to streamline and fast-track planning approvals (Sipe & Vella, 2014). The Lockyer Council purchased an area of 120 lots and coordinated a land swap program for willing households and businesses.

Grantham after the floods. *(Source: used with permission of the Locker Valley Regional Council)*

A large, cross-disciplinary team from the Council and consultancies led the implementation of the relocation, working closely with the community to maintain social cohesion, manage their trauma, offer 'a clear and quick timeline' of one year, and intensively coordinate activities to make it a reality (Bergin & Piggott-McKellar, 2024). The design firm employed used an Enquiry by Design process to genuinely engage the community and incorporate their views. Through cooperation and persistent problem-solving the timeline was achieved, with the first home built on the new site within 11 months of the flood (Sipe & Vella, 2014).

The case illustrates how the post-disaster period can serve as a vital window of opportunity for the implementation of climate change adaptation if suitable enabling factors are in place. It also illustrates how a future-oriented adaptation process of pre-emptive managed retreat can facilitate community disaster recovery by offering people a positive vision and accelerating their return to homes. As the design firm director put it, 'It felt as though the optimism provided by the relocation planning tangibly contributed to the town's capacity to look ahead to recovery' (Richards, 2024).

The case underlines what can be achieved when existing institutions and leaders are responsive, resourceful and collaborative, when new fit-for-purpose groups and mechanisms are created, when intermediaries are used for sustained community engagement (Bower et al., 2024), and when the process is designed and implemented with care (Torabi & Dedekorkut-Howes, 2021).

At the same time, the case illustrates the extreme difficulties of attempting collective managed retreat in the midst of a disaster. While the relocation was largely successful, the process was costly at many levels. For those involved, including the project team, the whole experience was quite traumatising (Bergin & Piggott-McKellar, 2024), in part because of the speed of change (NSW Reconstruction Authority, 2024). The Council was also left with a large financial debt.

This case study and related evidence can be found in the Governance Technical Report.

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The Australian Climate Service has been established to provide improved data, intelligence and expert advice on climate risks and impacts to support decision-making. In an age of information and uncertainty, accurate and timely information is crucial for making proactive decisions that reduce risks and impacts.

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We are particularly proud of the Australian Climate Service National Climate Risk Assessment Taskforce, whose members exceeded expectations with their professionalism and support for each other. The capability built through this National Assessment is a testament to the hard work and collaboration across many teams and provides a solid foundation for supporting Australian decision-makers.

As we move forward, the Australian Climate Service is committed to improving access to integrated and trusted data and expert advice. By leveraging our efforts, we aim to enhance our understanding of Australia's vulnerabilities to climate change and extreme natural hazards, supporting better planning, response, risk reduction, mitigation and adaptation. The Australian Climate Service is committed to building on this work to provide quality authoritative information.

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The National Assessment has drawn on Esri, TomTom, Garmin, FAO, and USGS for base maps used throughout this report.

Appendix: National Assessment Technical Report abstracts

National Assessment Technical Report abstracts

Priority risk project	Abstract
Aboriginal and Torres Strait Islander Peoples Technical Report	Aboriginal and Torres Strait Islander peoples have been sustainably managing and adapting land, sea and Country for millennia; however, the changes being amplified by climate change are increasing the level of threat. Climate change disproportionately affects Aboriginal and Torres Strait Islander peoples, contributing to poor health and social and economic life outcomes. The focus on Aboriginal and Torres Strait Islander self-determination, cultural governance and place-based responses provides the foundation for Aboriginal and Torres Strait Islander peoples and Australia to respond and adapt to the impacts of climate change. Aboriginal and Torres Strait Islander peoples and communities have a strong voice and are committed to and actively engaged in addressing these challenges. *Reference:* Australian Climate Service. (2025). *Aboriginal and Torres Strait Islander Peoples Technical Report. A technical report for the National Climate Risk Assessment*. Australian Climate Service.
Air Quality and Communicable Disease Technical Report	The report examines the feasibility of future modelling of air quality associated with bushfires and the related impacts on the health system in 2050. It found that mortality, cardiovascular- and respiratory-related hospital admissions, and emergency department asthma presentations from air quality are likely to increase in 2050, with future bushfires adding to that burden. A study on communicable diseases showed that rising temperatures by 2050 could increase transmission of diseases such as influenza and methicillin-resistant Staphylococcus aureus. Preliminary modelling suggested climate change – induced temperature and rainfall changes could cause mutations in pathogens such as influenza and Japanese encephalitis virus. Reference: Boyle, J., Diouf, I., Emmerson, K., Golchin, M., Hickson, R., Kargarfard, N., Sexton, J., Shausan, A., Wilson, L., Wozniak, T., Yoon, J., Seabrook, S., & Jayasena, R. (2025). *Air Quality and Communicable Diseases Technical Report. A technical report prepared for the Australian Climate Service as part of the National Climate Risk Assessment*. CSIRO.
Australia's Future Climate and Hazards Report	In an increasingly warming world, Australia's climate hazards are changing. Climate science and modelling show that extreme weather is expected to behave differently compared with events of the past. Hazards may occur more frequently, with greater intensity or different characteristics, and multiple hazards may occur at the same time, causing wide-ranging impacts across the built, economic, social and natural environments. The Future Climate and Hazard Insights Report forms part of the Australian Climate Service evidence base supporting Australia's first National Climate Risk Assessment. It presents a national view of Australia's current climate and priority hazards, and how these are likely to change over the rest of the century under different global warming scenarios. *Reference: Australian Climate Service. (2025). Australia's Future Climate and Hazards Report. Australian Climate Service*
Australia's National Climate Risk Assessment: An Overview	Australia's first National Climate Risk Assessment provides a comprehensive analysis of the potential risks and impacts from a changing climate. It identifies risks across various sectors, including our economy, agriculture, health, infrastructure, and ecosystems, to inform policy and decision-making. A rapid assessment, undertaken in 2023 provided decision-makers with an initial understanding of 56 key climate risks to Australia. The second pass assessment in 2024 has validated and improved understanding and characteristics of these risks, particularly 11 priority risks, as well as the interactions between them and across different systems and sectors, to arm decision makers with more comprehensive information for planning and action. *Reference: Australian Climate Service. (2025). Australia's National Climate Risk Assessment: An Overview. Australian Climate Service.*

Climate and Communicable Disease Discussion Paper	The paper examines climate sensitivity in communicable diseases, offers a framework for assessing priority risks for Australia by 2050, and outlines essential research and analyses to understand these risks. Insights were compiled through desktop research and consultations with 57 experts from research, industry and government sectors. The report identifies mosquito-borne diseases as the most climate-sensitive. Diseases rated high or moderate in risk include avian influenza, dengue, Japanese encephalitis, melioidosis and salmonellosis. Key near-term priorities for analyses and investment are monitoring and surveillance activities. *Reference:* CSIRO. (2025). *Climate and Communicable Disease: Discussion paper*. CSIRO.
Climate Risks to Aboriginal and Torres Strait Islander Peoples	This report recognises Aboriginal and Torres Strait Islander peoples as a distinct and vital system within the National Assessment. It presents a summary of nationally significant climate risks and opportunities affecting Aboriginal and Torres Strait Islander peoples' health and wellbeing, food and water security, and economic livelihoods. Developed through co-design and culturally appropriate Gatherings, the report elevates Aboriginal and Torres Strait Islander voices and knowledges in national climate risk assessment and adaptation. *Reference: Australian Climate Service. (2025). Climate Risks to Aboriginal and Torres Strait Islander Peoples. Australian Climate Service*
Communities Technical Report	The report highlights the vulnerabilities of Australian communities to climate-driven risks, including sea level rise, heatwaves, bushfires, floods and tropical cyclones. Projections show that significant populations in the Northern Territory, Queensland and Western Australia are already living in high-risk zones, emphasising the need for climate resilience strategies. Many residential properties and small businesses face challenges in obtaining or affording insurance as risks escalate. Beyond physical damage, these hazards threaten social cohesion, cultural identity and local economic stability. The increasing frequency of extreme weather events worsens existing vulnerabilities, especially in major coastal cities and low-lying regions. *Reference:* Australian Climate Service. (2025). *Communities Technical Report. A technical report for the National Climate Risk Assessment.* Australian Climate Service.
Critical Infrastructure Technical Report	This risk assessment employs 2 approaches to evaluate the impact of climate risks on 3 critical infrastructure sectors: energy, transport and telecommunications. The Multi-Hazard Severity Score metric examines regions with changing hazard severities due to climate variability, using infrastructure datasets to assess severities at asset locations. Complementing this, a Social Cost metric quantifies the cost of infrastructure unavailability due to climate impacts, with a focus on the transport sector. Results indicate increasing climate-related risks to critical infrastructure, with varying risk profiles across asset classes and LGAs in Australia. *Reference:* Lee, G., Dennis, G., Cohen, R., Garg, N., & Prakash, M. (2025). *Critical Infrastructure Technical Report. A technical report prepared for the Australian Climate Service as part of the National Climate Risk Assessment.* CSIRO.

Governance Technical Report	This report investigates governance risk in relation to climate change impacts, responding to its identification as a priority risk in Australia's National Assessment. It explores the risk of maladaptation and inaction due to inadequate governance structures by considering the multifaceted interplay between adaptation, risk and governance. The report introduces new conceptual frameworks and empirical analyses, highlighting the need for strong governance to manage climate risks and enable adaptation effectively. Key findings include the importance of resourcing, clear roles and responsibilities, appropriate risk assessment, enhanced community engagement, and coordination across all levels of governance to address the complex and dynamic nature of climate change risks. *Reference:* Rickards, L., Webb, J., Houghton, S., Fünfgeld, H., Juhola, S., Constable, A., Barry, N., T, D., F, Y., Kreyscher, K., Raisele., K., & Larin, T. (2025). *Governance Technical Report. A technical report for the National Climate Risk Assessment.* Australian Climate Service.
Health and Wellbeing Technical Report	Australia is facing significant health and wellbeing risks from various climate hazards, which are likely to become more severe. This project provides new insights into current and future health risks and outcomes related to heatwaves, tropical cyclones, riverine flooding and bushfires. It includes hazard-specific indicators and analyses to understand how health risks and outcomes are distributed spatially and across society. The project also examines complex risk factors and determinants of health, showing how they combine to shape health outcomes. *Reference:* Beaty, M., Rokeya, A., Donovan, J., Haque, S., Jones, F., Lin, A., Nazmul, R., Prescott, V., Zhou, K., Benger, N., Bertinshaw, J., Black, M., Byrne, T., Cao, K., Cash, C., Coetzee, L., Dowse, E., Etherington, C., Halstead, I., Jacobs, S., Nairn, J., Schrader, I., Troup, M., Varghese, B., Wong, D. (2025). *Health and Wellbeing Technical Report. A technical report for the National Climate Risk Assessment.* Australian Climate Service.
Insights from the Adaptation Stocktake	This report presents findings of a systems-based analysis of the *Australian Adaptation Stocktake*, undertaken in partnership with the National Environmental Science Program's (NESP) project Enabling Best Practice Adaptation. The analysis draws on a novel Adaptation Stocktake of over 670 examples of adaptation policies, plans, projects and actions across local, state and national scales in Australia, enabling comparison of progress across scales, sectors and systems and providing information on the types of hazards being addressed by adaptation, and the aims of adaptation projects. The report concludes that in order to evaluate the effectiveness of adaptation, it is critical for governance institutions to articulate adaptation needs and establish measures of success for adaptation. *Reference:* Waters, E., Brullo, T., Miranda, A., Bagot Jewitt, S., Gmeiner, K., Sabdia, F., Boulter, S., & Barnett, J. (2025). *Insights from the Adaptation Stocktake. A technical report for the National Climate Risk Assessment.* Australian Climate Service.
National Disasters and Emergency Management Technical Report	Australia's national disasters and emergency management aims to safeguard resilience, wellbeing and prosperity. This report highlights climate-driven risks, identifying at-risk locations affected by heatwaves, bushfires, floods and cyclones. Climate change increases strain on essential services, supply chains and public health, with challenges posed by Australia's vast geography and ageing volunteer workforce. Successive compounding events further stretch resources, necessitating Australian Defence Force assistance. Strengthened coordination, risk assessment, and adaptation strategies are essential for future resilience as Australia faces a changing climate. *Reference:* Australian Climate Service. (2025). *National Disasters and Emergency Management Technical Report. A technical report for the National Climate Risk Assessment.* Australian Climate Service.

Natural Ecosystems Technical Reports	Australia's natural environment is highly exposed and vulnerable to climate change across the land and sea country. The magnitude of predicted change takes us outside the conditions to which most of our native species have adapted. This creates an uncertain future for our ecosystems which, when combined with the many indicators of decline from other pressures, creates a plausible risk of collapse of one or more fundamental ecosystem processes. Rapid action to both reduce emissions and halt and reverse nature loss is recommended to limit the impacts of climate on our natural environment and the services it provides. The Natural Ecosystems assessment is delivered through 4 separate technical reports and one appendix: • Natural Ecosystems Technical Report: Synthesis. *Reference:* Nicol, S., Bergstrom, D., Austin, J., Bollard, B., Brody, S., Brooks, S., Bugnot, A., Bustamante, R., Dunstan, P., Ferrier, S., Fulton, B., Herr, A., Liedloff, A., Marvanek, S., Mokany, K., Prober, S., Richards, A., Stratford, D., Vickers, M., ... Woolley, S. (2025). *Natural Ecosystems Technical Report: Synthesis. A technical report prepared for the Australian Climate Service as part of the National Climate Risk Assessment.* CSIRO. • Natural Ecosystems Technical Report: Freshwater. *Reference:* Herr, A., Stratford, D., Marvanek, S., Austin, J., & Nicol, S. (2025). *Natural Ecosystems Technical Report: Freshwater. A technical report prepared for the Australian Climate Service as part of the National Climate Risk Assessment.* CSIRO. • Natural Ecosystems Technical Report: Marine. *Reference:* Bugnot, A., Woolley, S., Brodie, S., Bustamante, RH Dunstan, P., Richardson, AJ Blanchard, J., Blamey, L., & Fulton, E. (2025). *Natural Ecosystems Technical Report: Marine. A technical report prepared for the Australian Climate Service as part of the National Climate Risk Assessment.* CSIRO. • Natural Ecosystems Technical Report: Terrestrial. *Reference:* Liedloff, A., Austin, J., Bergstrom, D., Brooks, S., Marvanek, S., Prober, S., Vickers, M., Williams, K., Bollard, B., Ferrier, S., Mokany, K., Richards, A., & Nicol, S. (2025). *Natural Ecosystems Technical Report: Terrestrial. A technical report prepared for the Australian Climate Service as part of the National Climate Risk Assessment.* CSIRO. • Natural Ecosystems Technical Report: Terrestrial Appendix. *Reference:* Liedloff, A., Williams, K., Vickers, M., Marvanek, S., Brooks, S., Nicol, S., Prober, S., Bergstrom, D., Austin, J., Bollard, B., Ferrier, S., Mokany, K., & Richards, A. (2025). *Natural Ecosystems Technical Report: Terrestrial Appendix. Supplementary details relating to the Terrestrial Technical Report prepared for the Australian Climate Service as part of the National Climate Risk Assessment.* CSIRO.
Primary Industries Technical Report	Australia's primary industries operate across the country and surrounding seas and are exposed to changes in the climate. This assessment focuses on climate conditions that impact productivity for broadacre cropping, horticulture, forestry, livestock, fisheries and biosecurity. Future productivity is likely to be impacted by climate change across many industries and many regions, and impacts are generally expected to increase with increasing global warming. Impacts from changes to temperature extremes, such as increased marine heatwaves, more livestock heat stress days, increased risk of crop heat damage, increased overwintering of pests, and lower cold exposure are likely. For most growing regions, it is projected that water demand will increase via increased evapotranspiration. *Reference:* Darbyshire, R., Blamey, L., Bolt, A., Brodie, S., Buhagiar, L., Bustamante, R., Greenwood, S., Holzworth, D., Hopper, M., Huth, N., Keogh, T., Mayberry, D., Nidumolu, U., Paroz, A., Rich, J., Rosauer, D., Roxburgh, S., Thomas, I., & van Herwaarden, A. (2025). *Primary Industries Technical Report. A technical report prepared for the Australian Climate Service as part of the National Climate Risk Assessment.* CSIRO.
Real Economy Technical Report	This report consolidates the various analyses and results that informed the Economy, trade and finance system, the relevant priority risk and other systems and risks in the National Assessment. The Australian economy is diverse but also concentrated in terms of physical industrial activities and locations. It is therefore unevenly susceptible to the impacts of physical climate risks across industries and regions. Extreme and sudden weather events are increasing in frequency and severity, making impacts more intense. Impacts on our highly interconnected economic system are specific and depend on the nature of each event. Severe impacts may become difficult when the economy is driven beyond its capacity to recover. *Reference:* Australian Climate Service. (2025). *Real Economy Technical Report. A technical report for the National Climate Risk Assessment.* Australian Climate Service.

Supply Chains Technical Report	From 2021 to 2024, extreme weather events severely disrupted Australian supply chains, affecting production and market operations. This report modelled future supply chain impacts from population growth and extreme flooding using the Transport Network Strategic Investment Tool (TraNSIT), offering insights into supply chain dynamics in key sectors such as food, fuel and medicines. Analysis revealed that regional and remote area supply chains are the most vulnerable to extreme weather, with continued vulnerability projected for 2050 and 2090. Freight often fails to reach destinations or faces significant delays. Critical commodities such as medicines and horticultural products are expected to experience greater impacts. *Reference:* Higgins, A., Tong, M., Islam, Z., Marquez, L., & McFallan, S. (2025). *Supply Chains Technical Report. A technical report prepared for the Australian Climate Service as part of the National Climate Risk Assessment.* CSIRO.
Water Security Technical Report	Future climate risk to Australia's water security is extreme. Projected continued widespread declines in rainfall and streamflow, a more variable climate, and extensive dry conditions will coincide with warming that raises evaporation, reducing soil moisture, runoff and groundwater recharge. Increased severe floods and bushfires will further degrade water quality, straining already limited water sources. Every region will face serious water security challenges, with natural environments enduring the most severe impacts. Effective water management will be one of few adaptation measures to mitigate ecosystem function risk. Water scarcity will threaten primary industries and remote communities, posing risks to food security and regional economies. *Reference:* Matic, V., Bende-Michl, U., Seifollahi Aghmiuni, S., Faulkner, C., Chatterji, S., Lowe, J., Harkin, A., Oke, A., Johnston, E., Gao, D., Lintern, A., Ispording, R., & Sidiqui, P. (2025). *Water Security Technical Report. A technical report for the National Climate Risk Assessment.* Australian Climate Service.

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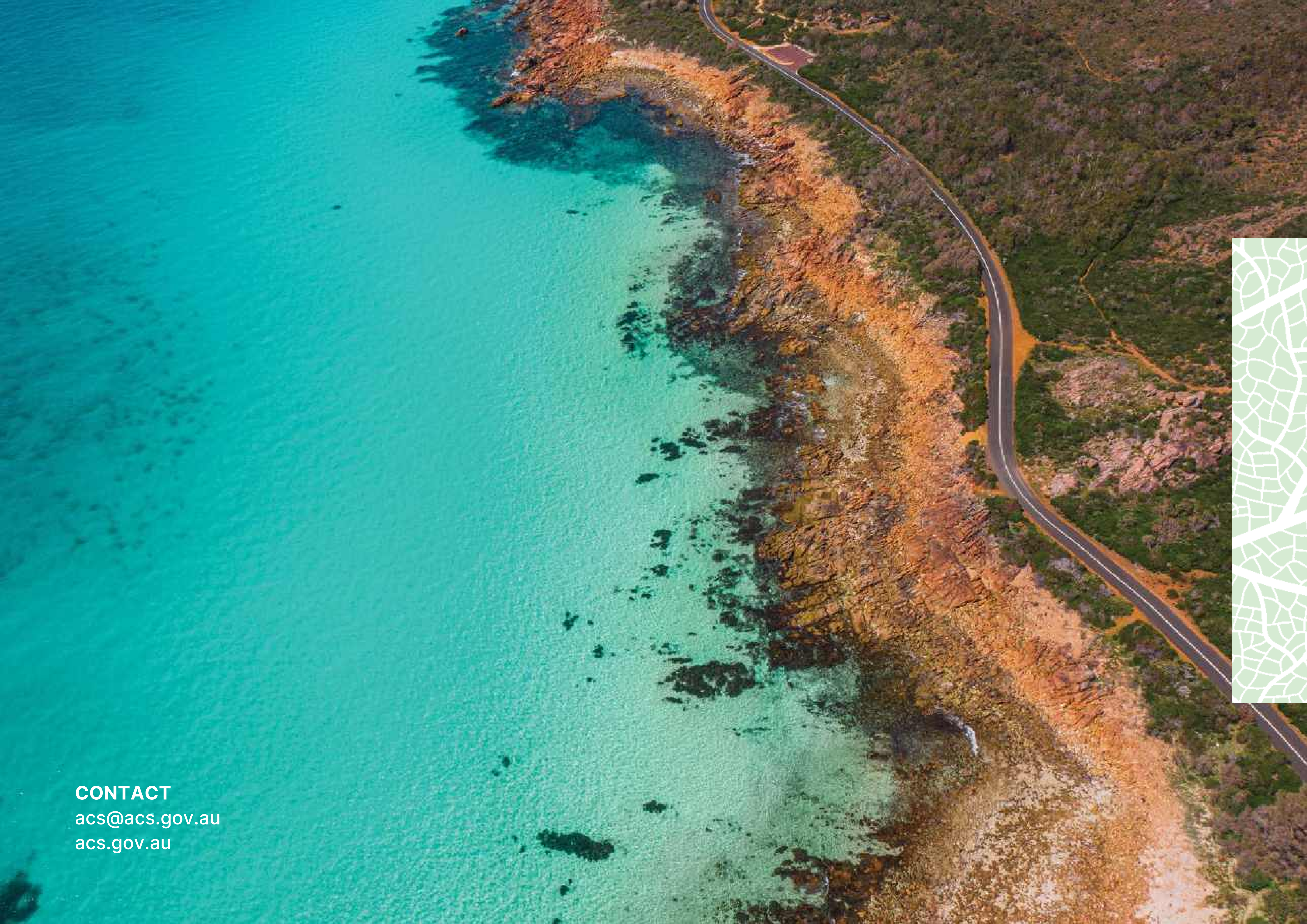

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