RESILIENT HILLS & COASTS

# Bushfire & Biodiversity
# **Part A: Literature Review**

*"Political has dominated the fire world for several decades and is based on perceptions and beliefs"*

Dr Kevin Tolhurst AM

Prepared for Resilient Hills & Coasts by the Nature Conservation Society of South Australia

# Acknowledgements and citation


## First Nations people

Resilient Hills & Coasts partners acknowledge the traditional owners of the lands and waters of the Adelaide Hills, Fleurieu Peninsula and Kangaroo Island. We acknowledge the deep feelings of attachment and the relationship of Aboriginal people to country, and respect their ongoing custodianship.

## Governance and contributions

This literature review is one of three milestones (Part A), delivered by the Resilient Hills & Coasts Bushfire and Biodiversity Project. The other deliverables from this project include:

- Part B: Spotlight Studies
- Part C: Discussion and Recommendations.

The project was governed by the Resilient Hills & Coasts Steering Committee, with additional direction provided by the project's Working and Advisory Groups (see table below). The project was managed and overseen by the Resilient Hills & Coasts Coordinator Olivia Davies, and later Jen St Jack. The table below lists the people that were involved.

| Representation | Organisation or group | Person |
|---|---|---|
| Working Group | Adelaide Hills Council<br>Alexandrina Council<br>Kangaroo Island Council<br>Mount Barker District Council<br>District Council of Yankalilla<br>City of Victor Harbor<br>Southern and Hills Local Government Association<br>Resilient Hills & Coasts<br>Landscapes Hills and Fleurieu<br>Landscapes Kangaroo Island<br>Regional Development Australia Adelaide Hills, Fleurieu and Kangaroo Island | Tonia Brown and Andrew Kirkley<br>Monika Rhodes<br>Anna Osman<br>Greg Sarre<br>Corey Jackson and Amy Williams<br>Lee Jeffery<br>Graeme Martin<br>Olivia Davis and Jen St Jack<br>Che Biggs and then Caroline Dorr<br>Will Durack<br>Sue Arlidge |
| Advisory Group | Adelaide Hills Council<br>Department for Environment and Water<br>Resilient South<br>South Australian Country Fire Service<br>South Australian State Emergency Service<br>Native Vegetation Council | Pia Charlton<br>Jason Higham and Damon Ezis<br>Stefan Caddy-Retalic<br>Aidan Galpin<br>Dave O'Shannessy<br>Adam Schutz |
| Consultant and project delivery | Nature Conservation Society of South Australia | Bec Duffield, Kirsty Bevan, Nicole Fickling, Tessa Roberts, Elen Shute, Rhys Morgan |

## Content development and reviews

Resilient Hills & Coasts engaged the Nature Conservation Society of South Australia (NCS) as the consultant to develop and deliver the project milestones. The NCS undertook the research and content development, with advice from the Working and Advisory Groups. The NCS worked closely with Resilient Hills & Coasts Coordinators Olivia Davies and Jen St Jack. Draft versions of all documents were provided to the Steering Committee, the Working and Advisory Groups and other stakeholders, on account of their knowledge and expertise. The following people are further acknowledged.

- The NCS Project Lead Bec Duffield and the NCS Research Team Nicole Fickling, Tessa Roberts, Elen Shute and Rhys Morgan. The NCS CEO Kirsty Bevan is appreciated for her review and QA of all deliverables.
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## Version

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## About Resilient Hills & Coasts

Resilient Hills & Coasts (RH&C) is a collaborative, cross-sector partnership in the Adelaide Hills, Fleurieu Peninsula and Kangaroo Island region, working to strengthen the resilience of communities, economies and natural and built environments to a changing climate.

Members of the partnership include six councils (Adelaide Hills, Alexandrina, Kangaroo Island, Mount Barker, Victor Harbor and Yankalilla); the Southern Hills Local Government Association; two Landscape Boards (Kangaroo island Landscape Board and Hills and Fleurieu Landscape Board); Regional Development Australia (RDA) Adelaide Hills, Fleurieu and Kangaroo Island; and the Government of South Australia (Resilient Hills and Coasts, 2020).

The RH&C region covers 8,752km$^2$ and includes a mixture of farming, conservation, and residential land uses, within rural, semi-rural, urban, and peri-urban settings.

## Language statement

The term 'First Nations people' has been used when referring to Australia's first people (AIATSIS n.d.). The term 'Indigenous' has been used as it relates to fire management by First Nations people, as this was the description provided through foundational and supporting literature. It is recognised that this term may not reflect the diverse culture, language, family groups, beliefs, and practices.

## Abbreviations

| Abbreviation | Name |
|---|---|
| RH&C | Resilient Hills & Coasts |
| RH&C SC | Resilient Hills & Coasts Steering Committee |
| BMCs | Bushfire Management Committees |
| LGA | Local Government Authority (Councils) |
| NCS | Nature Conservation Society of South Australia |
| SA | South Australia |
| MLR | Mount Lofty Ranges |
| DEW | Department for Environment and Water |
| CFS | Country Fire Service (South Australia) |
| SAFECOM | South Australian Fire Emergency and Community Services |
| NVC | Native Vegetation Council |
| NVB | Native Vegetation Branch |
| CRC | Cooperative research centre |
| EPBC | Environment Protection and Biodiversity Act |

## Definitions

| Term | Meaning |
|---|---|
| Resilient Hills & Coasts region | The Adelaide Hills, Fleurieu Peninsula and Kangaroo Island region. |
| Resilient Hills & Coasts | A collaborative, cross-sector partnership in the Adelaide Hills, Fleurieu Peninsula and Kangaroo Island region, working to strengthen the resilience of communities, economies and natural and built environments to a changing climate. |
| Spotlight study | The specific studies developed by the RH&C Bushfire and Biodiversity project |
| Wildfire | For the purpose of this document, a wildfire means the same event as a Bushfire. It is unplanned and ignited deliberately or through natural causes. |
| Bushfire | A bushfire is an unplanned fire event that can be ignited deliberately or through natural causes. |

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## Attachments

# 1. Introduction

This literature review investigates and summarises information on bushfire and biodiversity legislation and governance, fire ecology, First Nations fire management, the relationship between fires and biodiversity, community resilience, climate change and the impact that this will have on biodiversity resilience. An additional section (section 8) is provided that summarises recent research findings following the 2019-2020 bushfires in the region.

### *Climate change as a driver of extreme conditions and biodiversity loss*

Climate change is increasingly being recognised as one of the biggest crises to face the world (United Nations n.d), with no country unaffected by the consequences of global warming, increased carbon dioxide, and rising sea levels (United Nation n.d, IPCC 2021). The realism of climate change is largely uncontested by scientists, with overwhelming support that it is predominately accelerated and driven by anthropogenic drivers (Gill, 2012; Nunez et al., 2019; van Oldenborgh et al., 2021; A. P. Williams et al., 2019). In acknowledgement that climate change is a significant event, with catastrophic consequences that are predicted to intensify and become more frequent, widespread, and disastrous, 40 countries (comprising 2319 jurisdictions) have declared a climate emergency (United Nations n.d, IPCC 2021).

As a result of climate change, Australia is getting hotter and drier (Bureau of Meterology, n.d.; CSIRO, 2020a; Gill, 2012; Trewin et al., 2021) as demonstrated by the millennium drought and the unpredictable weather events that have resulted in devastating storms, floods, and fires (Bureau of Meterology & CSIRO, 2022; T. Penman et al., 2023). The bushfire risk is further amplified by conversion of landscapes (T. Penman et al., 2023); expanding peri-urban settlements (the urban-rural interface) and an increased population (Bardsley et al., 2015, 2018; Gill, 2012); higher fuel loads from weed species (Setterfield et al., 2013; Walker & Morgan, 2022); and suppression of Indigenous fire management in some parts of the country (Bardsley et al., 2019; T. Penman et al., 2023; Rumpff et al., 2023; Williamson & Weir, 2021).

In addition to the climate change emergency, there is recognition of an emerging crises on the natural world; specifically biodiversity, due to population growth and development, land use, resource exploitation, habitat clearance and fragmentation, pollution, invasive species and disease and dieback (Australian Government, 2022; Gill, 2012; Greenfield, 2022; H. Murphy & van Leeuwen, 2021). The International Union for Conservation of Nature forecasts that currently 28 percent of species are threatened with extinction worldwide (IUCN n.d), and Australia, with one of the highest extinction rates in the world (Australian Government, 2022), has 1,790 species that are currently identified as threatened with extinction (Ecological Society of South Australia 2019). Human induced climate change is also intensifying and exacerbating the stress on Australia's biodiversity assets, specifically through bushfires and extreme weather events. While climate change can impact on nature and biodiversity's state and condition, biodiversity is also viewed as a "natural solution" that can mitigate against climate change by providing ecosystem services and carbon sequestration and storage (Greenfield, 2022; Searle & Chen, 2018; United Nations Framework on Climate Change, n.d.).

### *From the 2019-2020 Black Summer bushfires and into the future*

After a severe drought and increasing temperature, Australia was impacted by a bushfire season during the summer of 2019-2020 that was unprecedented in geographic scale, intensity, and duration. South Australia suffered tremendous loss from these bushfires (hereafter called 2019-2020 bushfires) with three human deaths, 196 homes destroyed, 68,000 livestock perished and 280,000 hectares burnt

(Government of South Australia, 2020a). The effect on biodiversity was concerning as forty threatened (at the state level) plant and animal species had half of their known habitat destroyed (Government of South Australia, 2020b).

Australia is prone to natural hazards such as bushfires (Commonwealth of Australia, 2020; CSIRO, 2020b) with some vegetation communities and biota having adapted, or able to recover from burns, depending on the scale, intensity and frequency of the fire (Gallagher et al., 2023; Rumpff et al., 2023). However, there are also ecological communities and biodiversity assets that are fire sensitive and less able to survive and recover post-burn — either due to the fire itself (Gallagher et al., 2023) or emerging threats after the fire (such as predation and weed invasion) (Legge, Duncan, et al., 2023). Likewise, the ecological benefits of a prescribed and controlled burn is also variable as some species will respond favourably (D. A. Taylor, 2019; Trezise et al., 2022), while others demonstrate a decline (Pastro et al., 2011; Prowse et al., 2017).

As the intensity and frequency of bushfires is likely to increase with the effects of climate change (The Royal Commission into National Natural Disaster Arrangements, 2020b) and the ignition, spread and intentisy of fires is often difficult to manage (as it is influenced by fuel, topography and weather), there is a need for strategies that focus on bushfire mitigation and preparedness. Equally as important, is identifying risks to biodiveristy (including bushfire management) to prevent further loss and extinctions. Some of the approaches for integrating biodiversity and bushfire prevention (via reduced fuel load) include prescribed burning and fire management by Indigenous fire practitioners (Firesticks Alliance, n.d.; Hoffman et al., 2021; Steffensen, 2020). It has also been argued that prescribed burning does not offer value for biodiversity at a landscape scale (Pastro et al., 2011; T. D. Penman et al., 2006; Prowse et al., 2017) , or it does not demonstrably influence the area of a bushfire (Campbell et al., 2022).

### *Impacts and resilience within South Australian regional communities*

The local government (council) areas of Kangaroo Island, Adelaide Hills, Mount Barker, Alexandrina, Yankalilla, and Victor Harbour are part of a cross-agency climate partnership agreement that aims to "strengthen the climate resilience of communities, economies and natural and built environments" (Resilient Hills & Coast 2022). There are significant and unique biodiversity assets within the region that represents the six councils. As an example, the Adelaide Mount Lofty Ranges (MLR) is a renowned biodiversity hotspot, currently nominated for World Heritage listing, that includes the Resilient Hills & Coasts council regions of Adelaide Hills, Alexandrina, Mount Barker, and Yankalilla (Marshall & Am, 2019). However, biodiversity and fire management in the MLR, for single or multiple outcomes, is challenging as the region is modified and highly fragmented, populated by a range of demographic groups with different values and needs, and has a growing peri-urban (urban to rural interface) footprint. Also, the 2019-2020 bushfires included the local government (council) areas of Kangaroo Island, Adelaide Hills, and Mount Barker, with devastating effects on each of these communities. Gill et al. (2014), expressed this regions complexity "the AMLR exhibits in microcosm many of the challenges faced by conservation managers in the wider fire-prone world — increasing human populations, changing atmospheric composition, changing climate, changing fire regimes, changing land uses and increasing land use intensity—resulting in the loss of biodiversity and increasing numbers of naturalised species".

# 2. Strategic context

## 2.1 Bushfire management

For the purpose of this literature review, bushfire management includes the four key phases of the Australian Governments 'Australian Emergency Management Arrangements 2019' (Australian Institute for Disaster Resilience, 2019) 'Prevention, Preparedness, Response and Recovery'. Strategic bushfire management aims to bring together a range of stakeholders, with vested interest and influence, to establish agreed objectives for managing bushfires within the landscape (Victorian Government Safer Together, n.d) and for "improved coordination and collaboration across government, and non-government organisations and with the community, and improving understanding of the shared responsibility we all have to manage bushfire risk in South Australia" (Government of South Australia, 2021).

The four key phases of bushfire management are demonstrated as Figure 1, with the inclusion of an additional element, 'Monitoring, Evaluation, Reporting and Identifying Improvements'. Prevention focuses on strategies for reducing or eliminating the impact of a bushfire hazard on communities and economies, and it is usually directed by key legislation and policies. It is defined by the Australian Institute for Disaster Resilience as "All activities concerned with minimising the occurrence of incidents, particularly those of human origin. Regulatory and physical measures to ensure that emergencies are prevented, or their effects mitigated. Measures to eliminate or reduce the incidence or severity of emergencies". It is noted by the Country Fire Service (CFS) that prevention of bushfires is not always possible, however "mitigation activities can be undertaken to reduce the likelihood, vulnerability, and consequences" (Government of South Australia, 2021). Bushfire preparedness involves a range of stakeholders to implement strategic actions before a bushfire occurs, to reduce the impact, extent, and severity of the fire. This includes ensuring that if a bushfire occurs, there are adequate arrangements and firefighting services deployed during the event (Government of South Australia, 2021). This includes a range of different preparations such as emotional and psychological, systems and processes, and material and physical. Response is the immediate actions that are needed in reaction to a bushfire event, to protect life, property and the environment (Australian Institute for Disaster Resilience, 2019). In terms of responding to a bushfire, CFS is the hazard leader and control response agency for bushfires in the RH&C Bushfire Management Areas of Kangaroo Island, Fleurieu and Adelaide and Mount Lofty Ranges. The CFS firefighting is supported by the "South Australian Metropolitan Fire Service (MFS), Department for Environment and Water (DEW), Private Farm Fire Units, South Australian Police, local government and a wide range of government and non-government agencies" (Government of South Australia, 2021). The bushfire recovery phase is the planned work that is required to rebuild and re-establish infrastructure, homes, livestock and the environment, after a bushfire event. It also involves identifying health risks to people, both physical and emotional.

As Figure 1 illustrates, many of these stages have feedback loops into other stages. The learnings from response and recovery can be fed back into the preparedness and prevention to enable future improvements. An overarching 'monitoring, evaluation, reporting and identifying improvements' stage occurs after the event, and considers all four components. Examples of this include independent reviews and parliamentary inquiries or agency specific evaluations.

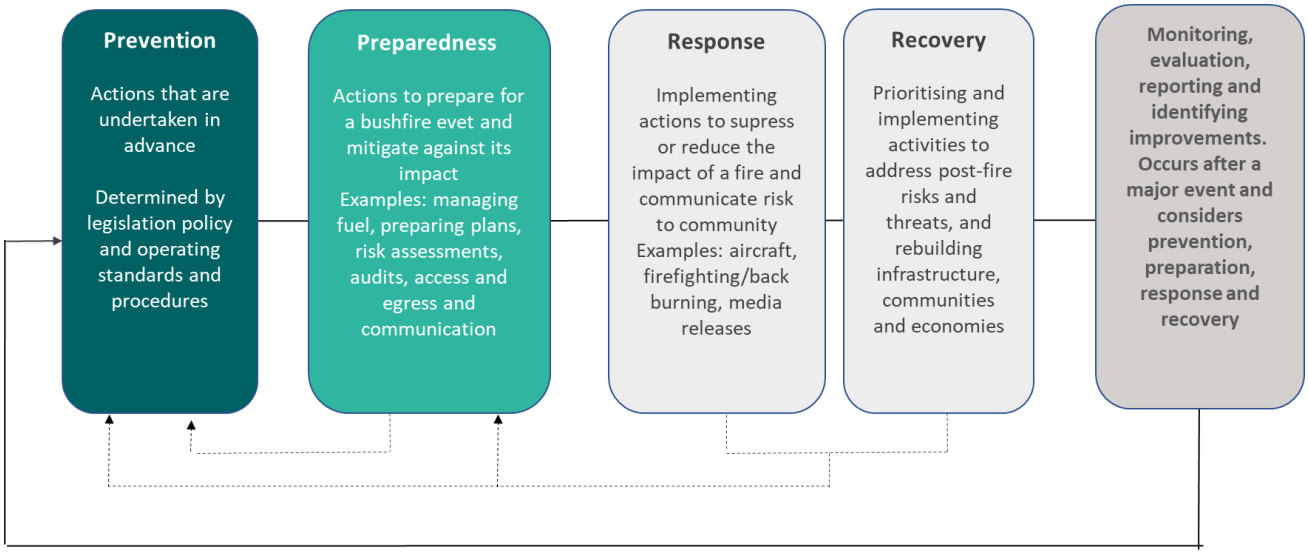


Figure 1: The key stages of bushfire management, Diagram was produced by Nature Conservation Society of SA and based on a schematic provided by Damon Ezis (DEW) during stakeholder engagement.

This RH&C project is focussed on bushfire preparedness, and the types of activities that households and community can undertake to be better prepared, while still ensuring the protection and improvement of biodiversity assets.

## 2.2 Governance and Legislation

### *National level*

Emergency management legislation at the federal level includes the *Defence Act 1903* and the National Emergency Declaration Act 2020. This legislation is supported by the Australian Government's Australian Disaster Preparedness Framework, National Disaster Risk Reduction Framework and First National Action Plan.

At a national level, the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is the key legislation for protecting Australia's threatened species – see here. This is Australia's national environment law to regulate activities that are likely to have a significant impact on national protected matters (threatened species and ecological communities).

Although the South Australian government has the primary responsibility for its environmental assets and implementation of fire management (suppression and prevention), some activities may require approval under the EPBC Act if the proposed action will either have a significant impact on matters of national environmental significance (MNES) or the action is not exempt under EPBC Act. On advice from the Threatened Species Scientific Committee in 2022, inappropriate fire regimes have been identified as a threating process under this national legislation to the survival of over 800 species and 65 threatened ecological communities (also see section 5) .

Some activities that are listed as not requiring approval include:

- Those that have been approved or authorised under South Australian legislation before the commencement of the EPBC Act
- Land uses that occurred before the commencement of the EPBC Act, as long as this activity has not been enlarged, expanded or intensive after July 2000. This includes maintaining access and fire breaks, roadside weed control, control burns, and maintaining infrastructure

- Those that are in accordance with the endorsed strategic assessment policy, plan or program under national environment law
- Those that are declared to not need approval in an approved conservation agreement, under environmental law.

An ambiguous exemption under EPBC Act is the permission to undertake an activity that is "otherwise declared by the federal environment minister". It is not clear what types of activities they could be, or what justification and evidence is required, for the Minister to make such a declaration.

The Australian government also provides a list of fire prevention activities that are ***unlikely*** to require approval under EPBC Act. These have been listed in Table 1 and include "bushfire management activities carried out by state and territory governments, local councils, other authorities such as fire and emergency services, and individuals". It is unclear what other agencies, such as the South Australian Power Network, are considered as "other authorities".

Table 1: Activities that are unlikely to require approval under EPBC Act

| Unlikely to require approval under EPBC Act | Notes |
|---|---|
| Routine fuel reduction burns, including roadside burns, done in accordance with state or territory law requirements. | To be guided by South Australian legislation – *Native Vegetation Act 1991* and *Fire and Emergency Services Act 2005*. |
| Routine maintenance of fence lines, access roads or tracks. | Potential risk of overambitious clearing to maintain areas. |
| Routine maintenance of existing fire breaks, fire infrastructure, services and utilities. | Potential risk of overambitious clearing to maintain areas. |
| Replacing sheds or other infrastructure at the same site. | Potential risk of impacting on biodiversity value via the asset protection rules. |
| Localised weed control by hand or machinery. | None noted. |
| Minor sediment and erosion preventative works and repairs. | Potential risk of impacting on biodiversity value. |
| Clearing of a defendable space around a home or rural asset in accordance with state/territory and local government requirements. | Potential conflict if the area requiring clearance supports threatened species or threatened habitat and the science about the "defendable" is contested. |

### *South Australian level*

The South Australian government has the primary responsibility for protection of life, property and the environment, however, support can be provided through the Australian Government's National Emergency Management Agency (NEMA). The *Fire and Emergency Services Act 2005* and the *Emergency Management Act 2004* are South Australia's primary legislation for bushfire prevention, preparation, response and recovery. Under the *Fire and Emergency Service Act 2005*, bushfire management is coordinated through the State Bushfire Coordination Committee (SBCC) and nine Bushfire Management Committees that represent specific areas – see Figure 2). Within the RH&C footprint, there are three Bushfire Management areas – Kangaroo Island, Adelaide and Mount Lofty Ranges and the Fleurieu. It is noted that the function of the SBCC is supporting coordination and not implementation of the actions specified within bushfire plans (notably the States Bushfire Management Plan and Bushfire Management Area Plans). The South Australian Management Framework clearly identifies CFS as the hazard leader and control agency for rural fire within South Australia (Government of South Australia, 2021). The CFS also provides executive support to the State Bushfire Coordination Committee and the Bushfire Management Committees.

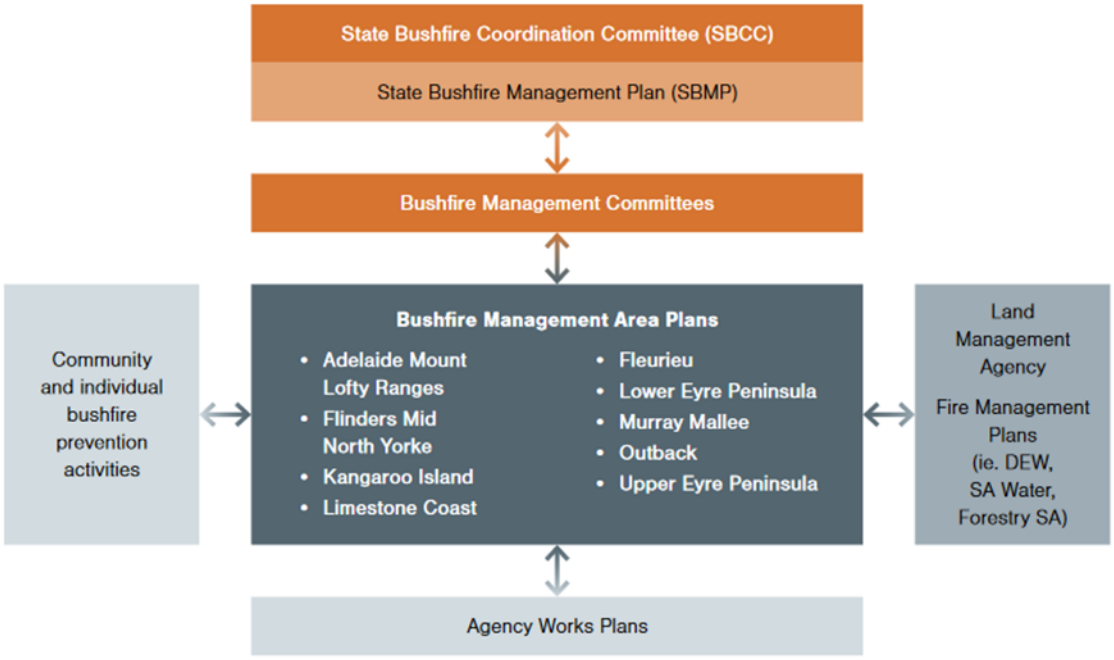


Figure 2: The governance and functions of the State Bushfire Committee: the diagram was copied from the SA State Bushfire Management Plan 2021-2025 (Government of South Australia, 2021).

The South Australian Fire and Emergency Services Commission (SAFECOM) was established under South Australia's *Fire and Emergency Services Act 2005* and is under the control of the Minster for Emergency Services and its Commissioner, to which it directly reports. SAFECOM provides governance, strategy and policy direction and leadership to emergency agencies including MFS, CFS and SES but it does not have a responsibility to provide operational and procedural direction relevant to emergency responses, including bushfires.

South Australian nature and environmental assets are protected under state legislation that includes *National Parks and Wildlife Act 1972*, *Wilderness Protection Act 1992*, *Native Vegetation Act 1991* and *Landscape South Australia Act 2019* – see Figure 3 and Figure 4. The Department for Environment and Water has the responsibility for governing the requirements under this legislation. The NCS also notes the South Australian Labor government's election commitment (2022) for a new Biodiversity Act that will presumably strengthen the protection of biodiversity across the state (South Australian Labour Party 2022). The new Act will "integrate the goals of the *Native Vegetation Act 1991*, the National Parks and Wildlife Act and the Landscapes SA Act and put the protection of biodiversity for the long-term at the centre of these laws" (South Australian Labor Party, 2022).

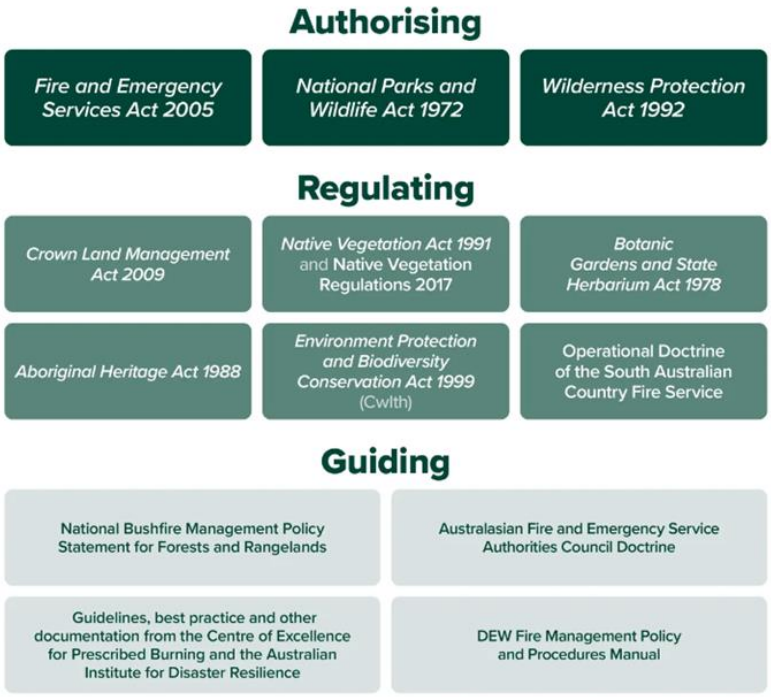


Figure 3: The authorising and regulatory legislation in South Australia that relates to bushfires and biodiversity. Source: the diagram was copied from the SA State Bushfire Management Plan 2021-2025 (Government of South Australia, 2021).

### *Local government*

The role of local government has changed since the *Fire and Emergency Services Act 2005* was amended in 2009 as they no longer have "responsibility for managing Bushfire Prevention Committees" (Government of South Australia, 2020a). However, the survey results from Moskwa et al. (2016) concluded that local government was regarded as the most important governance level for the reduction of bushfire risk and the conservation of local biodiversity.

Under the South Australian Fire and Emergency Act, local councils (local government that represents a specific geographic area) have an obligation to reduce fire risk, including:

- Maintain tracks for emergency services access and egress. This can require council regularly checking in with the CFS to ensure that they are complying with the required maintenance.
- Participation in local Bushfire Coordination Committee, the Emergency Management Committee, and the Fire Prevention Strategic Alliance.
- Representation on the State Bushfire Management Committee.

Local councils also have responsibility for appointing at least one Fire Prevention Officer (Part 4A Division 2 of the *Fire and Emergency Services Act 2005*) to support fuel load reduction. The responsibilities of the Fire Prevention Officer (105C of the *Fire and Emergency Services Act 2005*) includes (Government of South Australia, 2021):

- Assessing the extent of bushfire hazards within their area
- Providing advice and information on bushfire management
- Preparing and reviewing the Bushfire Management Area Plan/s

- Providing advice to landowners about bushfire management (prevention and preparation).

The Local Government Association of South Australia (LGA), an agency that advocates on behalf of local government, outlined their bushfire prevention and preparation responsibilities in their submission to the 'Draft State Bushfire Management Plan 2012-2025'. Some key points are listed below:

- The LGA has policies in place that support local government to meet its obligation under section 7 (d) of the *Local Government Act 1999* to: "take measures to protect their area from natural and other hazards and to mitigate the effects of such hazards."
- The LGA Policy Manual 4.1.6 'Bushfire Management' states: "Local government supports a balance between the protection of native vegetation and the necessity to develop bushfire prevention strategies that may include back-burning or cold burns. Councils shall ensure that clear evidence is developed to support back-burning/cold burning proposals and ensure vegetation is only disturbed when vital to the protection of communities."
- Councils also have responsibilities for fire prevention through their fire prevention officers, managing fuel load and communicating with their communities to be prepared for bushfire.

The LGA has produced an 'Emergency Management Framework' (LGA Board, 2019) with a vision of "Communities are disaster resilient because emergency risks are understood across the community, mitigated wherever possible, and there are effective systems to ensure community safety and wellbeing when emergencies occur". This framework provides additional guidance to local government in relation to bushfire management.

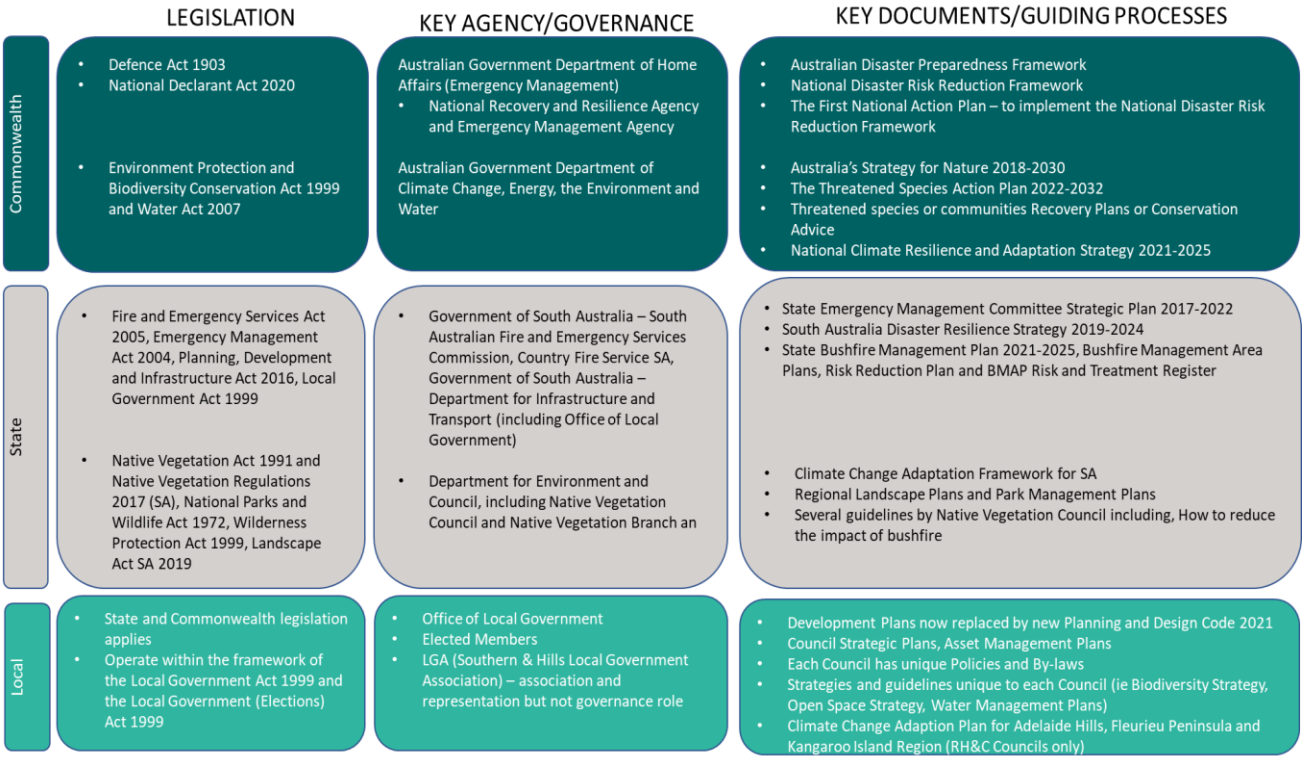


Figure 4: Overview of legislation, governance and key documents related to fire management and native vegetation management.

## 2.3 Bushfire safety responsibility

### *Bushfire safety responsibility (asset protection, fire breaks and fire-tracks)*

South Australia's Bushfire Management Plan (2022) was prepared and endorsed by the SA State Bushfire Committee under the requirements of the *Fire and Emergency Services Act 2005*. Under the *Fire and Emergency Services Act 2005* both individuals and community have "a legislative responsibility and duty of care to take action that will prevent bushfires" (Government of South Australia, 2021). For landowners, this can include asset protection (A Zones – activities to reduce risk of bushfire impact on buildings and assets), bushfire buffer zones (B Zones – managing fuels in areas additional to the A Zone), fire breaks and access tracks and prescribed burning to reduce fuel hazards. The exemptions and approvals required are outlined by Native Vegetation Council and the State Bushfire Management Plan South Australia (2022) – see Figure 5: Overview of the approvals required for bushfire hazard reduction activities in South Australia. Source: (Government of South Australia, 2021)..


Figure 5: Overview of the approvals required for bushfire hazard reduction activities in South Australia. Source: (Government of South Australia, 2021).

The management of crown land to prevent bushfires is covered in section 105G of the *Fire and Emergency Services Act 2005*. The SA Power Networks (SAPN) is responsible for maintaining clearance distances between vegetation and power lines on all public supply lines, except if it is the responsibility of council (South Australian Government n.d. weblink).

Under section 5 of the *Electricity Act 1996*, if SAPN believe that vegetation could potentially damage the powerline, or provide a risk of fire, the vegetation can be cleared in accordance with the Electricity (Principles of Vegetation Clearance) Regulations 2021. An electricity entity with a duty to keep vegetation clear of powerlines may clear vegetation that is within the bushfire risk area if the entity is satisfied that the vegetation is likely to fall onto a public powerline or private powerline under the entity's control, so as to damage the powerline, or give rise to a risk of fire, electric shock, or interruption of electricity supply, despite the entity not having a duty to carry out such work (but the entity incurs no liability for failure to clear such vegetation). Where SAPN is not required to maintain vegetation clearance on private property, to protect a powerline, they can offer to undertake the work at the expense of the landowner.

Within the RH&C region, there is significant biodiversity value along roadsides (see spotlight study #1), and the required clearance under the Electricity Regulations could impact these biodiversity assets at a local and landscape scale. Local Government, NPWSA, SA Water, and Forestry SA are also responsible for maintaining vegetation on their land, both for bushfire prevention and biodiversity protection.

### *Concept and application of shared responsibility*

Within the South Australian context, landowners are legally responsible for mitigating against fire risk under the *Fire and Emergency Services Act 2005* Section 105F. It is unclear from the literature review, if this responsibility effectively reduces communities' exposure to bushfire risk, and to a lesser extent, biodiversity loss. In terms of the legal responsibility of a fire, the liability for starting a fire sits with the person or agency that ignited the fire (Eburn & Cary, 2017). Eburn and Cary (2017) also discussed the hypothesis of 'whoever owns the fuel, owns the fire', and suggested that this is a moral position, but from a legal perspective, whoever "owns the fuel 'might' also own the fire".

Disaster preparation and community resilience approaches is increasingly underpinned by the concept of "shared responsibility" — that being, responsibility is equitably distributed amongst individuals, households, communities, businesses, and not-for-profit organisations (Dovers 2022; Cooper at al 2020). The importance and effectiveness of shared responsibility during the 2019-2020 bushfires recovery stage, at the local, regional, state, and national levels, has been noted (de Bie et al., 2023).

The principle of a shared responsibility for "bushfire prevention" is embedded in the *Fire and Emergency Services Act 2005* (Government of South Australia, 2021) that requires private landowners (section 105F), local (section 105G), state (section 105H) and Australian government (section 105I) landowners to:

- Prevent or inhibit the outbreak of fire on the land
- Prevent or inhibit the spread of fire through the land
- Protect property on the land from fire
- Minimise the threat to human life from a fire on the land.

The shared responsibility messaging is strongly embedded in various foundational and strategic documents in South Australia, at the state and local level (some examples are the 'State Bushfire Management Plan 2021', the 'Local Government Emergency Management Framework 2019' and 'Managing Native Vegetation: How to reduce the impact of bushfire and the steps you need to take August 2020'). A review of the use of "shared responsibility" for biodiversity conservation suggests that

the term is not being used consistently across agencies and councils, nor is it being used consistently across the literature. Although the general concept of shared responsibility is either embedded or implicit in communication material, the terms vary.

Though the concept of shared responsibility is widely used for bushfire management, it is less clear how to effectively convey this, and how it can be best applied at the preparation scale to address bushfire risk (McDonald & McCormack, 2022). A report by McLennan and Handmer (2014) discussed the principles of "shared responsibility" and how stakeholders can be supported to make better decisions. There is an additional concern about the ability of shared responsibility to be applied equitably and across all areas and regions. There is an assumption that all individuals and households have the ability to access and understand information and/or the capacity to implement actions required to protect themselves and the wider community (McDonald & McCormack, 2022).

Research conducted by Cooper et al. (2020) indicates that shared responsibility can be influenced by community narration, and that these narratives are determined by local features and community. The selection of information and trust in that information is likely to be greater if it is locally sourced as there could be a mistrust of information that is centralised. The NSW Hotspots Program (see spotlight study #12) has addressed this need and acknowledged that tailored communication has contributed to its success.

The State Emergency Service of Tasmania (SES Tasmania, n.d.) have online resources to train people that are involved in emergency management. The resources emphasise the importance of community engagement in fostering a sense of shared responsibility in the community, and therefore improving community resilience. The training material refers to Cottrell's (2009) 'Know your patch' to 'grow your patch' which provides a method of defining the local community as a starting point, that will then result in shared responsibility in the community. This method was (in 2011) being used by multiple state emergency services organisations to inform personnel and/or volunteer training programs. The method describes steps that emergency management personnel need to follow to understand their local community.

In a study comparing international disaster mitigation policy makers understanding of shared responsibility, it was acknowledged that the government agency shared responsibility role was central and the more powerful part of the shared responsibility collaboration (McLellan, Reid, Beilin 2019). There is an opportunity to evaluate the performance of a collaborative shared responsibility relationship using a five-dimensional framework developed by Thomson et.al (2008) — Table 2.

Table 2: Indicators to assess collaborative shared responsibility (Source Thomson, Perry and Miller 2008)

| Dimension | Indicator |
|---|---|
| 1. Joint decision-making | Agency and community organisation take each other's opinions seriously when decisions are made about collaboration activities. |
| | Agency and community organisation brainstorm together to develop solutions to mission-relevant problems facing the collaboration. |
| 2. Administration | Agency and community organisation understand each other's roles and responsibilities in the collaboration. |
| | Agency and community organisation meetings accomplish what is necessary for the collaboration to function well. |
| | Agency and community organisation agree about the goals of the collaboration. |
| | Agency and community organisation tasks are well coordinated. |
| 3. Autonomy | The collaboration does not hinder either party from fulfilling its own mission. |
| | Neither party's independence is affected by having to work with the other on activities related to the collaboration. |
| | Neither party feels conflicted about trying to meet their own, as well as the collaboration, expectations. |
| 4. Mutuality | Both parties have combined and used each other's resources so both benefit from the collaboration. |
| | Both parties share information that will strengthen their operations and programs. |
| | Both parties feel that what they bring to the collaboration is appreciated and respected by the other. |
| | Both parties believe that their own goals are achieved better working with the other rather than going it alone. |
| | Both parties work through differences to achieve win-win solutions. |
| 5. Trust | The representatives of both parties believe that the representatives of the other party are trustworthy. |
| | Each party can count on the other to meet its obligations in the collaboration. |
| | Both parties believe that it is worthwhile to stay and work with the other rather than terminate the collaboration. |

Source: Thomson, Perry & Miller 2008, Table 6.1, p.101.

## 2.4 Comparing state and territory bushfire and biodiversity legislation

A review of other states and territories indicates that their legislation, governance, and approaches of bushfire management is variable —Table 3. This review also provides information on the state and territories approach to firebreak requirements and asset protection, and the information tools that are provided to the public. Key programs and plans are also outlined and highlighted with an asterisk if it is considered relevant to RH&C.

Some initiatives that might be of interest to the RH&C region includes:

- The Tasmania Fire Service provides an online tool for calculating a recommended fire break in the urban-rural interface (described as peri-urban for the RH&C project).
- Tasmania has produced a review of information to assist with safe burning on private lands called 'Operational Guidelines and Review of Current Knowledge for Planned Burning in Tasmania".
- Western Australia has produced new 'Burn Smart – A planned burning guide for small landholders'. This document is targeted for properties under 2 hectares and provides all the information required to decide about burning for fuel reduction.
- In Western Australia, local governments are required to develop an 'Integrated Bushfire Risk Management Plan' that addresses bushfire risk across all tenures.

- The New South Wales Rural Fire Service provides a user friendly 'Know your risk' that effectively conveys bushfire risk in context of different settings.
- An online mapping tool (for New South Wales) assists households to self-identify their fire danger based a range of attributes that includes location, vegetation, household construction, physical health, equipment and facilities.
- The New South Wales Hotspots Program trains landowners and land managers to actively participate in fire management – see RH&C Spotlight Study 12.
- The 'Safer Together' program, in Victoria, is an across-agency initiative that uses the latest science and technology to address bushfire risk on private and public land.
- Since 2012, Victoria's 'Community-Led Planning' supports communities to develop their own risk reduction plans and focusses on seventeen high-risk communities.
- The project 'Sparking Conversations, Igniting action' is a bushfire resilience initiative that focuses on 12 communities in the greater Hobart area, Australia. It uses communication and the sharing of people's stories to improve the ability of community to be resilient against bushfires – see here.

Table 3: Comparing select state and territory legislation, key agency, strategy and planning, asset protection and firebreak rules, fuel assessment methodology and other initiatives or offerings of note. The asterisk might be of interest to RH&C in the future.

| State or Territory | Key Fire agency/legislation | Key biodiversity agency/legislation | Strategy and planning | Bushfires and biodiversity | Asset Protection Zones and firebreak requirements and guidance | Fuel assessment | Key things to note (points that are asterisked could be considered for RH&C) |
|---|---|---|---|---|---|---|---|
| **ACT**<br><br>Fire Services funded through Territory budget, and increasingly from the Fire and Emergency Services Levy, which has grown rapidly over the last decade. | Key legislation - *Emergencies Act 2004*.<br><br>The overall responsibility for the suppression of bushfires in the ACT lies with the ACT Emergency Services Agency (ESA) here, primarily with the ACT Rural Fire Service (ACT RFS) here.<br><br>ACT Rural Fire Service (ACTRFS) is responsible for protecting life, property and the environment from all bush and grass fires in rural ACT areas.<br><br>The ACT Multi Hazard Advisory Council is established under this Act and has an advisory role (to the Minister/s). | Key legislation - *Nature Conservation Act 2014*<br><br>Environment, Planning and Sustainable Development Directorate here. Biodiversity is protected under the *Nature Conservation Act 2014.*<br><br>Department is also responsible for development assessment under the *Planning and Development Act 2007*. | • Yearly *Bushfire Operations Plan* (BOP) that outlines that actions that are required to meet the Strategic Bushfire Management Plan (a requirement under the Emergencies Act 2004). The plan is reviewed every 5 years. | • It is clearly stated that the Emergencies Act has precedence over the *Nature Conservation Act 2014*, for the purpose of protecting life or property and controlling, extinguishing or preventing the spread of a fire. It is less clear if this extends to preparation activities.<br>• No burn target number of hectares – uses residual risk approach, where bushfire risk is calculated using computer modelling by simulating fires and calculating the remaining risk. See Parliament research paper (McCormick and May 2021). | • The asset protection zones and fuel management standards are separated according to the asset interface classification, vegetation type inner or outer APZ.<br>• The fuel management standards for APZ is specified according to length, break in between canopy or fuel gap to ground and vegetation stubble height. | • The *ACT Bushfire Management Standards* refers to the *Victorian Governments Overall Fuel Hazard Guide* | • A template for Farm FireWise is provided*<br>• The Strategic Bushfire Management Plan is a thorough, fit for purpose document.<br>• *ACTmapi* spatially represents bushfire prone areas, abatement zones, fire management zones and bushfire operation plans - here. |
| **Tasmania**<br><br>It is noted that local councils collect a fire service rate that is given to the Tasmania Fire Service to pay for their operations. As of the time of this review, the Tasmania Government were considering a new Emergency Services Levy. | Key legislation – *Fire Service Act 1979* and *Emergency Management Act 2006*<br><br>The Tasmanian Fire Service (TFS) here sits in the Department of Police, Fire and Emergency Management and is governed by the *Emergency Management Act 2006* (currently under review).<br><br>When the Fire danger rating exceeds 50, recommended not to plan and defence. | Key legislation - The *Nature Conservation Act 2022* and *Threatened Species Protection Act 1995*<br><br>Delivered by the Department of Natural Resources and Environment Tasmania (along with 110 other Acts). | • There is a *State Fire Protection Plan* that is more about governance and emergency management arrangements (less strategic).<br>• The *State Vegetation Fire Management Policy* is developed by the State Fire Management Council (as per the *Fire Service Act 1979*). | • The Fuel Reduction Program communicates that fire doesn't harm the environment, but it doesn't address biodiversity conflicts or complementarities.<br>• The information on bushfires (wildfires) on the Department of Natural Resources and Environment Tasmania website is largely about caring for injured or orphaned animals after a fire.<br>• A coastal works manual provides messaging about maintaining vegetation and biodiversity protection.<br>• No specific target area for burns. The cross-agency, whole-of-state fuel reduction program will focus on areas that pose the greatest risk of bushfires in public and private land. Uses residual risk approach, where bushfire risk is calculated using computer modelling by simulating fires and calculating the remaining risk. See Parliament research paper (McCormick and May 2021). | • The Tasmania Fire service provides guidelines and an online tool for calculating the fuel break in the urban-rural interface*. The tool is based on users specifying the predominant vegetation type, vegetation community, slope and the maximum fire distance (as detailed in the guidelines).<br>• Three fire management zones of Asset Zones (human settlement), Asset Protection Zones (the area within 1.05 km of human settlement) and Strategic Fuel Management Zones (the area between 1.05 km and 6.05 km from human settlement). | • The Department of Natural Resources and Environment Tasmania refers to Overall fuel hazard guide for South Australia (Department for Environment and Heritage, SA 2008). | • The Fuel Reduction Program is across the state and across agencies and includes public and private lands, overseen by Tasmania Fire Service and implemented by the Bushfire Risk Unit within TFS.<br>• A *Community Protection Planning* process initiative*: is implemented by TFS. It is a process that collates a range of attributes and features to predict potential fire impact at a community-level. A risk management response is developed for that community, and it involves working with communities, stakeholders and agencies short video here. It is guided by the National Emergency Risk Assessment Guidelines (NERAG).<br>• An *Operational Guidelines and Review of Current Knowledge Planned Burning in Tasmania* was published in 2009*. This enables safe and effective burning on private land that includes biodiversity (albeit minimal) considerations. |
| **Western Australia**<br><br>Fire Services are mostly funded through the property-based | Key legislation – *Fire and Emergency Services Act 1998*, *Bushfires Act 1954*, *Fire Brigades Act 1942*<br><br>Department of Fire and Emergency Services as directed by *the Fire and Emergency Services Act 1998.* The State | Key legislation - *Biodiversity Conservation Act 2016* and *Conservation and Land Management Act 1984* | • State Bushfire Advisory Council<br>• Guidelines for applying Bushfire Risk Standards - here<br>• Under the State Hazard Plan - Fire, | • The *Guidelines for applying Bushfire Risk Treatment Standards* specify exclusions to the standards.<br>• It is clear that the *Bushfires Act 1954* is superior to other environmental legislation, and | • Asset Protection Zones (within 20 m from the wall of any habitable building) require tree crowns a minimum of 10 m apart, low trees pruned to height of 2 m, fuel load is less than 5 cm height or 2 tonnes per hectare, tall shrubs are not planted in clumps within 3 m of habitable building. | • Fire break requirement depends on size of property allotment, location (residential/rural)*. Lots 4001 m2 and above =3-m-wide trafficable firebreak | • An *At Risk* communities program* – (shared responsibility) focussing on those at greater risk.<br>• A planned burn for bushfire mitigation purposes can occur at intervals greater than six years |

| State or Territory | Key Fire agency/legislation | Key biodiversity agency/legislation | Strategy and planning | Bushfires and biodiversity | Asset Protection Zones and firebreak requirements and guidance | Fuel assessment | Key things to note (points that are asterisked could be considered for RH&C) |
|---|---|---|---|---|---|---|---|
| Emergency Services Levy. | Emergency Management Committee and Office of Bushfire Risk Management work at a state level to oversee WA bushfire risk management.<br><br>A bushfire risk management planning program (state-wide) direct the Rural Fire Division to reduce bushfire risk. Local government is heavily supported including grants to employ Bushfire Risk Planning Coordinators (local government). | Department of Biodiversity, Conservation and Attractions is the relevant department. | local governments in Western Australia (WA) with significant bushfire risk are required to develop an integrated Bushfire Risk Management (BRM) Plan that addresses bushfire risk across all land tenures.* | the Fire and Emergency Services Commissioner can take oversight of bushfire control.<br>• The Department of Biodiversity, Conservation and Attractions has considerable information available on fire management - fuel reduction and biodiversity is a strong theme.<br>• The Good Neighbour Guidelines - here.<br>• Fire information notes to assist landowners to manage fuel loads while minimising impacts to biodiversity - here.<br>• The Burn Smart guidelines includes information on biodiversity and recommends appropriate burn intervals for particular vegetation communities.<br>• Annual burning target of 200,000 hectares to ensure that 60% state managed fuels are less than 6 years old at any one time. | • Firebreak requirement for properties over 4047 $m^2$ and should be at least 3 m and maintained to a height of 10 cm. The recommended width varies between Councils (eg Margaret River suggest 4 m width) - here.<br>• Areas that are identified as Risk Treatment Area has two zones – the Inner Zone (defendable space between flammable vegetation and building) and the Outer Zone (land that is between 10 and 20 m of a relevant building). The allowed vegetation clearance is specified for each zone, except for the exclusions. | within 10 m of all boundaries.<br>• Visual fuel load assessment guidelines are provided for various regions in Western Australia - here. | without an authorisation under the *Biodiversity Conservation Act 2016.*<br>• Once the bushfire prone area is identified, a 100 m buffer is applied to the periphery of the bushfire prone vegetation.<br>• A bushfire preparation tool kit that essentially amalgamates all key considerations for an individual Landowner, in one fit for purpose document.*<br>• A Bushfire Ready program is supported by Bushfire Ready Facilitator to enable communities to meet and discuss how to be bushfire ready and prepared - here.<br>• New Burn Smart guidelines* were released in 2021 to assist Landowners with conducting burns to manage fuel load- here.<br>• Residents can request to install an alternative fire break, negotiated with local council, if it is impractical to install firebreaks according to council guidelines. |
| **New South Wales**<br><br>Resilience NSW is the central billing and distribution agency for contributions from insurance companies and local government councils for FRNSW, NSW Rural Fire Service and NSW State Emergency Service | Key legislation - *Rural Fires Act 1997*, *Fire and Rescue Act 2004* and *State Emergency Act 1989*<br><br>Under the Rural Fires Act 1997 the Bush Fire Coordinating Committee (BFCC) must constitute a Bush Fire Management Committee (BFMC) for each area in the State, which is subject to the risk of bush fires. Each BFMC is required to prepare and submit to the BFCC a draft Bush Fire Risk Management Plan (BFRMP). | Key legislation – *National Parks and Wildlife Act 1974*, *Threatened Species Conservation Act 1995* and *Biodiversity Conservation Act 2016*<br><br>Requirements under these Acts are the responsibility of the New South Wales Department of Planning and Environment. | • New South Wales *State Emergency Management Plans*<br>• New South Wales *Fire Management Manual*<br>• Climate Change Impacts on bushfire Risk.<br>• Bushfire Risk Management Plans (BFRMPs).<br>• National parks and reserves in NSW have specific *Fire Management Strategies** | • The Rural Boundary Clearing Code excludes a range of high biodiversity assets thus providing them with greater protection.<br>• Enhanced Bushfire Management Program (operating since 2011) that focusses on fuel reduction programs.<br>• The Applied Bushfire Science Program was established to address bushfire risks to environmental and Aboriginal cultural values across New South Wales.<br>• Annual burning target of 135,000 hectares for five year rolling average. | • Vegetation clearance within the Rural Zone is permitted up to 25 m ("This provides for the removal, destruction or pruning of any vegetation (including trees) by landowners on their own property within 25 m of the boundary of their holding. The clearing of vegetation provided for under this scheme is for bush fire hazard reduction and clearing should only be done to the minimum extent necessary for that purpose. As such, a landowner is not required to clear the entire 25 m in order for the clearing to be considered lawful"). There are exclusions that are based on biodiversity values.<br>• Asset Protection Zone width depends on slope, the type of asset and the type (and management) of surrounding vegetation.<br>• 10/50 vegetation clearance –tree clearance within 10 m of a home is permitted, with no approval required. The clearance of underlying vegetation is permitted within 50 m (the 10/50 vegetation clearance code of practice) – note this has been reviewed with key recommendations here. | • Reference to the Victorian Governments Overall Fuel Hazard Assessment Guide. This is embodied in the New South Wales Governments Fire Management Manual 2022-23. | • The NSW Rural Fire Service provides an online mapping tool for households to better understand their fire danger* based on location, vegetation, household construction (and age), ability to respond (health, age, mental capacity etc), equipment available (current and future) and various other attributes - here.<br>• The NSW Rural Fire Service website provides a user friendly "Know your risk"* that empowers residents to better understand the type of fire risk in context of different settings - here.<br>• The NSW Hotspots program* that trains landowners and land managers with the skills and knowledge to actively participate in fire management. This is presented in the projects Spotlight Study #12.<br>• The NSW Rural Fire Service provides bi-annual Bushfire Bulletins - here |
| **Victoria**<br><br>Annual funding is provided to the CFS through the State | Key legislation - *Country Fire Authority Act 1958*, *Emergency Management Act 2013*, *Fire Rescue Victoria 1958*<br><br>The State Emergency Plan oversees the roles of agencies responsible for | Key legislation - *Wildlife Act 1975* and *Flora and Fauna Guarantee Act 1988* | • *State Emergency Management Plan*<br>• Emergency Risks Victoria<br>• The *State Emergency Bushfire Sub-Plan.* | The Bushfire Fuel Management Guide refers to potential conflict between biodiversity and bushfire preparation ("Achieving the<br>• objectives of an Asset Protection Zone may have a | • Depending on the location of the property, there is a 10/30 rule and a 10/50 rule that does not require approvals. This is predominately determined by when building permit was issued, or previous bushfire impacts. | • Overall fuel hazard assessment guide 2010 | • The Victorian Governments Safer Together program is a partnership between fire and land agencies and communities, combining in-depth local knowledge with the latest science and technology to reduce |

| State or Territory | Key Fire agency/legislation | Key biodiversity agency/legislation | Strategy and planning | Bushfires and biodiversity | Asset Protection Zones and firebreak requirements and guidance | Fuel assessment | Key things to note (points that are asterisked could be considered for RH&C) |
|---|---|---|---|---|---|---|---|
| Government via the Fire Services Property Levy. | emergency management, and the Victorian Preparedness Framework. The Country Fire Authority is accountable to the Minister for Emergency Services. | | | negative impact on natural environment values Where this is likely, planners should seek to moderate the negative impact, as far as practicable, provided that this does not compromise the safety objectives of this zone").<br>• The *Safer Together* program (across-tenure approach) highlights the need to also manage the impacts of bushfires on threatened species.<br>• No burn target number of hectares – uses residual risk approach, where bushfire risk is calculated using computer modelling by simulating fires and calculating the remaining risk. See Parliament research paper (McCormick and May 2021). | • Fence line clearance can occur without a permit if it doesn't exceed 4 m in width here.<br>• Four main management zones a) Asset Protection b) Bushfire Moderation c) Landscape Management and d) Fuel Management exclusion. Each of these has a trigger for the management required. | | bushfire risk on both public and private land -here.<br>• *Community Led Planning* (including Community-based planning) is an approach that supports communities to develop their own localised risk reduction plans. This initiative commenced in 2012 and involved 17 high-risk communities*.<br>• The Country Fire Authority also provide *Bushfire Preparation* Meetings to ensure that community are prepared before the summer bushfire season. |
| **South Australia**<br><br>Funding for the CFS is provided by the State Government, through Revenue SA and Transport SA, who collect the Emergency Services Levy, from home & vehicle owners. | Key legislation – *Emergency Management Act 2004* and *Fire and Emergency Services 2005*.<br><br>The State Emergency Plan is prepared under section 9 (1)(b) of the Act.<br><br>The new State Bushfire Management Plan identifies the need to look at the relationship between the State Bushfire Coordination Committee and the State Emergency Management Committee. | Key legislation – *National Parks and Wildlife Act 1972*, *Wilderness Protection Act 1992*, *Landscape South Australia Act 2019* and *Native Vegetation Act 1991*. | • *South Australian Emergency Management Plan.*<br>• The first *State Bushfire. Management Plan* (2021-2025) was published in 2022 as a requirement under the *Fire and Emergency Services Act*.<br>• The *Nature Conservation Directions Statement 2020* here and the outdated *No Species Loss* here.<br>• The document *The Effects of Fire on the Environment* is excellent educational tool here. | • The Native Vegetation Council have ecological prescribed burning guidelines here.<br>• DEW (NPWSA) have Ecological Fire Management Guidelines here.<br>• Prescribed burns in 2020-2021 was 6261 (compared to 4091 in 2019-2020). The literature review could not source future targets.<br>• The Natural Values Team provides input on biodiversity considerations in fire management. | • CFS guidelines specify preparing a 20 space around a home (includes removing fine fuels) and a 5-m fuel break along all fence lines and around buildings or sheds.<br>• With approval from CFS (and notification to NVC), clearance permitted includes a) large trees within 20m of a dwelling, b) establishing fuel break (less than 20m wide - Exception: if there is land already sufficiently clear of vegetation to provide comparable protection within 200 m (other than one that runs at a right angle), c) vegetation to maintain a fire track less than 15m wide.<br>• Clearance to access or establish a fence is permitted if it meets the requirements of a) needed for access, b) maximum of 10m wide for boundary fence, c) maximum of 5m for on-property fence, d) maximum of 1m in a road reserve.<br>• Asset Protection zone (A-zone;); · Bushfire Buffer zone (B-zone;); and · Conservation-Land Management zone (C-zone;), Strategic Fuel Management Zones (S-zone) and Exclusion Zone (X-zone) – see here<br>• The State Bushfire Coordination Committee have guidelines for firebreaks, fire access tracks and sign standards. These are reviewed every 5 years and the current version is 2018 | • NPWSA have the Overall Fuel Hazard Guide here and ensure it complies with the CFS Fire Management Zone Standard and Guidance for Use here. | • Strategic aim prevention>preparedness>response>recovery.<br>• There are several useful documents on bushfires and biodiversity produced by DEW.<br>• South Australian guide on *Reducing Fire Risk in Gardens* here.<br>• The South Australian Burning on Private Land program provides ecological fire management strategies for eight species here. |

# 3. Understanding fires and bushfires

## 3.1 Fundamentals of fire ecology

### *What is fire ecology?*

Fire ecology is the study of fire in ecosystems and how it contributes to ecological processes (D. G. Nimmo et al., 2022). As "Fire is one of Earth's most potent agents of ecological change" (D. G. Nimmo et al., 2022), fire can be studied in a range of contexts. Different contexts may include analysing the immediate or long-term impacts of fire on particular species or communities, or looking at the driving processes of fire in different ecosystems or under different conditions (D. G. Nimmo et al., 2022). In Australia, fire ecology is a particularly important field of research due to the susceptibility of the Australian landscape to bushfires, and the increasing severity and frequency of bushfires such as the 2019-2020 bushfires (T. Penman et al., 2023) due to climate change. Although Australia's First Nations people have a strong relationship with fire (McKemey et al., 2021; The Royal Commission into National Natural Disaster Arrangements, 2020a), non-Indigenous Australians do not have a cultural co-existence with fire, and are less inclined to understand that fire is a natural process in the landscape (Edwards & Gill, 2016). It important that ecological fire concepts are conveyed and understand by community, so they have an improved appreciation of the critical role of fire in shaping landscapes and biodiversity, the cultural importance of fire for First Nations people, and the limitations to fire prevention.

### *Why is fire ecology important?*

Understanding how species and ecological communities respond to fire is crucial in a fire-prone landscape (D. G. Nimmo et al., 2022). Each species has a preferred "fire regime" with some plants, for example, requiring fire to trigger seed germination processes, while other species may be highly sensitive to fire (Santos et al., 2022). An improved understanding about fire ecology will serve many purposes including; ensure that community and decision makers can make confident decisions about how to manage the impact of fires; provide opportunities to engage with community about effective biodiversity conservation and management and the role of fire; and improve predictive capability on bushfire spread, intensity and frequency.

The issue of "inappropriate fire regimes" is growing around Australia as some landscapes have been highly modified, are subject to poorly planned prescribed burns, or are experiencing changing conditions due to climate change (Santos et al., 2022). Inappropriate or altered fire regimes can include fires that are too frequent, not frequent enough, too hot, too cool, have too little spatial extent, too large a spatial extent and more (Bardsley et al., 2019; Santos et al., 2022). These inappropriate or altered fire regimes may have detrimental impacts on species, ecological communities, and the wider biodiversity resilience of Australia.

Australia's biodiversity is in a state of decline and the combined impacts from climate change, habitat fragmentation and degradation, invasive species, and altered fire regimes, are placing huge pressure on native animal and plant species (Silcock & Fensham, 2018; J. C. Z. Woinarski et al., 2015). Following the 2019-2020 bushfires, there is elevated concern about future extent and severity of fires. For example, 44% of threatened Australian plant species had at least some of their range burnt (Gallagher et al., 2021), and 118 threatened species (animals and plants) lost over half of their habitat (Wintle et al., 2020). These devastating impacts highlight the need for an improved understanding of the processes involved in bushfires and how to mitigate against these in the future.

Using fire ecology concepts to better manage and mitigate the impacts of future fires on vulnerable or significant ecosystems is important, not only for the inherent value of biodiversity, but also for the benefits that biodiversity provides to people, communities, and landscapes. Biodiverse natural spaces, including conservation parks, roadside vegetation, and urban trees, provide a range of ecosystem services such as the fixation of carbon dioxide (crucial in mitigating the impacts of climate change), temperature regulation, and many more (Mace et al., 2012; Romanelli et al., 2015).

Bushfires on the other hand, can have substantial and devastating impacts on human assets and communities. The physical impacts may include loss of human and animal lives and the loss of homes, businesses, other infrastructure, and agricultural stock (crops, livestock, etc.) (Filkov et al., 2020). Other indirect impacts may include extended time spent away from home fighting fires or on high-alert, and a decline in short and long-term economic output (Gangemi et al. 2003). The economic impacts from the 2019-2020 bushfires have been estimated at more than $10 billion (Penman et al., 2023). Effectively conveying information on fire ecology to decision-makers and the general community is crucial to minimise the risk of exposure and reduce the impacts of fire on human assets and biodiversity.

### *What does a fire need?*

Fire is the result of a reaction between heat, oxygen, and fuel (Bushfire and Hazards CRC). It requires the heat to ignite and then fuel and oxygen to continue and expand, once established the fire then self-generates its own heat, thus becoming self-supporting (CSIRO, 2022). These three core elements of heat, fuel, and oxygen, known as the fire triangle (Figure 6), are further explained below (CSIRO, 2022):

- Heat - Fire needs a source of heat to cause ignition and support the combustion of materials. Some potential sources include lightning or power tools and machinery.
- Fuel - Fires also require a source of fuel to start and to continue to burn. In the context of bushfires, this fuel is mostly vegetation, but many other materials are also combustible. Different materials have variable thresholds of temperature before combustion. Radiant heat from the fire can heat up materials to the required temperature but can also dry out materials, making them more easily combustible.
- Oxygen - Fire also requires an oxidizer to ignite and continue burning. While oxygen is not the only oxidation agent available, it is by far the most abundant.

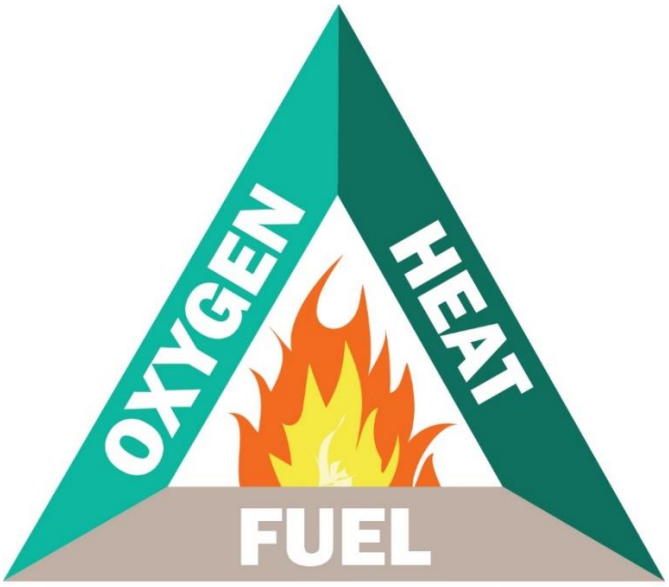


Figure 6: The three key elements of the fire triangle.

### *What influences the behaviour of a fire?*

The way that a fire behaves is determined by ignition, the way it moves and spreads, the development of flames and heat, and the consumption of fuel (typically vegetation) (Bushfire and Hazards CRC n.d; Department for Environment and Water n.d. website). Understanding the behaviour of fire is important as it empowers land managers, landowners, and decision makers to understand the factors that will perpetuate a fire, thus providing guidance on fire management and preparation. Fire behaviour attributes are core elements of bushfire models. Fuels, weather, and topography are the key determinates of fire behaviour (Department for Environment and Water; Bushfire and Hazards CRC, NSW Hotspots Program). This is further described below (Country Fire Service SA, 2023; CSIRO, 2022).

- Fuels: As the primary source of fuel for bushfires, vegetation can heavily influence the behaviour of the fire. Vegetation characteristics may include fuel type, arrangement, and quantity.

  The fuel type or specific vegetation composition (what different plant species are present) has an influence as some species are more flammable than others and have different densities of woody and leafy fuels.

  There are four broad categories of fuels: surface fuel, near surface fuel, elevated fuel, and canopy (Figure 7). Surface and near surface fuels include the arrangement of fine fuels such as leaf litter and grasses. The arrangement of vegetation such as the connectivity between individual plants or stands of vegetation both horizontally and vertically can significantly influence fire behaviour. For example, fire may more easily spread to the canopy in vegetation with high vertical connectivity through the surface, near surface, and elevated fuel layers (e.g., tall grasses, large woody shrubs, and a low canopy has high vertical connectivity) (Figure 7). This creates a higher intensity fire with more chance of spotting (spread of fire through embers). The 2019-2020 bushfires on Kangaroo Island, for example, were characterised by high connectivity between larger and smaller stands of remnant vegetation, allowing the fire to spread (Bonney et al., 2020).

  Connectivity and vegetation arrangement should not be considered in isolation, the quantity of vegetation can also influence the fire behaviour as more vegetation equals more fuel.


Figure 7: Categories of fuel along the vertical plane from the Bushfire Centre of Excellence and the Department of Fire and Emergency Services WA (2021). Note that the canopy fuel is not labelled however it is the uppermost layer in the diagram.

- Weather*:* Temperature, humidity, and long and short-term conditions concerning rainfall are large influencers of fire behaviour. Drought conditions or little recent rainfall will contribute to lower moisture levels in the vegetation increasing the potential fire hazard (CSIRO, 2022). In South Australia, daily weather conditions are now measured using the Australian Fire Danger Rating System (AFDRS) and are updated daily at 5pm during the fire season (Australian and New Zealand National Council for Fire and Emergency Services, 2022).

  While wind is considered a component of weather conditions, it can have a strong impact on fire behaviour independent of other weather conditions. The wind speed and direction influence the speed and direction of fire and can heavily influence the size of the fire front. For example, if a fire is being blown by a northerly wind with the fire front occurring south from the point of origin and a south-westerly wind change occurs, the fire front would shift to the eastern flank resulting in a much large front. A wind change like this is one of the most dangerous things that can occur during a bushfire. This change from a northeast-north westerly wind direction to a southerly wind was another characteristic of the fires on Kangaroo Island during the 3rd and 4th of January 2020 (CS Resilience & SA CFS, 2020).

  Atmospheric stability is the vertical movement of air in the atmosphere. An unstable atmosphere causes increased upward and downward wind currents, resulting in more dangerous fire behaviour. A stable atmosphere is characterised by relatively little air movement, resulting in calmer fire behaviour.

- Topography: Bushfire behaviour is also influenced by the topography of a landscape. Fires spread faster uphill as the fire can burn and preheat materials ahead of it. For each 10° slope increase, the speed of fire will double. For example, if a fire is spreading at 5 km per hour on flat ground and it hits a 10° slope increase, the fire spread will increase to 10 km per hour (The Bushfire Foundation n.d website). Similarly, fire spreads slower downhill.

## 3.2 Influencers of bushfire risk

The assessment of fire risk, fire hazard, and fire exposure are often used interchangeably, and it is critical to define how these are different so that community and households are clear about what they are doing and for what purpose.

Bushfire risk can be defined as the likelihood (what is the possibility of a fire starting) and consequence (the "effects" of the fire) of a fire igniting, spreading, and impacting on people, property, assets, and the environment. There are a range of factors that can determine this risk that vary in terms of the ability of individuals or agencies to manage.

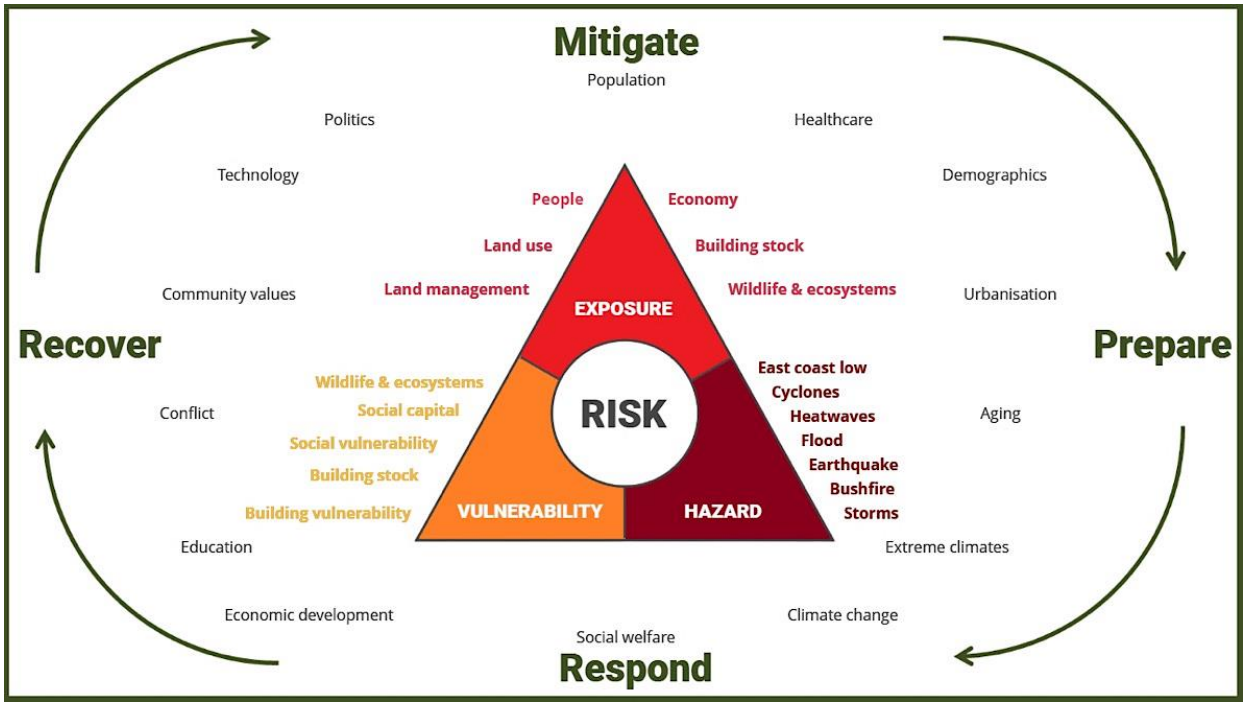


Figure 8: The key determinates of bushfire risk and the four fire management stages (Source: The Royal Commission into National Natural Disaster Arrangements Report 2020.

Factors such as weather, topography and fuels cannot always be managed, however other risk factors such as location of assets and use of building materials can be better planned. It is assumed that under the right conditions, a bushfire can start anywhere, particularly in a bushfire hazard area. Therefore, there is emphasis on assessing the risk of fire and the likely consequences if the bushfire were to spread and how it may spread.

There are three key factors that contributes to, and influences the level of bushfire risk (Figure 8) (The Royal Commission into National Natural Disaster Arrangements, 2020b). These are summarised below:

- Bushfire hazard: the hazard will influence what what a fire will do and how it will behave in the landscape. It is a source of potential harm or a situation with a potential to cause loss.
- Bushfire exposure: the different elements that are "exposed" to a bushfire and the tangible losses that can occur. The different types of elements can include people, pets, houses and other infrastructure, materials, and production assets. As an example, building a house away from native vegetation will reduce exposure, and having accessible and well-maintained roads, will reduce exposure as people can safely leave during a bushfire event.

- Bushfire vulnerability: the probability of people, assets, community, and production to be harmed or damaged by a bushfire. As an example, a household without a vehicle that lives in a remote fire-prone area is more vulnerable to a bushfire when compared to a household that has a vehicle and lives in a well-connected area, as the latter could safely leave an area during a bushfire. Another example is a low socio-economic demographic group that are not educated on bushfire risk and/or don't have the financial ability to implement bushfire preparedness activities, are likely more vulnerable to bushfires.

As of 1 September 2022, a new fire danger rating system was introduced that provides a simple, consistent, and action-orientated approach to understanding fire danger ratings and the protection actions that are required. The new four level fire danger system includes; moderate (plan and prepare); high (be ready to act); extreme (take action immediately to protect life and property); catastrophic (for survival, leave bushfire risk areas) – see here.

# 4. First Nations fire management

## 4.1 Background

Prior to European colonisation, Indigenous land managers used fire as a regenerative tool to maintain vegetation and cultural landscapes in many parts of Australia (Bardsley et al., 2019; Natural Hazards Research Australia, 2023). Deliberate burning of native vegetation was practiced for many reasons: to reduce fuel loads in order to prevent wildfires in many vegetation types; to thin out the understorey and make it walkable for people; to promote seed germination of fire-dependent plants; to stimulate the growth of green shoots which in turn provided forage for herbivores; and to maintain important cultural sites (Steffensen, 2020).

Indigenous fire management is still widely used and accepted over large areas of northern Australia, where traditional burning practices have remained in continuous use (e.g. Yibarbuk et al., 2002). In recent times in Northern Australia, burning by First Nations groups has been formally woven into wildfire-suppression and carbon emissions abatement policies across savanna habitats (Perry et al., 2021).

There has been renewed interest in reviving Indigenous burning techniques as a cultural practice and a land management tool in southern Australia over the last few years, among Indigenous and non-Indigenous communities (W. Smith et al., 2021; Steffensen, 2020). This reflects a growing recognition worldwide about the importance of fire-management by Indigenous groups (Hoffman et al., 2021). Interest and public support for a revival of First Nations land management using fire appears to have increased in southern Australia since the 2019-2020 bushfires. The topic gained sufficient public profile that by 2020 it was discussed by the Royal Commission following the 2019-2020 bushfires, as a method to suppress wildfires (The Royal Commission into National Natural Disaster Arrangements, 2020a). Support for Indigenous land-management is a key recommendation from a recent review and synthesis by the CSIRO of the 2019–2020 bushfires (J. Woinarski, Legge, et al., 2023).

## 4.2 Traditional fire-management practices & biodiversity

It is understood that First Nations groups typically conduct small-scale, cool, low-intensity burns of leaf litter and the understory in South Australia, resulting in a patchwork of vegetation of different fire-ages within the landscape. The season and timing of burns is carefully selected, usually following rain, so that flammable material smoulders slowly, flames do not reach the canopy, and soil moisture helps limit the speed at which the fire front travels which gives wildlife a chance of escaping (Steffensen, 2020). Such cool burns are intended to be regenerative. In contrast, bushfires that threaten biodiversity, are usually larger in scale and burn hotter — and as a result often scorch or completely denude the canopy and kill or displace wildlife (Ward et al., 2023).

From the mid-20$^{th}$ Century onwards, it was increasingly acknowledged that European fire-management practices, or lack thereof, were contributing to catastrophic wildfires in many Australian regions through fuel build-up. This led to the introduction of prescribed burns to reduce fuel loads in order to prevent major bushfires and to create firebreaks, primarily to protect infrastructure (Burrows & McCaw, 2013). Later, as non-Indigenous fire-managers became more conservation-aware, prescribed burns began to be carried out in a patchwork fashion, to reduce overall fuel loads within landscapes while maintaining a mosaic of habitats of different fire ages to conserve native species and habitats (Burrows & McCaw, 2013; Gill, 2012). While from a biodiversity perspective this was doubtless an improvement on unabated fuel-load build-up, or prescribed burns taking no account of vegetation age, prescribed burns in a mosaic pattern do not fully replicate traditional, cool, small-scale burns, and do

not necessarily involve a nuanced reading of local vegetation or soil conditions. For example, in some landscapes prescribed burns are not conducted from the ground, but through dropping aerial incendiary devices from helicopters (B. P. Murphy et al., 2015).

Discussions around the biodiversity implications of re-establishing First Nations fire-management practices within landscapes, where the management has been suppressed, need to consider that many habitats have been heavily modified since European colonisation, and many are now heavily impacted by invasive species. It is unlikely that pre-European environments can be replicated simply by applying fire in traditional ways. For example, in northern Australia highly invasive gamba grass (*Andropogon gayanthus*) has greatly increased fuel loads where it occurs. When burnt, this plant has the potential to degrade native habitats across entire landscapes due to the intense heat it creates which kills off native vegetation (Setterfield et al., 2013). Bushfires are known to exacerbate the impacts of invasive plants (Keighery et al., 2023) and animals (Legge, Duncan, et al., 2023) on native ecosystems. It is likely that in nearly all habitats, invasive species will require consideration and management before or after planned burns, to achieve the best possible outcomes for biodiversity.

## 4.3 Cultural burns, Indigenous land management & fuel hazard reduction

Given heightened interest in re-establishing Indigenous fire-management practices in southern Australia, its potential for the Resilient Hill & Coasts region requires careful consideration. Indigenous burning practices are highly nuanced and landscape-specific, and should not be viewed simplistically as a 'one size fits all' bushfire prevention and land-management solution that can be appropriated by non-Indigenous practitioners (Lindenmayer & Bowd, 2022). Respectful engagement with local First Nations representatives by government agencies, NGOs, and fire-management authorities is needed — recognising that building relationships is key (W. Smith et al., 2021), that First Nations cultures and burning practices are pluralistic, and burning practices are under re-development in regions where they have historically been suppressed (C. Robinson et al., 2023).

The dissemination of knowledge about Indigenous burning practices frequently relies upon volunteer or day-labour from Indigenous practitioners (C. Robinson et al., 2023; W. Smith et al., 2021). This may ultimately benefit First Nations groups by increasing their social license to practice cultural burns in locations from which they have previously been excluded (C. Robinson et al., 2023). However, non-Indigenous groups should take care not to call upon the time, knowledge, and labour of First Nations land-managers for free, with the aim of fuel load reduction to mitigate bushfire risk for the benefit the broader community. Sustainable, long-term funding models are needed to support Indigenous involvement in land-management (Ens et al., 2012).

Despite these caveats, fuel-load reduction using controlled burns is a common goal of Indigenous land-managers, and the revival of traditional burning practices may have the effect of reducing the risks that bushfires pose to the broader community. The suppression of Indigenous burning practices is thought to have altered the structure of vegetation across areas of south-eastern Australia within the last 200 years, and is a key concern for some Indigenous groups (Fletcher et al., 2021; Laming et al., 2022). There is evidence that these changes to vegetation structure have likely increased the risk of bushfires that threaten not only biodiversity, but infrastructure and human lives as well (Fletcher et al., 2021; Mariani et al., 2022).

The term 'cultural burn' is sometimes used as an umbrella term for any burn carried out by Indigenous practitioners for any purpose, but increasingly, some are careful to distinguish between burns practiced by First Nations groups for their own cultural reasons — including the maintenance of culturally significant sites and the passing of stories, language and other traditional knowledge — and land-

management of a more general nature carried out by Indigenous practitioners, including fuel-load reduction. The goals and decision-making priorities of First Nations groups and non-Indigenous fire managers and conservationists may differ, and any differences of opinion about whether and when to burn, and where, need to be carefully navigated (C. Robinson et al., 2023).

There may also be differences of opinion between First Nations groups about what burns are appropriate or necessary. A recent article argued that in Victoria, conservation legislation introduced in the 1970s suppressed the burning practices of pastoralists who had, until then, managed pasture by mimicking the earlier Indigenous burning practices of the region, leading to the proliferation of flammable eucalypts and more frequent and intense bushfires in formerly open country (Laming et al., 2022). However, some Indigenous knowledge-holders and scientists are concerned that this narrative has been overstated and extrapolated over too wide an area, and may be misleading government policy on fire suppression, conservation, and the logging of Victoria's native forests (Wilson, 2023). Further research into past burning practices across multiple regions, and experimental burning protocols, will be needed to inform future burning regimes across southern Australia.

## 4.4 Indigenous fire and land-management in the RH&C region

The western side of the Fleurieu Peninsula, comprising the Adelaide Plain, is the Country of the Kaurna nation, the Adelaide Hills extending south to Mount Barker and west to Myponga is Peramangk country, and the southern side of the Fleurieu Peninsula is Ngarrindjeri country. There is little recorded information about what burning practices were used by local First Nations groups in the Mount Lofty Ranges/Fleurieu Peninsula prior to European colonisation in the 1830s, and therefore little guidance about how different vegetation types were maintained **(Bardsley et al., 2019)**. However, there is local interest in reviving burning practices that were suppressed from the colonial era onwards. Recent workshops on cultural burning have been held in various locations, including the first cultural burn to take place on the Adelaide Plain in the modern era, which was performed in Adelaide's south parklands in 2021 (Landscape SA, 2022).

Kangaroo Island — known to local Indigenous groups by the name Karta — is unique in the RH&C region, in that no Indigenous communities were resident on the island at the time of European contact. It is unlikely that its vegetation was being actively managed with fire for hundreds, or perhaps thousands, of years (Draper, 2015). Despite this, the island is of great cultural and spiritual importance to at least four First Nations groups on the mainland — Kaurna, Ngarrindjeri, Peramangk and Narrunga. For these groups, it is the culturally taboo 'island of the dead' (Draper, 2015). Following the 2019–2020 bushfires, which severely burnt around half of Karta-Kangaroo Island and threatened numerous unique plants and animals with extinction, members of the Kaurna, Ngarrindjeri and Narungga communities travelled to the island for a three-day workshop on cultural burning, with the intention of resuming a cultural responsibility to care for the landscape using fire (The KI Islander, 2022).

Land-management by First Nations groups within the RH&C region is very early in its development but has an opportunity to grow. Current guidelines on ecological fire management for native vegetation in SA, published a decade ago (Government of South Australia, 2013), described the past burning practices of Indigenous groups in Australia as having 'compromised' whatever natural fire-regimes that existed on the continent before 50,000 years ago. Ten years later, burns led by First Nations fire-managers have now begun to occur in multiple regions in southern South Australia with the endorsement of the Landscape Boards (Landscape SA, 2022), which is an indicator of how much progress has been made in changing public and government attitudes towards more traditional uses of fire to care for the land.

# 5. Fire and Biodiversity

In its broadest sense, biodiversity, or biological diversity, is the total diversity of all living things. The word encompasses all species of plants, animals, fungi, and all varieties of micro-organisms. An ecosystem with a wider variety of lifeforms (higher species-richness) is generally regarded as healthier, and more stable and resilient to change, than a simpler one composed of fewer lifeforms. A recent global study found, for example, found that greater plant diversity within ecosystems was associated with higher ecosystem stability over the last 20 years of climate change (Oliveira et al., 2022).

Conserving biodiversity involves preventing extinctions of individual species so that overall species-richness is maintained. It also involves: maintaining species-richness within individual habitat patches; maintaining a diversity of different habitat types across a landscape; and maintaining genetic diversity within populations, so that organisms and ecosystems have the capacity to adapt to altered environmental conditions such as climate change, as well as recover from localised events such as bushfires. Perceptions about the biodiversity effects from fire depend on the scale at which they are assessed. Most fire-response studies focus on a single site and therefore only consider within-patch species-richness (alpha-diversity), rather than between-site variation (beta-diversity), or diversity across entire landscapes (gamma-diversity) (Farnsworth et al., 2014).

Fire has been a feature of Australian ecosystems for millions of years (Keeley & Pausas, 2022), and the relationship between fire and biodiversity is complex. Fire is both a key driver of ecological processes across the continent, but is also increasingly a threat to the survival of many species and ecosystems (e.g., de Bie et al., 2021; Ward et al., 2023; Woinarski et al., 2015). Since April 2022, "Fire regimes that cause declines in biodiversity" has been listed as a Key Threatening Process under the Commonwealth *Environment Protection Biodiversity and Conservation Act*, 1999 (the EPBC Act). Under this legislation, inappropriate fire regimes have been identified as a threat to the survival of over 800 species and 65 threatened ecological communities. The Federal Environment Minister in 2022 opted to support the "development of alternative approaches to reducing the risk of fire to Australia's biodiversity, including stronger action on climate change" (DCCEEW, 2022b) in favour of developing an overarching *Threat Abatement Plan* under the EPBC Act to address the *Key Threatening Process*.

## 5.1 Plants and fire

Some Australian plant species and habitat types are sensitive to fire but have evolved strategies for coping with it, while others actively benefit from certain fire regimes. Major Australian plant families have evolved fire strategies that have lasted for tens of millions of years, and the responses they have evolved include: the growth of lignotubers (swollen stem bases) from which plants can resprout (e.g. melaleucas); epicormic sprouting, that is, regrowth from buds held beneath the bark (e.g., eucalypts); fire-stimulated germination of seeds from the soil bank (e.g., species of *Pomaderris*); and serotiny, or fire-stimulated release of seeds from hard capsules held on the plant (e.g., banksias) (Keeley & Pausas, 2022). The germination of many native plants is greatly enhanced by fire, not necessarily directly through heat, but is aided indirectly via chemical compounds derived from burnt vegetation (Keeley & Pausas, 2018).

Eucalypts (plants in the genus *Eucalyptus*, and related genera such as *Corymbia* and *Angophora*), which are the dominant overstorey trees throughout most of Australia's savanna and sclerophyll biomes, are thought to have evolved the ability to resprout after fire some 60 million years ago, corresponding with the rise of highly flammable habitats (Crisp et al., 2011). The eucalypt groups that dominate forests and woodlands of south-eastern Australia arose within the last 20 million years, and those that are dominant within semi-arid open woodlands, mallee and mallet` (a small tree form of Eucalyptus found

in Western Australia) of southern Australia diversified within the last two to three million years as the continent became more arid (Thornhill et al., 2019). The flammability of Australian vegetation is therefore of great antiquity, and relatively recent, drier, climates have intensified the diversification of the highly flammable eucalypts throughout most of Australia.

Despite many of Australia's dominant plant species having evolved in response to aridity and fire-prone conditions over the last few million years, this does not make ecological communities immune to the effects of current and future climate change, nor to the application of inappropriate burning regimes. Inappropriate fire regimes have been identified as a key threatening process for 65 threatened ecological communities across Australia, some of which are eucalypt dominated, as well as to individual species of plant (DCCEEW, 2022b, 2023). Threat factors include: fire frequency (too frequent or not frequent enough); fire season (out-of-season fire can interfere with critical life processes such as reproduction); and fire intensity/severity (some plants may benefit from very high temperature fires, others from lower temperature fires) (DCCEEW, 2022b).

Reflecting the diversity of responses that Australian plants have to fire, the 2019–2020 bushfires had both negative and positive effects on different species. Short-range (meaning a reduced distribution) endemics were particularly at risk, and some such as the Wollemi Pine required intensive protection to survive, but on the other hand, a number of rare fire-ephemeral species — that is, ones that emerge only after fire — were reported from various locations after the fires, including at locations that did not burn and where germination was presumably triggered by chemicals in drifting smoke (Gallagher et al., 2023). Actual impacts on individual species are difficult to determine, but a large proportion of South Australia's endemic and threatened plants had some or most of their known ranges burnt (see Table 4).

Table 4: South Australian plants affected by the 2019–2020 bushfires (modified from Gallagher et al., 2023)

| No. of species | Range data available | No. of endemics impacted by 2019–2020 fires | % of endemics impacted by 2019–2020 fires | Endemics with >30% of range burnt | Endemics with >50% of range burnt | Endemics with >90% of range burnt |
|---|---|---|---|---|---|---|
| **SA endemic plant species** | | | | | | |
| 488 | 457 | 160–319 | 31–70% | 56–58 (12–13%) | 37–38 (8%) | 3–6 (0–1%) |
| **SA threatened plant species** | | | | | | |
| 807 | 769 | 404–665 | 53–87% | 34–40 (4–5%) | 19–21 (2–3%) | 3–4 (<1%) |

## 5.2 Fungal and bacterial community responses to fire

The diversity and distribution of fungal communities is relatively poorly studied and understood, even before considering their relationships to fire. For example, Australia has around 15,000 formally described fungal species, but their actual diversity is estimated to sit between 50,000 and 250,000 species (May et al., 2023). Despite fundamental gaps in our understanding of their diversity, distribution, and ecological interactions, fungi are known to play intricate roles in healthy ecosystems. They decompose organic matter, form ecologically crucial mutualisms with plant roots that help with nutrient uptake and seedling establishment, as well as forming mutualisms with algae/cyanobacteria that comprise the lichens that form soil crusts, and furthermore provide an important food source for mammals in the aftermath of bushfires (May et al., 2023).

Bacterial communities are even more poorly understood than fungal ones, and a limited amount of research exists on their fire responses. A study of soil bacteria and fungi in dry sclerophyll forests in

south-eastern Australia found that bacterial communities were more resilient after fire than fungal ones (Bowd et al., 2022). Given that soil microbial communities appear to take several years to recover after fire, too-frequent prescribed burns or bushfires, may harm their ability to recover (Bowd et al., 2022). Some species re-establish quickly, while other species favour long-unburnt habitats (May et al., 2023). Due to low levels of baseline knowledge of soil microbes, routine monitoring of bacteria and fungi should be integrated into ecological monitoring programs to assess their recovery dynamics after fire and the ecological implications of this (Bowd et al., 2022).

## 5.3 Fauna and fire

As with plants, the Australian fauna has evolved alongside fire for millions of years and has developed strategies to co-exist with it. Some animal species may benefit from it directly, e.g., opportunistic foraging in a fire scar by lyrebirds (Doty et al., 2015), and possibly even the intentional spreading of fire by several species of raptor in northern Australia in order to drive out prey (Bonta et al., 2017). Others animal species benefit indirectly, such as through fire opening up habitat structure and so making it easier to detect predators (Doherty et al., 2022), or via stimulation of new plant growth and flowering that increasing food resources for birds (Gill et al., 1999).

Despite benefits to some species, and the adaptation of others to cope with fire, inevitably individual animals may be killed in large numbers by bushfires. It is estimated that nearly three billion vertebrate animals died during the 2019–2020 bushfires (van Eeden & Dickman, 2023). In healthy ecosystems with large and well dispersed populations this should not threaten the survival of species; however, fire can threaten the survival of species when they have small remnant populations, populations that are geographically concentrated, or exist in poorly connected habitat 'islands' that mean they can't escape or recolonise easily. Many species are also highly susceptible to predation in the aftermath of a fire because of a loss of shelter, and because they may have to forage for longer or in different locations than usual to meet their requirements (Doherty et al., 2022).

Fire impacts animals, but conversely, animal activities can also influence fire. For example, grazing (grass-eating) animals reduce fuel loads, browsing (shrub/tree-eating) animals may limit the spread of fire upwards into forest canopy by increasing the vertical separation of understory and overstory, and trodden pathways created by animals are likely to act as natural fire breaks because of an absence of leaf litter (Foster et al., 2020). Digging animals are also thought to influence fuel loads and flammability by incorporating leaf litter into the soil, which removes some of the flammable material and also increases soil moisture (Davies et al., 2019). Ants and termites are likely to play a similar role by mobilising soil into the leaf litter layer (Foster et al., 2020). In theory, bioturbation of the soil and leaf litter by small animals should lead to reduced wildfire risk due to faster breakdown of the highly flammable litter layer (Hayward et al., 2017).

In the Adelaide and Mount Lofty Ranges region, one species of small digging marsupial known to have gone locally extinct since European colonisation, is the Greater Bilby *Macrotis lagotis* (Armstrong et al., 2003). Whether this has adversely affected regional bushfire risk is uncertain given several other small digging mammals remain — the Southern Brown Bandicoot (*Isoodon obesulus obesulus*), Bush Rat (*Rattus fuscipes*), and Short-beaked Echidna (*Tachyglossus aculeatus*). Similarly, on Kangaroo Island the Southern Brown Bandicoot, Bush Rat, and Echidna also persist (A. C. Robinson & Armstrong, 1999), and presumably continue to influence soil and litter processes where they occur. The Holocene fossil record of Kangaroo Island shows that it supported a wider diversity of small digging mammals within the past few thousand years than today, but a host of 20$^{th}$ Century species introductions to the island have complicated our understanding of which species were surviving on the island at the time of European

arrival (A. C. Robinson & Armstrong, 1999). Pre-19th Century animal-fire dynamics on the Island are therefore speculative.

### *Birds*

There are abundant studies of bird populations in relation to fire, but there remains substantial knowledge gaps (Lindenmayer, 2022). Bird diversity depends at least in part on the fire age of vegetation. A study in mallee habitat found that long-unburnt habitat patches supported a greater diversity of birds than younger patches, and concluded that retaining these unburnt patches was probably of greater importance to bird diversity than maintaining a mosaic of vegetation with different fire ages (R. S. Taylor et al., 2012). Similar findings in the Mount Lofty Ranges reinforce this, where fire was found to favour only certain guilds of birds (large generalist species, and ground-feeders) while disadvantaging woodland specialists (Prowse et al., 2017). Protecting long-unburnt habitat from bushfires and prescribed burns is a key recommendation for conserving bird diversity in the aftermath of the 2019–2020 bushfires (Garnett et al., 2023).

Proximity to unburn habitat can be an important factor in how quickly bird populations recover from fire. Following a large-scale wildfire in the Pilliga Forest in central-eastern New South Wales, bird diversity remained steady in nearby unburnt areas, but sites within the fire scar took longer to recover the further away from the edge of the fire scar they were. Research indicates that avian diversity bounced back to pre-fire levels within two years at sites 2 km from the edge of the fire scar, but at sites 4 km from the edge of the fire scar bird diversity was still recovering 7 years after the fire (M. J. Murphy et al., 2021). Fire extent, and proximity to unburnt habitat, are likely to be factors in how well the populations of some animal species recover after fire, and at a landscape scale, communities may take longer to recover following larger scale fires than smaller ones (M. J. Murphy et al., 2021).

Most bird species are highly mobile and are therefore better able to escape bushfires than many other animal groups, but populations can still be severely impacted, especially by large-scale fires, if food resources are reduced. Following the 2019–2020 bushfires, the IUCN's *Red Index* for Australian birds declined by >9%. Kangaroo Island's birds were severely affected, with 16 endemic species or sub-species having >25% of their habitat burnt; the highest in the country was the KI Southern Emu-wren *Stipiturus malachurus halmaturinus*, which had 68% of its modelled distribution burnt (Garnett et al., 2023).

There are currently three bird species in South Australia for which fire management guidelines have been published, all of which have very limited geographical distributions and are classed as Endangered (see Table 5). Two of these (Glossy Black-cockatoo and MLR Southern Emu-wren) occur in the RH&C region. Considering the 2019-2020 bushfires, guidelines for additional species, including Kangaroo Island endemics, may need to be developed.

Table 5: South Australian birds with fire-management guidelines

| **Common name** | **Scientific name** | **SA status (NPW Act 1972)** | **National status (EPBC Act 1999)** |
|---|---|---|---|
| Glossy Black-cockatoo | *Calyptorhynchus lathami halmaturinus* | Endangered | Endangered |
| South-eastern Red-tailed Black-cockatoo | *Calyptorhynchus banksii graptogyne* | Endangered | Endangered |
| Mount Lofty Ranges Southern Emu-wren | *Stipiturus malachurus intermedius* | Endangered | Endangered |

### *Frogs*

Frogs are relatively poorly studied compared to other vertebrate groups, and fire impacts are therefore less well known, especially impacts on tadpoles (Mahony et al., 2023). It is likely that tadpoles would be subject to many of the negative impacts from fire experienced by other aquatic vertebrates (see *Aquatic ecosystems and fire* below). A review of genetic datasets after the 2019-2020 bushfires revealed that much genetic data that has been collected on frogs is as yet unpublished, but indicates that frog species diversity is likely to be underestimated due to cryptic diversity within species complexes (Catullo et al., 2021).

Mahony et al., 2023 identified two main functional groups of frogs in relation to fire-adaptedness: species that are fire-adapted and live in fire-prone habitats, which generally shelter from fire in wet mud, tree hollows, or under debris and rocks; and fire-sensitive species that live in habitats that rarely if ever burn, which usually shelter in flammable shrubs or leaf-litter, and are therefore unlikely to survive fire. During the 2019-2020 bushfires many riparian habitats burnt for the first time in living memory (Mahony et al., 2023). Prescribed and cultural burns to manage flammable riparian vegetation have been suggested to mitigate against future fire risks (Fryirs et al., 2022). If this is adopted, potential impacts on fire-sensitive frog species would need to be assessed.

### *Snakes and lizards*

Australia has 10% of the world's snake and lizard (squamate) species, of which 96% are endemic, but they are poorly studied compared to other vertebrate groups, and genetic data suggests that their diversity is underestimated; together, these factors make it difficult to assess population trajectories over time (D. Nimmo et al., 2023).

A study in remnant habitat in an urban setting in Perth found that squamate numbers and diversity returned nearly to baseline within two to three years after fire (Davis & Doherty, 2015). However, effects are likely to depend on the species, with some preferring long unburnt habitat with abundant leaf-litter (Davis & Doherty, 2015), and nearly 80 species of squamate Australia-wide considered to be threatened by altered fire regimes (D. Nimmo et al., 2023).

Ideal fire regimes to maintain squamate diversity require further research. It was assumed in the past that a mosaic of vegetation with different fire-ages would benefit squamate diversity, but experimental prescribed burns to create a mosaic of fire ages did not confirm this (Pastro et al., 2011), this result was also experienced at the landscape scale (Farnsworth et al., 2014).

### *Mammals*

Australian mammals have fared particularly poorly since European colonisation, with altered fire regimes being just one of a number of factors that have contributed to their decline, along with other forms of habitat loss/degradation, and predation by introduced cats and foxes. As a result of these impacts, around 30 species of mammal are known to have gone extinct Australia-wide (Burbidge et al., 2008; Woinarski et al., 2015), and Australia is acknowledged to have one of the highest rates of mammal extinctions in the world (Woinarski et al., 2015).

Despite having suffered higher rates of extinction than other vertebrates at the species level, Australia's surviving mammals retain high levels of between-population diversity. A process of benchmarking unrecognised taxonomic and genetic diversity after the 2019–2020 bushfires revealed that Australia's mammals have 40 unrecognised 'evolutionarily significant units' (ESUs – populations that are isolated from one another, are regionally distinctive, or that require managing as separate entities) — more

than twice the number of ESUs in the next highest group, the reptiles, which had 19 unrecognised ESUs (Catullo et al., 2021). Knowledge of these distinctive populations will need to be taken into account in regional and state-wide fire-management planning.

Unsuitable fire regimes are a threat to the vast majority (88%) of Australia's threatened mammal species (Santos et al., 2022). There are currently four threatened mammal species in South Australia for which fire management guidelines have been developed (see Table 6). Of these, two — the KI Dunnart and Southern Brown Bandicoot — occur within the RH&C region and will require ongoing consideration when deciding on regional fire management strategies for biodiversity. The KI Dunnart was the most severely affected mammal taxon in the country after the 2019–2020 bushfires, with 95% of its known habitat occurring within the fire scar (Woinarski et al., 2023). One of the major impacts that fires can have on rare fauna is reducing the overall size of their populations, which could have knock-on effects on the recovery of entire ecosystems where they play important roles such as pollination or spreading fungal spores. One strategy to combat this is ongoing commitment to measures such as feral predator control to enable the size of native mammal populations to increase, providing a buffer against future fires (Woinarski et al., 2023).

Under climate change scenarios, a continuation of once-suitable fire regimes has the potential to cause mammal populations to decline (Santos et al., 2022), and current strategies may need to be adjusted to suit individual species and their habitats. As with other taxonomic groups, it has long been assumed that prescribed burns to create a mosaic of habitat patches of variable post-fire ages should help to retain mammal diversity within landscapes. However, studies do not necessarily bear this out in practice, and long-unburnt patches are likely to be of particular importance (Pastro et al., 2011). Patches of old-growth habitat with tree hollows on which many small mammals (and other taxa) depend are increasingly rare because of bushfires and compounded by timber harvesting, and such patches should be prioritised for protection in fire planning and in on-ground fire-fighting operations (Woinarski et al., 2023).

Table 6: South Australian mammals with fire-management guidelines

| **Common name** | **Scientific name** | **SA status (NPW Act 1972)** | **National status (EPBC Act 1999)** |
|---|---|---|---|
| Kangaroo Island Dunnart | *Sminthopsis aitkeni* | Endangered | Endangered |
| Sandhill Dunnart | *Sminthopsis psammophila* | Vulnerable | Endangered |
| Southern Brown Bandicoot | *Isoodon obesulus obesulus* | Vulnerable | Endangered |
| Yellow-footed Rock-wallaby | *Petrogale xanthopus xanthopus* | Vulnerable | Vulnerable |

The 2019–2020 bushfires necessitated emergency actions to sustain some populations of rare mammals, such as aerial food drops and erection of nest boxes and artificial hollows; treatment of injured animals for later re-release was largely restricted to koalas. Actions required in the aftermath of the fires included feral predator control in and around the fire scars, to minimise predation of surviving individuals (Woinarski et al., 2023).

### *Terrestrial invertebrates*

Australia's invertebrates are megadiverse (>300,000 species) and understudied, but it is estimated that they have roughly 40 times the species diversity of vertebrates (Marsh et al., 2023). Aquatic invertebrates are considered below (see 5.4 *Aquatic ecosystems & fire*). Due to the diversity of invertebrates and the small numbers of researchers working on them, their ranges and conservation status are usually difficult to determine, and knowledge of their fire ecology is extremely limited (Saunders et al., 2021). However, impacts on invertebrates from large-scale bushfires are likely to have

wide-ranging effects throughout ecosystems because of the roles they play in ecosystem processes (Marsh et al., 2023).

A rare study of invertebrate communities in a habitat burnt frequently as part of a fire-hazard reduction experiment found marked changes in the relative abundances of different vertebrate groups. In the frequently-burnt landscape, abundance of ticks & mites decreased by 31%, insect larvae declined by 35%, flies decreased by 58%, and beetle abundance reduced by 31%, while bugs increased by 77%, ants by 250%, and spiders by 33%. The groups that declined were those primarily associated with the leaf litter, pointing to the likelihood that fuel-reduction burns that reduce leaf litter could have profound, and likely underappreciated, impacts on invertebrate biodiversity (Gill et al., 1999).

Most of the invertebrate species identified as priority species for conservation, following the 2019–2020 bushfires, were short-range endemics with a high percentage of their known range overlapping with fire extent; five species — including the endemic Kangaroo Island Assassin Spider — had their entire known range burnt, albeit with poor knowledge of distribution of most species (Legge et al., 2022). Few invertebrate species have threatened species status under Australian legislation, and because of these combined factors, area-based conservation approaches rather than species-based approaches may be the best strategy for the conservation of most invertebrates in the short term (Marsh et al., 2023).

## 5.4 Aquatic ecosystems and fire

Although bushfires are a land-based phenomenon, they can have profound but underappreciated impacts on freshwater and marine ecosystems. Effects can occur tens or hundreds of kilometres downstream or offshore, manifest with a significant time-lag, and may last for decades (Santori et al., 2023; Whiterod et al., 2023). Effects can include silting of water, nutrient fluxes resulting in algal blooms that in turn lead to deoxygenation of water, changes to water temperature and pH, and major changes to river substrate, for example changing from cobbles before a fire to gravel and silt afterwards (Whiterod et al., 2023).

Following the 2019-2020 fires, impacts on river systems were heightened by heavy rainfall which caused erosion in burnt catchments, leading to synchronous kills of fish and other aquatic life. This necessitated emergency conservation measures for some short-range species that were at imminent risk of extinction in Australia's eastern states. Sixteen species of freshwater fish and eight species of freshwater crayfish were captured, and either kept temporarily in captivity and later re-released into the wild, or translocated directly into unaffected rivers (Whiterod et al., 2023).

Such emergency actions may become necessary in South Australia under future climate change scenarios, which is expected to both increase bushfire risk and result in more intense heavy rainfall events (DEW, 2022).

Bushfires followed by heavy rainfall and flooding are expected to have similar impacts on estuarine and marine environments as they have had in river systems, but with possible additional impacts from the downstream accumulation of industrial chemicals, and fire retardants used in fire-fighting efforts (Santori et al., 2023).

## 5.5 Human fire management and effects on biodiversity

Indigenous fire-management practices are reviewed in section 0, but in summary, the controlled application of fire has been a force shaping Australian ecology for tens of thousands of years. The long-term effects of this for biodiversity are uncertain, and research into this is ongoing, but regardless, there

is likely to be an ongoing and increasing role for land management by Indigenous practitioners into the future. This is an explicit priority for biodiversity conservation under the Federal Government's Strategy for Nature 2019–2030 (Commonwealth of Australia, 2019).

Prescribed burning in some ways mimics Indigenous fire practices, in an attempt to reduce fuel loads (see section 0). Over time, patch-burning regimes have been refined to maintain a mosaic of vegetation of different post-fire ages. The adoption of patch-burning reflected the belief that 'pyrodiversity begets biodiversity' — that is, maintaining a patchwork of habitats with different fire histories within landscapes should by default support greater biodiversity, because vegetation is more variable in composition and structure, and that many species are fire-dependent while others are fire-sensitive (Jones & Tingley, 2022).

Empirical research testing the 'pyrodiversity begets biodiversity' hypothesis has shown that it does not necessarily hold true: biodiversity's responses to fire history varies by spatial and temporal scale, by species, by geography, and by biome (Jones & Tingley, 2022). Any fire creates heterogeneity within a landscape, and in the absence of data about which specific fire regimes (i.e., frequency, temperature, season, extent) can either benefit or harm local biodiversity, the assumption that 'pyrodiversity begets biodiversity' could be used to justify almost any prescribed burning regime (R. S. Taylor et al., 2012). Pastro et al. (2011) assessed the biodiversity effects of prescribed burns on plants, lizards, and mammals, and concluded that there was little difference between alpha and beta diversity between burnt and unburnt patches, and that there was no clear benefit to biodiversity from mosaic burning beyond creating fire breaks that would protect habitat.

Where knowledge exists about which burning regimes suit a particular vegetation community or species, particularly threatened ones, this knowledge should be applied when making decisions about fire management. There is a need to consider the effects of fire regimes on biodiversity at the landscape as well as the local scale: most fire-response studies focus on a single site and therefore only consider alpha-diversity, but the 'pyrodiversity begets biodiversity' hypothesis assumes that differences in species diversity between sites (beta-diversity) will automatically produce higher overall species diversity across the whole landscape (gamma-diversity) (Farnsworth et al., 2014).

In a direct test of the 'pyrodiversity begets biodiversity' hypothesis, a study in the south-eastern Australian mallee found that having a patchwork of vegetation with different fire-ages did not promote greater overall bird diversity across the landscape, but highlighted the key role of long-unburnt patches of vegetation in maintaining bird diversity (R. S. Taylor et al., 2012). Old stands of unburnt vegetation have also been identified as crucial for small mammals (Woinarski et al., 2023),and reptiles (Davis & Doherty, 2015). Maintaining some long-unburnt patches within landscapes may therefore be of greater importance to the persistence of some species than maintaining a patchwork of habitats with a variety of fire-ages.

## 5.6 Adaptation of future fire management regimes for biodiversity

Fire management regimes will need to change and be adapted into the future if they are to prevent catastrophic fires such as the 2019-2020 bushfires, while assisting native habitats and species to regenerate and persist. What fire regimes are appropriate in the future is likely to depend on which climate change scenario eventuates. A recent report on climate change projections for South Australia includes three global warming scenarios that could impact on biodiversity across the state (DEW, 2022).

- Climate change – see section on climate change, e.g., there are now fewer suitable days per year where prescribed burning, for ecological outcomes, can take place.

- Habitat modification that has changed habitats and the way they burn or recover – e.g., habitat fragmentation, invasion by weeds and feral animals, absence of a lot of native fauna that has gone extinct either locally, regionally, or completely including many small digging mammals that probably reduced habitat flammability by digging in leaf litter and increasing soil's ability to hold moisture prior to European arrival.
- Use of fire retardants in aerial bombing operations to create containment lines ahead of a fire front contains nitrogen and phosphorous compounds that may disadvantage Australian native plants that are adapted to low-nutrient soils, and may promote the growth of weeds (DCCEEW, 2022); their use or composition may need to be carefully considered in some locations.

# 6. Climate change impacts on bushfires and biodiversity

## 6.1 Climate change impacts in the RH&C region

Climate change has and continues to impact communities, economies, health, and the natural environment, with changes expected to continue and intensify (Australian Academy of Science n.d). The Resilient Hills & Coasts partnership recognises the impact this will have in the region with warmer and drier weather and increased risk of bushfires, heatwaves, flooding and droughts (Resilient Hills & Coasts, 2020). Here, we provide an overview of the projected climatic change in South Australia and the RH&C region specifically, based on information provided in the Guide to Climate Projections for Risk Assessment and Planning in South Australia (DEW, 2022). This guide provides climate projections for 2030, 2050, and 2090 based on the Representative Concentration Pathways (RCPs) developed by the Intergovernmental Panel on Climate Change (IPCC). Commonly referenced RCPs based on emissions scenarios include RCP2.6 (low emissions), RCP4.5 (intermediate), RCP6.0 (intermediate), and RCP8.5 (high emissions) to cover variability in global climate change action. Each climatic projection will be described for intermediate (RCP4.5) and high carbon emissions (RCP8.5) scenarios, and are compared with a 1986-2005 baseline (DEW, 2022).

### *Bushfire frequency and history in the RH&C region*

The RH&C region was severely impacted by the 2019-2020 bushfires, in terms of scale, intensity and loss of homes, lives, and biodiversity. The area has a demonstrated fire history at different frequencies and these are presented as Figure 9, Figure 10, Figure 11 and Figure 12 and provided as an attachment (Attachment 1).

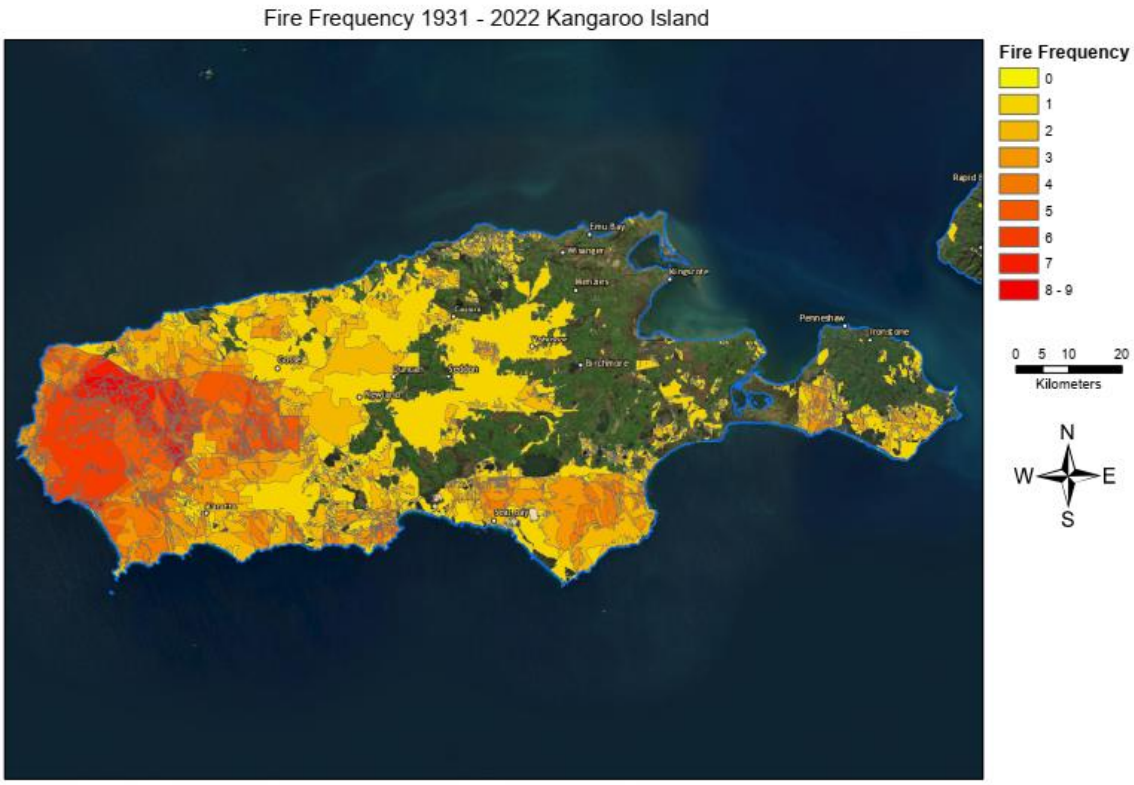


Figure 9: The fire frequency (includes bushfires and prescribed fires) in Kangaroo Island council region.

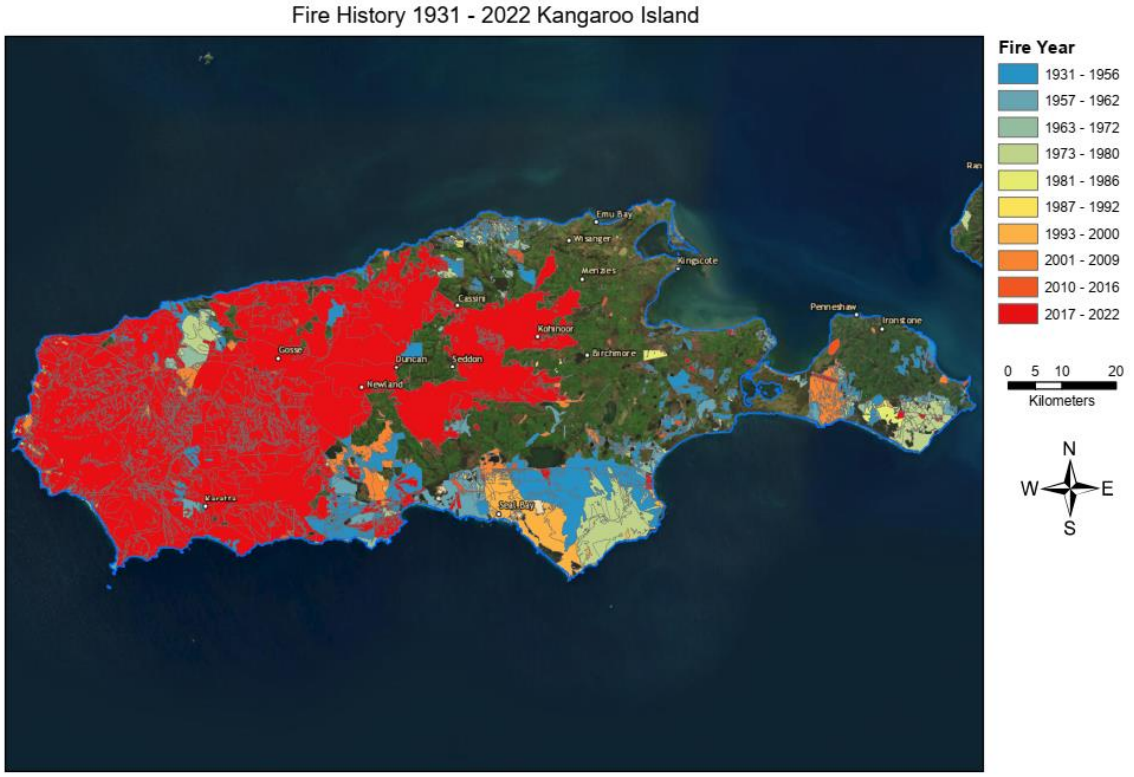


Figure 10: The fire history (includes bushfires and prescribed fires) in Kangaroo Island council region.

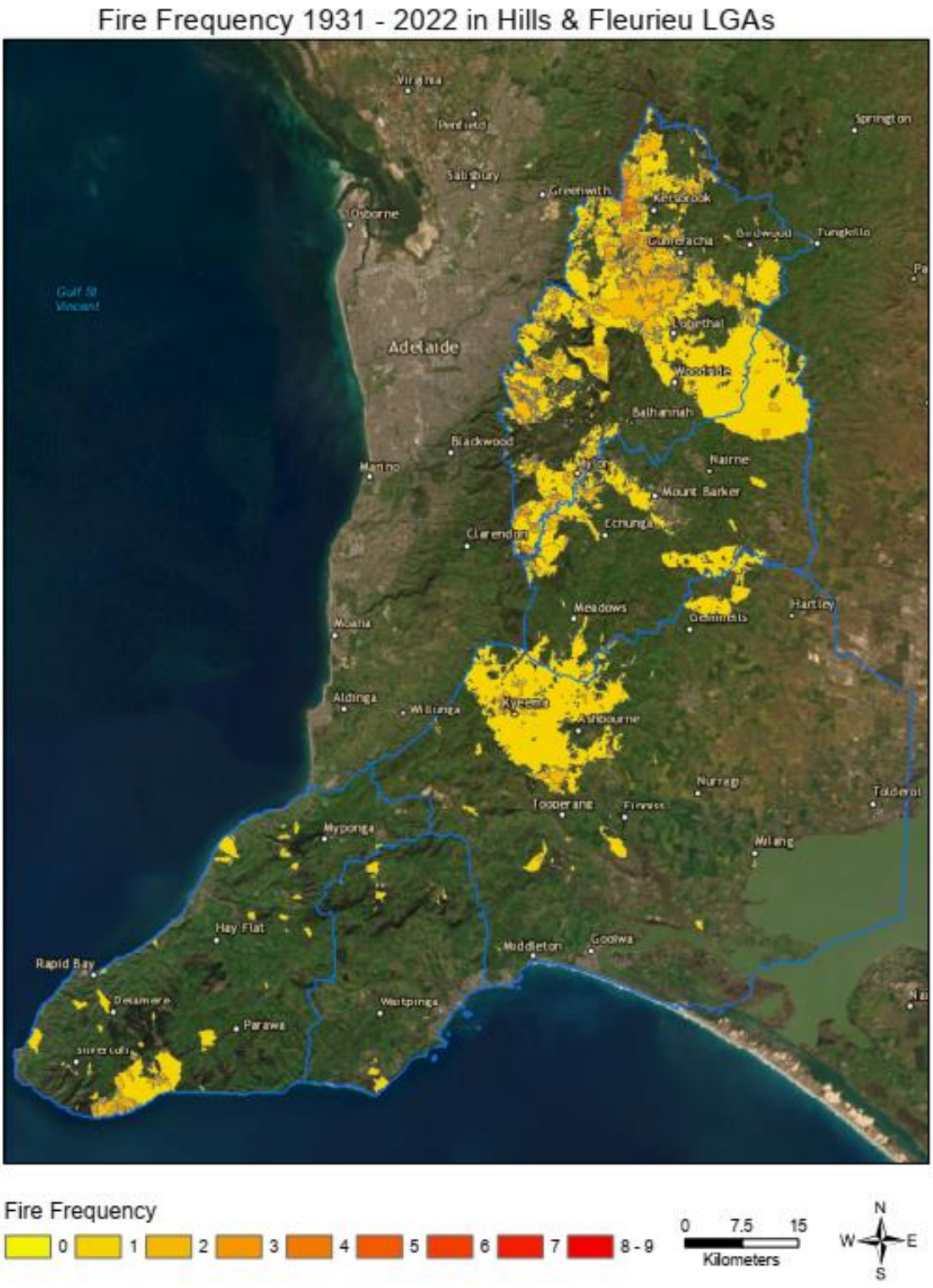


Figure 11: The fire frequency (includes bushfires and prescribed fires) in Yankalilla, Victor Harbour, Alexandrina, Adelaide Hills and Mount Barker council regions.

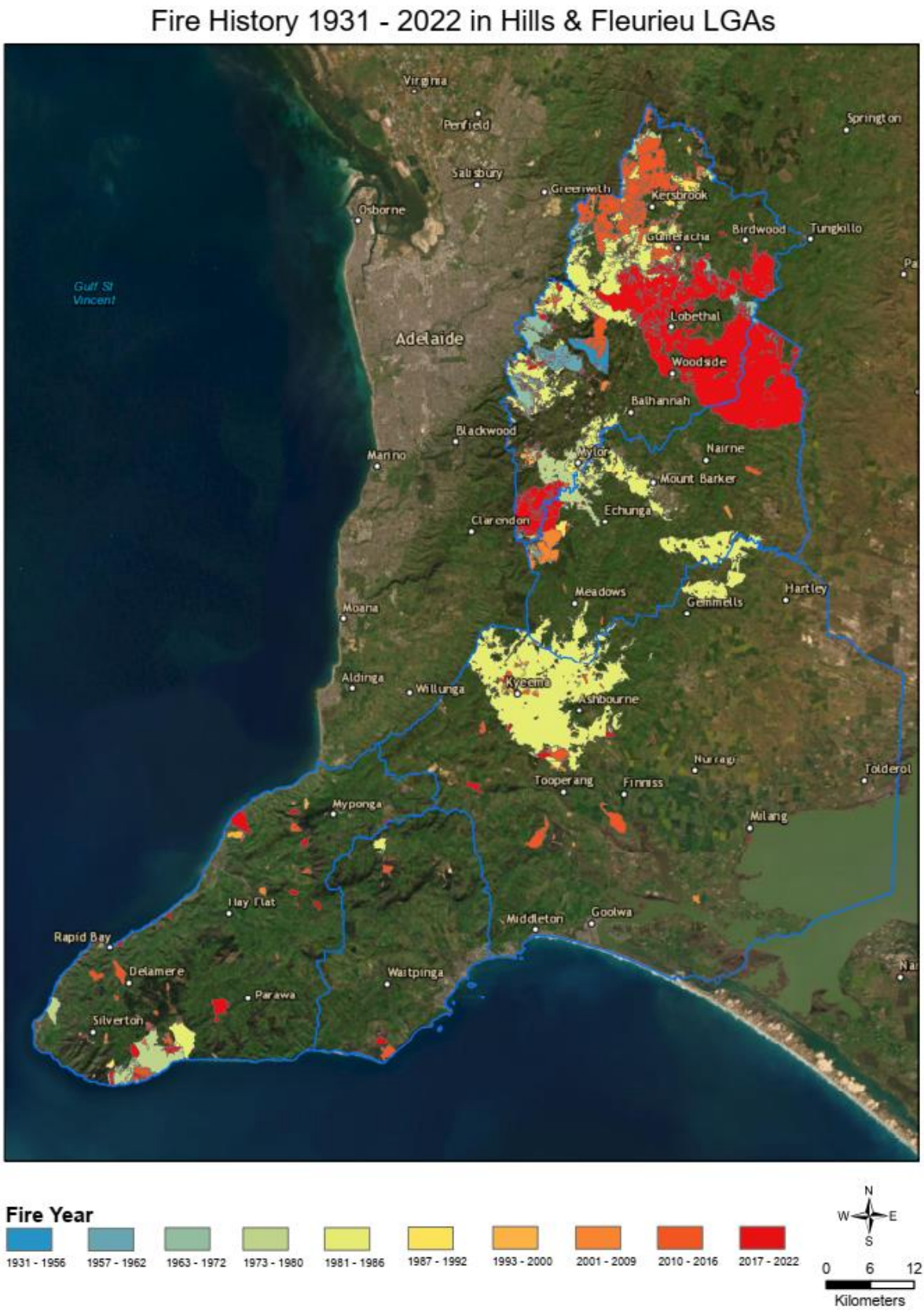


Figure 12: The fire history (includes bushfires and prescribed fires) in Yankalilla, Victor Harbour, Alexandrina, Adelaide Hills and Mount Barker council regions.

### *Adelaide Hills and Fleurieu climate change*

By 2050, there will be a projected increase in annual daily maximum temperature of 1.5°C in the Adelaide Hills and Fleurieu under RCP4.5, and an increase of 1.6°C under RCP8.5. Notably, looking at seasonal temperature changes, the warming during spring is projected to be the greatest rise with a daily maximum increase of 1.9°C at RCP4.5 and 1.7°C at RCP8.5. An increased number of extreme heat days with increased temperatures and an increased number of severe fire danger days is also projected. By 2090, most of the Adelaide Hills and Fleurieu, will see a projected increase in the number of severe fire danger days from 4.2 to 5.3 under RCP4.5, and 6.9 under RCP8.5. In areas that form part of the Murray Basin, the number of severe fire danger days is projected to shift from 3.6 to 5.3 under RCP4.5, and 5.9 under RCP8.5 by 2090.

Annual rainfall in the Adelaide Hills and Fleurieu region is projected to change by 4.1% at RCP4.5 and -9.4% at RCP8.5 by 2050. Similar to the temperature change described above, the greatest difference will be during the spring season, with a projected rainfall change of -22.3% (RCP4.5) and -14.7% (RCP8.5). Increased intensity of extreme rainfall events is projected across the region.

### *Kangaroo Island climate change*

It is projected that by 2050, there will be an increase in annual daily maximum temperature in the Kangaroo Island region. The projected increase is 1.4°C under RCP4.5, and 1.5°C under RCP8.5. Seasonally, spring is projected to be the season that with the greatest increase in warmth with increased daily maximum temperatures of 1.7°C at RCP4.5 and 1.6°C at RCP8.5. An increased number of extreme heat days is also projected for the Kangaroo Island region. By 2090, Kangaroo Island will experience a projected increase in severe fire danger days from the current baseline of 4.2 to 5.3 under RCP4.5, and 6.9 under RCP8.5.

In the Kangaroo Island region, annual rainfall by 2050 is projected to decrease, specifically by -5.8% under RCP4.5 and -10.0% under RCP8.5. The greatest decrease in seasonal rainfall is projected for the spring season, of -24.1% (RCP4.5) and -17.0% (RCP8.5). Increased intensity of extreme rainfall events is projected across the region.

### *How will climate change influence bushfires in the RH&C region?*

Across the RH&C region, there is projected to be a general increase in maximum temperatures, extreme heat days, intensity of extreme rainfall events, and a decrease in rainfall (DEW, 2022). These conditions are likely to lead to increased frequency and severity of bushfires across the RH&C region. In support of these projections, long-term trends of increasing forest fire danger index (FFDI) values (note: the Australian Fire Danger Rating , that represents the level of threat, has replaced this) have also been observed (T. Penman et al., 2023). Similarly, it has been estimated that climate change has already increased the probability of extreme heat “by at least a factor of 2”, therefore also increasing conditions ideal for bushfire (van Oldenborgh et al., 2021). This increased heat associated with climate change was suggested as one of the precursors of the devastating 2019-2020 bushfires across Australia (T. Penman et al., 2023).

In the context of the 2019-2020 bushfires, it has been emphasised that the extreme conditions were a result of anthropogenic climate change and natural climate variability. The climate drivers El Niño-Southern Oscillation (decreased rainfall and increased temperatures in El Niño phase in RH&C region, see Bureau of Meteorology), Indian Ocean Dipole (decreased chance of rainfall during the positive phase in RH&C region, see Bureau of Meteorology), and the Southern Annular Mode (decreased chance of rain in the negative phase during summer in RH&C region, see Bureau of Meteorology) may all

contribute to fire-promoting conditions across various parts of Australia (Abram et al., 2021). The Indian Ocean Dipole and Southern Annular Mode were strongly associated with the extreme conditions that were precursors to the 2019-2020 south-eastern bushfires (Abram et al., 2021). While these modes of climate variability are 'natural', Abram et al. (2021) note that these fire-promoting phases are "unusually frequent" compared with the historical record.

The combination of the fire-promoting phases of the Indian Ocean Dipole and Southern Annular Mode and the increasing temperatures, multiple heatwaves, flash drought, and intensification of droughts resulted in the catastrophic bushfire conditions during 2019 and 2020 (T. Penman et al., 2023). In South Australia, there were days that the FFDI exceeded 50 (> 50 = severe conditions, >100 = catastrophic) throughout November, December, and January (T. Penman et al., 2023). As highlighted previously, temperatures and the number of extreme heat days are predicted to increase, while rainfall is projected to decrease in the RH&C region (DEW, 2022).

There are multiple key variables that influence the danger rating of a bushfire including weather and vegetation type (see section 3. Understanding fires and bushfires). Although fire fuels do influence bushfire risk and severity, analysis of the fine fuels across New South Wales prior to the 2019-2020 fires, indicate that the fine fuel biomass was no greater than historical values (Nolan et al., 2021). The fine fuel dryness, however, was record breaking, and likely a larger influence of fire behaviour than the biomass of fine fuels (Nolan et al., 2021).

The significant influence of climate and weather on bushfire severity has been supported by numerous studies (Clarke et al., 2022; Price & Bradstock, 2012; A. P. Williams et al., 2019). Williams et al. (2019) looked at the impact of climate change on wildfires in the fire-prone state of California in North America where they observed a five-fold increase in areas burned annually between 1972 to 2018. In the less forested areas (or areas with more spare vegetation), higher than average annual rainfall created more fine fuel. This was followed by a swing to lower than average rainfall resulting in the drying of the accumulated fuels, promoting fire-prone conditions that resulted in more burned areas (A. P. Williams et al., 2019). Similarly, simulation model studies by Collins et al. (2013, 2015) and Jenkins et al. (2019) explored whether revegetation projects, in the southern and western regions of New South Wales, may increase the fire risk to assets. Collins et al. (2013) found that the probability of fire reaching an asset was dependent on the fire weather rather than the vegetation arrangement and patch size. Jenkins et al. (2019) also emphasised that fire intensity was not influenced by the planting size but by the weather, surrounding pasture loads (fine fuels), and suppression actions. Collins et al. (2013, 2015) highlighted that revegetation arrangement or increased biomass does not unequivocally increase fire size or severity, rather it is significantly influenced by weather.

Further, Clarke et al. (2022) simulated the effectiveness of various prescribed burn treatments under 2019-2020 bushfire season conditions. While prescribed burns did reduce the risk of bushfire, "the effect size was typically dwarfed by the effect of extreme weather conditions" (Clarke et al., 2022). Statistical modelling by Price and Bradstock (2012) also indicated that weather was the most substantial predictor of bushfire severity, particularly under severe or catastrophic conditions. It is also emphasised in these studies that the frequency of weather conditions conducive to bushfire will increase with climate change (Clarke et al., 2022; Price & Bradstock, 2012).

## 6.2 How will climate change impact biodiversity in the RH&C region?

Worldwide, the impact that climate change may have on biodiversity is being extensively researched. Many of these impacts are also likely to be observed within the RH&C region due to the projected warming and decreased rainfall under various scenarios (DEW, 2022).

One of the most well-known impacts of climate change is the increased frequency and severity of extreme events such as bushfires. As explored in the previous section 'Fire and Biodiversity', inappropriate fire regimes can severely impact biodiversity. Currently, it is estimated that 296 threatened or endangered vascular plants and 88% of threatened mammal species across Australia are at risk of extinction due to current fire management regimes (Santos et al., 2022; Silcock & Fensham, 2018). It is also consistently agreed that Australia, and the RH&C region, will experience increased temperatures, number of extreme heat days, and drier conditions (Canadell et al., 2021; DEW, 2022; T. Penman et al., 2023). These long-term climate trends and extreme weather forecasts create high bushfire risk conditions at an increasing frequency and severity. While modern anthropogenic fire management can contribute to inappropriate fire regimes, the "most consistent cause for shifting fire regimes is the effect of global climatic change" (Legge, Rumpff, et al., 2023). For further information on how altered fire regimes can adversely affect biodiversity, see section 5 'Fire and Biodiversity'.

Some (but not all) of the ways that biodiversity will be affected by climate change include (Butt et al., 2021; Nunez et al., 2019).

- Range shifts – a distributional shift of where a species occurs.
- Changes to morphology – this can affect a species ability to thermoregulate, genetic fitness and population dynamics.
- Phenological changes – the life cycle of a plant or animal and its interaction with seasons or other abiotic factors.
- Dieback and disease in vegetation communities – the gradual deterioration in plant health, sometimes resulting in plant mortality, can be caused by diseases and pathogens.

Figure 13 is an overview of the potential climate change impacts and their possible effects on species. This is highly dependent on the location and the species present but provides a useful starting point in considering how climate change may impact the species in a particular focus area, like the RH&C region.

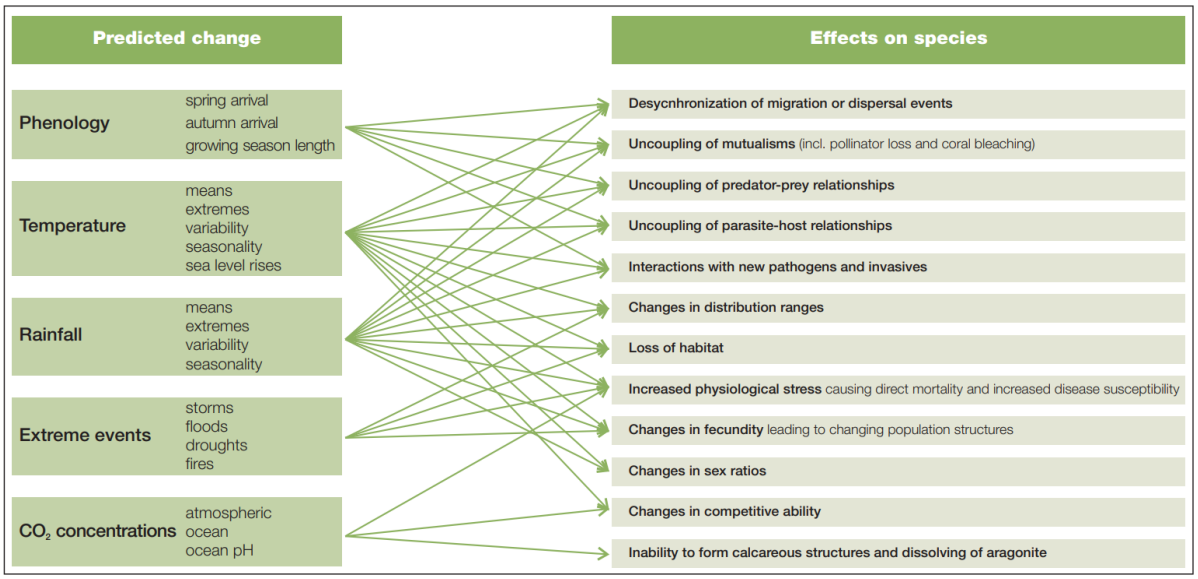


Figure 13: Predicted impacts of climate change and the effects on species as developed by Vie et al. (2009) for the International Union for Conservation of Nature.

### *Range shifts/reorganization of species assemblages*

Observed globally, is the pattern of species distribution shifting towards the north and south poles, to higher altitudes, and deeper into the ocean (Scheffers & Pecl, 2019). While this literature review did not find explicit examples of a species distribution shifts in the RH&C region, range shifts have been documented in other parts of Australia. For example, in the Wet Tropics World Heritage Area (North Queensland), population declines and range shifts were observed in bird species (Williams & de la Fuente, 2021). The local abundance of mid and high elevation bird species had decreased at the lower limit of their distribution, while the low elevation bird species had moved into higher elevations of the montane rainforest in the Wet Tropics World Heritage Area (Williams & de la Fuente, 2021). Similarly, ocean warming resulted in the contracted range of temperate kelp forests off the coast of south-west Australia by a distance of 100 km, replacing them with seaweeds and other species associated with subtropical and tropical habitats (Wernberg et al., 2016). Lastly, the extinction of the Bramble Cay melomys (*Melomys rubicola*) was the first recorded extinction of an Australian mammal due to anthropogenic climate change (Fulton, 2017). The Bramble Cay melomys was found on a small, vegetated area of the Bramble Cay in the Torres Strait. Increased salt water inundation due to sea level rise and increased storm activity, was associated with a reduction in vegetation on the cay that supported this species (Fulton, 2017). The loss of vegetation is believed to be the most likely cause for the loss of the Bramble Cay melomys as it had previously only been detected in the vegetated portion of the cay (Fulton, 2017).

As highlighted by Wernberg et al. (2016) and Williams & de la Fuente (2021), range shifts may result in the reorganization of species assemblages. The migration of species in response to climate change (whether this be change of temperature, rainfall, migration of food source) means that species are adapting (Butt et al., 2021; Scheffers & Pecl, 2019). However, this reorganisation may change ecosystem dynamics such as predation or competition with historically extant species (Scheffers & Pecl, 2019). Additionally, while some species can migrate rapidly enough to cope with the impacts of climate change, many species may not be able to. It has been highlighted that under a 3 to 4°C warming scenario, the area suitable for plants will be reduced by approximately 53%, and that temperate forests and shrublands (a substantial proportion of vegetation in the RH&C region) will experience the largest reductions in the species remaining (Nunez et al., 2019). Fragmented environments, long reproductive cycles, and the inability to move (e.g.,, plants) are key factors that may inhibit the migration and adaptation of species to climate change (Butt et al., 2021). Species that are not able to migrate may experience population decline due to unfavourable climatic conditions, migration of other species (food sources and pollinators), and increased predation, competition or disease from species that have migrated (Ong et al., 2021; Vié et al., 2009).

### *Changing morphology*

In addition to shifting or reducing a species range, it is suggested that climate change may also alter the morphology of species often through exposure to changing temperatures or altered food quality (Gardner et al., 2014). Morphology changes have already been observed in a number of bird species showing linear body size changes (Chambers et al., 2005; Gardner et al., 2014; Hoffmann et al., 2019). Within an Australian context, 24 passerine bird species were examined for changes in body size (specimens from 1960 to 2007), with 38% showing linear declines in body size, and 21% showing linear increases in body size (Gardner et al., 2014). The linear changes in passerine body size was consistent with studies on other continents and the observed climate changes (Gardner et al., 2014). Many of the birds that showed size changes in this study are present in the RH&C region such as the eastern spinebill (*Acanthorhynchus tenuirostris*), variegated fairy-wren *(Malurus lamberti)*, brown treecreeper

*(Climacteris picumnus*), and the singing honeyeater (*Gavicalis virescens*) (Gardner et al., 2014). Changes in body size may have implications for thermal biology such as energy and water requirements, and life history traits (i.e., reproduction), that may directly or indirectly impact individual fitness (Gardner et al., 2014). As this study only assessed 24 bird species, further research and monitoring is required to better understand past and current species morphology, and how climate change may impact individual species fitness and biodiversity resilience.

### *Phenological changes*

Phenological changes are alterations to processes associated with the plant and animal life cycles and their interaction with seasons or other factors (Forrest, 2016). Worldwide, changes to species phenology are some of the most well-studied aspects of climate change impacts. The early blooming of spring flowers and the early flight of migratory birds and butterflies are a few well-known examples of changing phenology in response to climate change (Forrest, 2016). While these phenological shifts may indicate adaptation to climate change (similar to range shifts), this can also cause a "de-coupling" of ecological processes when there are unequal phenological changes between trophic levels and interdependent species (Both et al., 2009; Forrest, 2016). For example, the eastern donkey orchid (*Diuris orientis*), an orchid native to the RH&C region, has been observed to have an increasingly earlier flowering time (Hoffmann et al., 2019; MacGillivray et al., 2010). The eastern donkey orchid flowers in the spring, but data records spanning 98 years (1897-2005) show the flowering time to be shifting earlier (flowering closer to the winter solstice) one to two days per decade (MacGillivray et al., 2010). Donkey orchid species mimic the appearance of native pea species (Mirbelioids) to lure bees into pollinating the orchid and is therefore dependent on having coupled/simultaneous flowering times (Hoffmann et al., 2019). As there has been altered flowering times observed for the eastern donkey orchid, it is possible that the flowering may be de-coupled from native pea flowering times, risking the success of reproduction. Although the eastern donkey orchid is a widespread species, the RH&C region is also home to many vulnerable and endangered species with restricted ranges (see Kangaroo Island species list and Adelaide & Mount Lofty Ranges species list). It is therefore, crucial to identify species at risk, understand the potential stressors and responses, and mitigate these impacts.

### *Dieback and disease in vegetation communities*

In addition to range shifts, and phenological and morphological changes in species, climate change may also cause dieback in vegetation communities. Dieback has been seen in vegetation communities around the world (Gomes et al., 2021), including in the mangrove communities of the Gulf of Carpentaria (Northern Territory) (Duke et al., 2021). More relevant to the RH&C region, however, are the observed diebacks in eucalypt forests around Australia. For example, tree crown dieback was observed in Northern Jarrah Forest of Western Australia in 2011 following extreme heat and reduced rainfall between 2010-2011 (Brouwers et al., 2013). In 2010/11, the region recorded a reduced average rainfall of 484-515mm compared to 946-998mm average annual rainfall for the previous 30 years (Brouwers et al., 2013).

Similarly, average maximum temperatures were 4.6% higher than average during 2010/11 (Brouwers et al., 2013). This was associated with the crown dieback of 236 patches of eucalypt forest between 0.3 and 85.7 ha in size (Matusick et al., 2013). Similarly, dieback of *Eucalyptus moluccana* in the Cumberland Plain Woodlands of Western Sydney has been associated with climatic changes and an outbreak of psyllids (parasitic invertebrates) (Hoffmann et al., 2019). While there was not only a single factor associated with the psyllid outbreak, higher average winter temperatures were suggested to have contributed to the disruption of "psyllid-parasitoid synchrony" (Hoffmann et al., 2019). This example of eucalypt crown dieback highlights the complex relationship between ecosystems and climate change.

Further, dieback of vegetation may contribute to increased fine fuel loads (and therefore bushfire risk), altered ecosystem functioning/dynamics, and potential decline or loss of species (Hoffmann et al., 2019).

## 6.3 Strategies for biodiversity resilience in context of climate change

Climate change is formally recognised under the EPBC Act as a factor causing habitat loss. It is named as a Key Threatening Process; "*Loss of terrestrial climatic habitat caused by anthropogenic emissions of greenhouse gases*". This Key Threatening Process has not been addressed via a national Threat Abatement Plan, as the Threatened Species Scientific Committee (TSSC) determined that sufficient actions to address greenhouse gas emissions were already underway by the Commonwealth, State and Territory governments to abate greenhouse gas emissions, and so further abatement actions would not be an efficient way to address climate change. The TSSC recommended instead that greater priority be given to actions promoting the adaptation of species and communities likely to be affected by climate change (DCCEEW, n.d.-a).

Strategies to ensure biodiversity resilience in the context of climate change are therefore likely to fall into two strategies, those that are species-focused, and those that are habitat- or area-focused. Individual threatened species may require recovery plans that address factors such as projected climatic shifts, their thermal and rainfall tolerances, keystone resources that may change in availability, seasonal movements, area of occupancy, and genetic diversity. Habitat- or area-focused strategies are a bigger-picture approach to conserving regional biodiversity that focus less on individual species and more on ecosystems. Increased threat from bushfires (e.g., (Abram et al., 2021) is one aspect of climate change that may need to be addressed via either kind of strategy.

### *Habitat continuity*

In the context of climate change, resilience of species and ecosystems will rely on their ability to adapt to altered conditions, or their ability to adjust their geographical ranges to remain within a tolerable climate envelope. Unassisted adaptation of species to new conditions relies upon them retaining sufficient genetic diversity so individuals can survive and reproduce *in situ* as climate changes (Sgrò et al., 2011), while range shifts rely upon the ability of species to move freely through the landscape, which in highly cleared and fragmented landscapes may be difficult (Beier, 2012; Nuñez et al., 2013). One of the explicit objectives of the Federal Government's *Strategy for Nature* (*Objective 7: Reduce threats and risks to nature and build resilience*) is the '*retention, protection and/or restoration of landscape-scale, native vegetation corridors*' (DCCEEW, 2022a). Maintaining or enhancing continuity between native habitat patches at any scale should ultimately contribute towards ease of movement of native species at a landscape scale and may help provide a buffer against climate change.

### *Translocations*

Where habitat continuity is not possible, or not possible quickly enough, species translocations may be a feasible option, although proper planning is needed to ensure that source populations are not harmed and that released populations will be viable (IUCN/SSC, 2013). Short-range endemic species with small populations are particularly at risk of extinction, and may require active intervention such as translocation (Gallagher et al., 2023; Legge, Rumpff, et al., 2023; Whiterod et al., 2023), preferably pre-emptively and not as an emergency response (Butt et al., 2021).

A recent example from South Australia of pre-emptive assisted colonisation for a species threatened by increased temperatures and aridity due to climate change, and which would be unable to disperse naturally, was the translocation of 600 endangered Purple-spotted Gudgeon fish (*Mogurnda clivicola*),

from two springs in the Gammon Ranges to permanent springs 120 km further south in the Flinders Ranges (Landscape SA, 2021). Translocations of threatened species are generally expensive and there is a high risk of failure, and should be undertaken when other conservation strategies are not possible (IUCN/SSC, 2013).

The concept of using locally-adapted, locally-sourced plants or animals for revegetation or translocation projects was accepted as best practice until relatively recently, it is becoming increasingly recognised that deliberate strategies to introduce genetic material from more distant locations (e.g., those that experience hotter/drier conditions) may be required to pre-empt climate change and ensure future persistence of populations (Hoffmann et al., 2021).

### *Maximising population sizes & extent*

Maximising the population size of native species within their current ranges is another strategy to give populations the best chance of resilience to events such as bushfires. For example, measures such as feral predator control will allow populations of native small mammals to expand, which could provide a buffer for populations to recover after impacts such as bushfires (J. Woinarski, Cripps, et al., 2023).

Maximising the population size of native species is not an explicit goal of the Federal Government's *Strategy for Nature* (DCCEEW, 2022a), but is consistent with Objective 6 of the strategy (*Maximise the number of species secured in nature*), which is to be achieved via '*the protection and restoration of native habitats, mitigation of threats, management of risks to environments and management of environments and their species*'.

### *Existing conservation strategies*

Conservation strategies that consider the context of climate change already exist for many key taxon groups, including for species that are not classed as threatened. These resources may currently be under-utilised, e.g., the *Action Plan for Australian Birds 2020* (Garnett & Baker, 2021), the *Action Plan for Australian Mammals 2012* (J. Woinarski et al., 2014), the *Action Plan for Australian Lizards and Snakes 2017* (Chapple, 2019), and the *Action Plan for Australia's Imperilled Plants* (Silcock et al., 2021). These publications provide actions expert guidance on recovery actions, including locally relevant information to the RH&C region, e.g., Kangaroo Island birds that were affected by the 2019-2020 bushfires (Garnett & Baker, 2021).

Legislated recovery plans are also in place for some threatened taxa at the national level. Examples of different kinds of national-level recovery plans include: plans for individual species (e.g., Painted Snipe *Rostratula australis*); plans that cover multiple related species with similar conservation needs (e.g., eight species of *Epacris* heaths in Tasmania); and regional or landscape-scale plans that address similar threats to multiple unrelated species within a geographic location (e.g., eleven species of unrelated threatened plants via the *Fitzgerald Biosphere Recovery Plan*; and nine threatened species including taxa as diverse as plants, terrestrial birds, seabirds and invertebrates via the *Lord Howe Island Biodiversity Management Plan*) (DCCEEW, n.d.-b).

As climate change is a cross-species threat, it may be worth pursuing more multi-taxon recovery plans that aim to simultaneously improve the conservation status of multiple threatened species, as well as providing benefits to species not currently listed as threatened. Area-based plans may be of particular benefit for conserving hyperdiverse, poorly-studied taxon groups, such as invertebrates, of which few are listed as threatened and little is known regarding their geographical distribution or population trajectories (Marsh et al., 2023).

# 7. Community resilience to future bushfires and biodiversity loss

Resilience can be broadly defined as "the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change" (IPCC 2007 via (Pyke et al., 2018). In the context of disaster resilience, it has been defined as the "ability of a system, community, or society exposed to hazards to resist, absorb, accommodate, and recover from the effects of a hazard in a timely and efficient manner" (UN International Strategy via (Pyke et al., 2018). Resilience may also be focused on a particular aspect of a community such as its economic resilience.

Vulnerability is often assessed in tandem with resilience in the context of shocks and stressors. Vulnerability is defined by Pyke et al. (2018) as the degree to which a unit (households, communities, etc.) is exposed to shocks or stressors.

Shocks are considered impacts that are immediate (i.e., the immediate threat to life that a bushfire close to people poses). Stressors, however, are slow onset impacts. For example, the case study presented on the town of Harrietville NE Victoria, Australia, listed stressors as misleading and sensationalised news coverage of the fires (the shock) and extended fire seasons caused by climate change (Pyke et al., 2018).

### *The importance of supporting and building community resilience*

Resilience is crucial for communities to withstand and persevere after disasters or other impacts. Vulnerability and resilience can be addressed not only in response to impacts but in anticipation. Building resilience may involve reducing vulnerability or improving coping mechanisms to shocks and stressors (Every et al., 2019). For example, ensuring appropriate fire breaks are in place around properties is a way of reducing vulnerability (Gurtner, 2022), while improving emergency communication systems may improve coping mechanisms (Every et al., 2019; Howard et al., 2018). Both approaches improve the resilience of a community.

Under climate change, more frequent and/or severe weather events (i.e., bushfires, droughts, and floods) are predicted for Australia (T. Penman et al., 2023). Therefore, improving the capacity of communities to cope with the impact of shocks and stressors is vital.

### *The strain of increasingly severe fire seasons on emergency response workforce*

Emergency management staff (e.g., fire fighters) will also be placed under increasing workloads and pressure in a changing climate (T. Penman et al., 2023). The Royal Commission into National Natural Disaster Arrangements report identified multiple strains on the emergency response capability during the 2019-2020 Summer bushfires (Commonwealth of Australia, 2020). It was highlighted that there was a lack of skilled or qualified personnel available when requested and states, including Victoria, reported a "strain on the capacity and capabilities of fire and emergency services" during the 2019-2020 bushfires (Commonwealth of Australia, 2020). The degree of resource sharing at a national and international level during disaster time was emphasised as crucial for maintaining capacity in emergency situations. For example, the involvement of Australian firefighters in the United States and vice a versa is an integral part of the emergency response to fires (Commonwealth of Australia, 2020). This resource sharing may be compromised with greater overlap of fire seasons due to climate change, resulting in the need to consider the development of short-term operational capability and strategic long-term capability (Commonwealth of Australia, 2020). In addition, it has been highlighted repeatedly

that the volunteer workforce constitutes a large proportion of the emergency services workforce in Australia (Commonwealth of Australia, 2020; Huynh et al., 2013; Lantz & Runefors, 2021; E. Smith et al., 2022). Reportedly, volunteers make up 90% of the firefighting and emergency services workforce in Australia, and 78% of responders in the 2019-2020 bushfires were volunteers (Commonwealth of Australia, 2020). Planning for increased frequency and severity of bushfires around Australia is crucial not only to improve capacity and alleviate strain on the emergency response workforce, but also to mitigate impacts on the physical and mental health of workers.

### *Physical and mental health impacts of natural disasters on emergency response staff and communities*

The physical and mental health impacts of bushfires is faced by firefighters and communities. Firefighters and other emergency response staff experience a range of physical health impacts. These include: physical strain and exertion (e.g., from lifting /moving equipment or debris); exposure to high temperatures and smoke; and lack of sleep (Fullagar et al., 2021; Hunt et al., 2019; Phillips et al., 2012). The combination of the physical activity associated with firefighting and lack of sleep has been associated with increased cortisol and other heat-related illnesses (Fullagar et al., 2021; Wolkow et al., 2016). This aligns with the noted prevalence of cardiovascular disease in firefighting populations and that "sudden cardiac death accounts for almost half of all firefighter duty-related fatalities" (Fullagar et al., 2021). Greater exposure to fire conditions and the occurrence of lack of sleep or rest time, is likely under more frequent and severe fire conditions, therefore resulting in increased risk to the physical health of firefighters.

Similarly, experiencing bushfires or other natural disasters can have short and long-term mental health impacts on firefighters and communities. A study that interviewed 58 volunteer fire fighters involved in the 2019-2020 bushfires reported that all individuals reported an impact on their mental well-being (E. Smith et al., 2022). More serious impacts were associated with repeated exposure to traumatic events and little recovery time between fire events and return to work (E. Smith et al., 2022). Similar patterns have been reported in wider communities where long-term mental health impacts are linked with rebuilding and repeated experience of traumatic events (Commonwealth of Australia, 2020). The mental health impacts (including depression, anxiety, post-traumatic stress disorder, etc.) of bushfires on firefighters and communities have been reported up to 5 years after an event (Commonwealth of Australia, 2020; E. Smith et al., 2022). To support the mental well-being of firefighters and communities, support needs to be active and reactive, to empower local leaders, and must be community-driven (E. Smith et al., 2022).

### *What are the barriers to community resilience?*

The barriers to community resilience are many and diverse. The specific barriers to resilience may be dependent on the location of a township or community, on the governance systems in place, and on a range of other socio-economic factors. Ensuring adequate understanding of the barriers to resilience will require case-by-case investigation.

Many studies have highlighted the variable levels of disaster preparedness that may be present in individual households and communities in Australia (Boon H, 2014; Every et al., 2019; Howard et al., 2018; Nicolopoulos N & Hansen E, 2009). For example, Every et al. (2019) reported that previous and/or personal experience of a bushfire, training or experience in emergency services, and information awareness, was a strong predictor of preparedness, both psychological (ability to prepare for the mental impacts of disasters) and material/physical (e.g., maintenance of defendable space, preparation of emergency kits, etc.). This aligns with research by Howard et al. (2018) who indicated a positive

association between the amount of time people had lived in the area with their level of preparedness and understanding of risks and appropriate response actions. The psychological and physical preparedness of individuals and communities may also be substantially affected by socio-economic factors. Any form of social isolation can impact the psychological and physical preparedness and coping abilities of individuals and communities. Demographic groups such as low-income, unemployed, and homeless are less likely to be able to access emergency communications and engage in preparation activities (Every et al., 2019; Howard et al., 2018). Similarly, older residents or those with physical disabilities may have less physical capacity to undertake preparation activities and have difficulties evacuating (Howard et al., 2018). It should also be emphasised that there is significant intersectionality of these population groups and the difficulties presented regarding disaster preparation and resilience (Howard et al., 2018). Culturally and linguistically diverse people face another set of barriers to resilience. Language barriers may contribute to social isolation and difficulty accessing and understanding disaster and bushfire information (Howard et al., 2018; Nicolopoulos N & Hansen E, 2009). Nicolopoulous and Hansen (Nicolopoulos N & Hansen E, 2009) found that fluency in English was associated with the implementation of safety precautions. Similarly, Nepal et al. (2012) identified that culturally and/or linguistically diverse groups were more dependent on word-of-mouth information. This could mean that these groups are not always getting the information required to be prepared and resilient to bushfires.

The literature repeatedly highlights that having strong community connections and social support is a significant contributor to individual, household, and community resilience (Berke et al., 2010; Howard et al., 2018; Maru et al., 2014; Redshaw et al., 2017; Timalsina & Songwathana, 2020), therefore, building community connections and tailored outreach are two broad strategies to tackle these barriers to resilience.

### *How bushfire preparation can build resilient communities*

In the context of bushfires, community resilience is dependent on both physical and psychological preparedness. Physical preparedness for a household may include bushfire preparation activities (e.g., maintaining defendable space, availability of independent water sources, upgrading infrastructure to fire-wise materials), the material resources needed to evacuate (i.e., transportation), or the capacity to stay and defend (Every et al., 2019; Howard et al., 2018). Psychological preparedness may also be influenced by a range of factors such as “bushfire knowledge, coping self-efficacy, proactive coping, dispositional optimism, locus of control, social support, demographic/situation factors, lived experience” (Every et al., 2019), and “self-evacuation archetypes” (Strahan et al., 2018). Additionally, Every et al. (2019) highlight that greater levels of psychological preparedness have been associated with greater material or physical preparedness. To improve overall bushfire preparation in communities, psychological, material, and physical preparedness are all required.

While psychological and physical preparation does not prevent bushfires or prevent the exposure to bushfires, it can contribute to a reduced risk of exposure and greater capacity to recover physically and emotionally from the impacts of a bushfire.

### *How can community resilience be supported?*

There are several approaches for supporting individual and community resilience. These may include governance and policy decisions or community-based initiatives (Pooley et al., 2010). Pooley et al. (Pooley et al., 2010) identified five key themes from discussions with residents in a bushfire affected community in the semi-rural community of Darlington, east of Perth, Western Australia. The five themes that residents indicated were crucial in improving their community resilience were: 1) a sense

of community, 2) social networks and social support, 3) the number of coping strategies in place, 4) the level of self-efficacy, and 5) the level of community competence. Similarly, community-led approaches, and community sector engagement programs are repeatedly emphasised as crucial in improving community resilience (Berke et al., 2010; Maru et al., 2014; Nepal et al., 2012; Redshaw et al., 2017). Redshaw et al. (Redshaw et al., 2017) reported an increase in house preparation, in obtaining neighbours' contact details, and practicing emergency bushfire plans following the "Meet Your Street" and "More than a Fire Plan" programs. Maru et al. (2014) and Berke et al. (2010) also reported strong engagement of the community in the community-led approaches.

In supporting community resilience, however, a better understanding of who is in a community is needed. For example, investigating who the vulnerable population groups are, what their specific barriers are, and what they need will be crucial to supporting household and community resilience (Berke et al., 2010; Every et al., 2019; Howard et al., 2018; Nicolopoulos & Hansen, 2009; Strahan et al., 2018). The strategies to support vulnerable groups may include equipping social and support workers with the right information (Howard et al., 2018) and developing targeted outreach programs (e.g., for specific cultural groups, for older people, etc.) (Berke et al., 2010).

The town of Harrietville, Victoria Australia, was the subject of a case study by Pyke et al. (Pyke et al., 2018) using a vulnerability and resilience assessment. The region is vulnerable to bushfires and has experienced four bushfire events from 2003 to 2018. The town is heavily dependent on tourism for its income and is a frequent thoroughfare for tourists to other destinations. While the economy was a heavy focus of the assessment, general resilience was also observed. Pyke et al. (Pyke et al., 2018) suggest that Harrietville shows the capability for resilience to bushfires and other extreme weather events due to three main factors: 1) the tourism system (low seasonality, year-round tourists), 2) community resources and governance arrangements, and 3) engagement and trust in emergency response processes and agencies. The community is described as having strong connections, resources, and a clear idea of actions that need to be taken during and in between crises.

In central Australia, a remote First Nations community has been engaging in initiatives and actions for climate change adaptation pathways (Maru et al., 2014). Maru et al. (Maru et al., 2014) reported that there was strong community support for a collaborative approach between First Nations people, pastoral, and conservation land managers, and that this collaboration had been developed over the last 20 years. The integration of Western and First Nations fire management practices had "lead to greater preparedness and responsiveness" and an increase in "desirable aspects of resilience" (Maru et al., 2014). This community was aiming to address the potential impacts of more fire directly on the people in their community, on environmental assets, and on traditional and modern livelihood opportunities (Maru et al., 2014). This highlights the ability to have multiple priorities in resilience and fire management.

To ensure long-term sustainability and impact, initiatives should be community-driven but supported by organisations and governments. This includes the development of appropriate policy, economic strategies, and climate change mitigation and adaptation pathways.

### *How we need community to build biodiversity resilience (can we get people to be ok with it)*

Biodiversity resilience is important to prioritise as it can contribute to general human well-being (Romanelli et al., 2015) and climate change mitigation (Cook-Patton et al., 2021). Building biodiversity resilience, however, requires substantial collaboration across organisations and groups, as well as support from the community as this requires actions on public and private lands. Multiple areas for improvement have been identified by de Bie et al. (de Bie et al., 2023) such as the need for 1) actions

to increase biodiversity resilience prior to bushfires, 2) further development of emergency plans for biodiversity prior to bushfires, 3) increased accessibility to biodiversity data, 4) the integration of biodiversity agency representation in emergency management, 5) and increased community engagement. Some examples of communities supporting biodiversity resilience include the translocation and cultivation of the endangered Coveny's Zieria (*Zieria covenyi*) prior to the 2019-20 bushfires and community advocacy to undertake fire mitigation measure to protect the Wollemi pine (*Wollemi nobilis*) (de Bie et al., 2021).

While, de Bie et al. (2021) highlights that many members of the community do value biodiversity and support balanced priorities, some still view vegetation inherently as a fire risk (Moskwa et al., 2016) and do not prioritise biodiversity assets. For example, one interviewee noted the conflict between protection of biodiversity versus protection of built assets, decision during the 2019-2020 bushfires, when a decision was made to direct a back burn towards a national park (burning 5000ha) to save a "small number of sheds" (de Bie et al., 2023). Changing the narrative to "consider the equivalency of value of some natural values compared to property" will require clear community support that could be underpinned by clear metrics (de Bie et al., 2023).

# 8. Bushfire preparation and biodiversity conservation - learnings from select 2019-2020 bushfire reviews.

Following the 2009 'Black Saturday' bushfires in Victoria, research revealed that planning and preparedness was inadequate amongst the people affected (Whittaker et al., 2013). The devastating 2019-2020 bushfires burned 19 million hectares in Australia and sparked numerous inquiries, reviews, and research papers. Immediately after the bushfires, a round table of leading scientists and bushfire experts agreed that collaboration between organisations and scientific communications needed to improve. The group also concluded that "research and technology collaboration efforts should include businesses, volunteers, first responder organisations and different levels of government to ensure new products, services, processes and practices are delivered to where they are needed" and there was a need for industry involvement in "mitigation and adaptation solutions" (Andrews MP 2020).

A summary of the round table discussion to the public was produced '2019-20 bushfires: a CSIRO explainer' and attributed the 2019-2020 bushfires to increased frequency of fire weather (record low rainfall, record high temperatures), drought conditions (contributing to fuel aridity) and mentions the impacts of climate change and the need for fire preparation measures (fuel management, ignition prevention and fire suppression tools) (CSIRO, 2020b). A review of the document for this literature review, noted that it does not mention biodiversity conservation.

The Royal Commission in Natural Disaster Arrangements was established in February 2020, and funding was allocated to the Bushfire and Natural Hazards CRC to undertake a research program called 'Black Summer' (Natural Hazards Research Australia, 2023). The Bushfire and Natural Hazards CRC produced a summary document outlining the findings from their research program, which breaks up the research findings over four main themes; Fire Predictive Services, Cultural Land Management, Community-Centred Disaster Risk Reduction, Bushfire Data and Reconstruction. Although this document is a summary of findings and does not include all content from the research projects, it was noted that, biodiversity was only mentioned three times, and only in the context of "people, property and biodiversity". The acknowledgement of climate change was only mentioned four times.

In 2023, a new publication "Australia's Megafires" (Legge et al., 2022) specifically addresses the "concerns shown by so many Australians about the impact these wildfires had on our nature". The research and findings summarise how the bushfires affected cultural values, ecological processes and communities and a range of taxa and lessons about biodiversity management, shared responsibility, and data and monitoring.

This section of the literature review summarises some of the key findings from these recent publications, that are relevant to RH&C Bushfire and Biodiversity project.

### *Bushfire preparation/mitigation*

- Improved bushfire risk prediction is needed for better bushfire preparation, with multiple 'Black Summer' research projects focussing on increasing the ability to predict fire risk and fire behaviour. It was suggested that 'fire behaviour analysts' will play an important role in future bushfire planning and response and that predictive services (including 'fire behaviour analysts') should be better integrated in emergency management beyond state control centres, and interact more with users/practitioners (Natural Hazards Research Australia, 2023).

- Although super-computer simulations help predict fire behaviour, the extreme fire behaviour of the 2019-2020 bushfires were not identified by existing models. Analysis of the ACCESS (Australian Community Climate and Earth-System Simulator) Fire Model after the 2019-2020 bushfires demonstrated the usefulness of such models in understanding extreme fire behaviour and integrating this knowledge into bushfire management operations, but with current technology, these models do not run in real time. The ACCESS-Fire Model assisted researchers to understand the extreme fire behaviour witnessed in the 2019-2020 bushfires, and provides an opportunity for development of real-time (coupled) capability in the future (Natural Hazards Research Australia, 2023).

- Another project furthered the understanding of soil and fuel moisture levels relating to fire risk. The Australian National University research built on this work to demonstrate the feasibility of dead fine fuel moisture hourly at a 5 km resolution over the whole continent of Australia (Natural Hazards Research Australia, 2023). This research will lead to improved fire danger predictions, using observed and modelled soil and fuel moisture forecasts to inform fire risk predictions.

- The effectiveness of prescribed burning in bushfire mitigation varies considerably and depends on the risk bring mitigated (e.g., asset loss, human life loss, etc) and the specific landscape properties such as vegetation type and population (Clarke et al., 2021). Research conducted by the University of Wollongong suggests that although the 2019-2020 bushfire season was determined by preceding weather conditions, the previous fire history (eg prescribed burns) influenced the severity of the 2019-2020 bushfire within some areas of New South Wales (Natural Hazards Research Australia, 2023). Similarly, the effectiveness of prescribed burning on Kangaroo Island, South Australia, was investigated using a large-scale fire behaviour simulation and it was concluded that there was a relationship of higher rates of prescribed burning resulting in less area burnt by bushfire (Natural Hazards Research Australia, 2023). Another research project that focussed on Kangaroo Island, used three fire simulation models to identify the prescribed burning and bushfire relationship and summarised that although prescribed burning can reduce the frequency and intensity of wildfires, “ultimately the levels of burning required to achieve this result are on a greater area of the landscape burned overall” (Natural Hazards Research Australia, 2023). This issue of scale was also summarised by Price (2023) who researched the effectiveness of prescribed burning in southern Australian forests. It was suggested that prescribed burning reduced “wildfire” modestly with a ratio of 3:1, that being three hectares of prescribed burn will reduce the area burnt by a wildfire by one hectare. It was also noted that this is “impractical and detrimental to biodiversity”.

- Community that has previous experience of bushfire are more motivated to plan and prepare, but research has shown that community expectations of bushfire risk information are growing. In a review of the 2019-2020 bushfires in NSW, research found that many people in the community expected detailed and near real-time local bushfire information, which they did not necessarily receive due to bushfire communication disruptions (Whittaker et al., 2021). Whittaker et al. (2021) concluded that community preparedness is complex and that “bushfire risk reduction is a shared responsibility between governments, fire and emergency services, businesses and communities at risk”.

- Minimising the risk and potential damage of bushfires through better preparedness was highlighted by CSIRO (2020). It was also acknowledged that in “ the medium to longer term,

the way we live and organise our communities, and how and where we build our houses also play an important part in how we prepare and respond to bushfire threats" (CSIRO, 2020b).

### *Biodiversity resilience and protection*

- To mitigate against future extinctions, and the impacts by future bushfires and climate change, species should be prioritised for conservation management that integrates in situ and ex situ strategies (Biggs et al., 2023). The 2019-2020 bushfires reinforced the need and value of ex-situ conservation as a long term strategy to protect priority flora and fauna species (Biggs et al., 2023).
- The publication "What did we learn about biodiversity management, policy and operations from the 2019-20 wildfires" (2023) provided interview feedback about protection of conservation assets that are exposed to wildfires (de Bie et al., 2023). Some key information from this research included a) conservation assets were more likely to be protected if they were mapped and biodiversity representatives were embedded into incident management teams, b) the lack of information and prioritisation of conservation assets reduced the ability to protect these species during the bushfire event, and c) biodiversity information was developed outside of the emergency management structures. Specific emergency planning for threatened species and communities resulted in the successful translocation of two species that were threatened by fire, the Wollemi pine and eastern bristlebird (de Bie et al., 2023). It was also noted that the protection of biodiversity was almost always subordinate to the protection of life and property.
- Protecting biodiversity assets against, and during future bushfire events, requires having relevant and up to date data, documented prioritisation of conservation assets (and mapping), embedding biodiversity expertise into fire operational command and risk management strategies (such as translocations).
- A review by Woinarski and Rumpff (2023) evaluated the findings and recommendations from the national '2020 Royal Commission into Natural Disaster Arrangements' and three state inquiries (South Australia, Victoria, and New South Wales). This review suggested that the inquiries did not satisfactorily consider biodiversity impacts, and that consideration should be given to biodiversity resilience, that might require an "integrated and well-resourced strategy that deals with multiple threats" (J. C. Woinarski & Rumpff, 2023). To support this view, it was highlighted that of the 80 national inquiry recommendations, only one of these was related to biodiversity (J. C. Woinarski & Rumpff, 2023).
- Biodiversity can be affected by the presence of predators, introduced species and herbivores that impact on habitat quality. Legge et. al (2023) noted that fire amplifies these impacts and there is an opportunity to undertake effective and expansive control of these threats after a bushfire (Legge, Duncan, et al., 2023). This is further supported by Keith et. al (2023) that note the management of threats such as predation, disease, and hydrological integrity, needs to be prioritised after a bushfire.
- Ecological communities are better protected through reduced extant and severity of fires that includes "decreased rate of ignition, early fire suppression and strategic fuel management within or in proximity to the ecological communities" (Keith et al., 2023).

### *First nations fire and land management*

- Cultural land management was identified as important in building resilient communities and landscapes, with first nations communities identified as critical stakeholders. It was recommended that land and fire management research and institutions should recognise the impact of research on country and First Nations communities, and there is a need to develop a First Nations research strategy, by First Nations people, to meaningfully support cultural land management (Natural Hazards Research Australia, 2023). This research also identified ten key strategies to support cultural land management, and these could be applied by RH&C.

- The use of fire to manage country, entwined with cultural values and traditions, has and will continue to be a highly skilled tool that is implemented by Indigenous Australian land management practitioners (van Leeuwen & Miller-Sabbioni, 2023). Since the 2019-2020 bushfires there has been increased interest in using First Nations fire management to reduce future bushfire impacts, and a growing acknowledgement that Indigenous Australians have stewardship over the country (van Leeuwen & Miller-Sabbioni, 2023). The research by van Leeuwen and Miller-Sabbioni (2023) identify the current perception of fire as "dangerous or a hazard" by non-Indigenous Australians, and that this has contributed to "suspending the ability" of fire management by Indigenous fire practitioners.

- A paper by Robinson et. al (2023) acknowledges the significant role that Indigenous communities have in undertaking fire management, and that its application is "dynamic, adaptive and subject to change over time". Although Indigenous communities want to lead cultural burning, there continues to be barriers. A range of solutions to address these barriers have been proposed that include a) empower Indigenous rights and authority, b) support collaboration and reconciliation, c) empower and support Indigenous-led wildfire planning, and d) empower Indigenous rights and authority to care for Country through fire (C. Robinson et al., 2023).

### *Climate change impacts*

- The '2019-2020 bushfires explainer' (CSIRO, 2020b) attributes the 2019-2020 bushfires to increased frequency of fire weather (record low rainfall, record high temperatures), drought conditions (contributing to fuel aridity) and mentions the impacts of climate change in exacerbating these conditions. Research found that whilst drought and heatwave conditions created conditions for extreme fire, local weather and topography also contributed to unusual fire behaviour in the five fires examined by researchers (including Kangaroo Island fires) (Natural Hazards Research Australia, 2023).

- Climate change is recognised as a "fundamental driver" of the 2019-2020 bushfires that influenced the intensity, severity and spread (J. C. Woinarski & Rumpff, 2023). This research by Woinarski and Rumpff (2023) also identified that the inquiries that were evaluated, all acknowledged that it is time critical to adapt management, policy, and legislation to reduce the risks associated with climate change and the frequency of fires.

# 9. Conclusion

Anthropogenically driven climate change is resulting in a warmer and drier climate and extreme weather events and bushfires, that will continue to affect communities, people, nature and biodiversity. The expanding peri-urban area (urban rural interface) intensifies the risk of bushfire threats to communities as townships and populations continue to grow. Biodiversity continues to be vulnerable to the effects from climate change with an increase in severity and frequency of bushfires, along with other pressures including predation and competition, habitat loss and fragmentation and disease and dieback, with many of these factors exacerbated after a fire.

The federal and state legislation that relates to bushfire management, considers bushfire protection and prevention, in context of people, assets and the environment. However, it is unclear if biodiversity protection, and protection of life and property, is equally prioritised in application. Key biodiversity legislation such as the Australian Governments EPBC Act provides exemptions under the Act for fire management activities that are undertaken in accordance with state legislation. It is hoped that the new South Australian Biodiversity Act will strengthen the protection of biodiversity across the state, and address any unbalanced prioritisation of biodiversity, people, and assets.

Bushfire prevention and mitigation messaging has a strong and consistent theme of "shared responsibility" at the state and federal level, however the fairness and effective application of this is uncertain. In contrast, the concept of shared responsibility for biodiversity conservation is diluted and terms are not used consistently, varying across literature and agencies. It is suggested that the use and messaging of "shared responsibility" could be applied to both biodiversity and bushfire prevention communication, and in combination (i.e. "bushfire preparedness and biodiversity conservation is a shared responsibility").

Fire management by First Nations groups is undertaken for a range of reasons including reduction of fuel loads, promoting germination of plants, and improving habitat (Firesticks Alliance n.d), however it has been largely repressed in some areas of South Australia. It has been suggested that the suppression of Indigenous fire management in some parts of Australia, has resulted in a changed landscape that supports a greater fuel load and greater fire risk. Since the 2019-2020 bushfires there has been increased public support for First Nations land management. It cannot be assumed that the objectives of fire management are always going to be the same between non-Indigenous people and Indigenous fire practitioners – the different perspectives and values need to be identified and considered. Relationship building and establishing trust between First Nations groups, communities, and agencies such as CFS, local government, state government, landscape boards and First Nations groups is critical, and will underpin future steps.

The interaction between biodiversity and fire is complex as burns can have both positive and negative effects on individual species and ecosystems. Bushfires are often described as 'destroying' areas of native bushland, but the effects of fire vary enormously depending on vegetation type, and on the intensity, extent, season, and frequency of burning, and on the landscape context. Bushfires or even prescribed burns, can threaten native biodiversity when they are too hot, occur too often or out of season, are large in extent, or happen in highly modified and fragmented landscapes that limit the ability of species to recolonise burnt patches, and where post-fire weed invasion is more likely. Rare and threatened species with limited geographical distributions are particularly vulnerable to fires, and may be at risk of becoming locally, regionally, or nationally extinct.

As the intensity and frequency of bushfires is likely to increase with the effects of climate change, and the ignition, spread and intensity of fires is often difficult to manage (as it is influenced by fuel, topography, and weather), there is a need for strategies that focus on bushfire mitigation and preparedness. In acknowledgement that fire is a natural process ("hazard") and can not necessarily be prevented, preparedness should focus on reducing vulnerability and exposure to high priority areas, communities, and biodiversity assets.

Identifying appropriate fire regimes and "best-practice fire management" for biodiversity outcomes, will depend on land management history and fire frequency, scale, and intensity, in addition to the highly nuanced and complicated factors of climate change, species ecological requirements and distribution, competition, predation, habitat fragmentation, modification and connectivity. The efficacy of prescribed burns to reduce the impact from bushfires, or to improve biodiversity resilience, and the use of these prescribed burns to achieve multiple outcomes, continues to be debated and contested.

In recognising climate change and the likely increase in bushfire occurrence and intensity, supporting community resilience, so they can psychologically and materially prepare and then recover, is critical and underpins bushfire preparedness. The barriers to resilience needs to be addressed, at a localised and demographic-group scale, and will likely rely on two key strategies of a) outreach and trusted communication, that is effectively delivered, and b) strengthening community connections. Integrating biodiversity conservation into resilience models is equally as important and achievable as community valuing biodiversity and nature and approaches that balance biodiversity with other fire management priorities.

The Resilient Hills & Coasts is a region with significant fire history, including the 2019-2020 bushfires, and will continue to be vulnerable to the impacts from frequent and large-scale bushfires. Although protecting life and property from significant bushfire impacts is essential, the region also has significant biodiversity values that should be equally considered and prioritised. An integrated approach and application of bushfire preparedness and biodiversity conservation is required, that acknowledges the site-specific trade-offs and management objectives, and is underpinned by a "shared-biodiversity and bushfire responsibility" concept.

The Resilient Hills & Coasts 'Bushfires, Biodiversity and Community Resilience Spotlight Studies' and 'Bushfires, Biodiversity and Community Resilience Discussion Paper' further explores the opportunities and initiative that will address bushfire exposure and biodiversity vulnerability within the region.

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