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Ecological communities: impact and response

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Summary

Context and challenges

- Many ecological communities (ECs) are in decline due to the impacts of inappropriate fire regimes and other threatening processes, many of which compound the impacts of fire.
- Although Australian legislation, and that of most states/territories, provides for listing of ECs as threatened (TECs), national assessment of the impacts of the 2019–20 wildfires on ECs is constrained by inconsistent EC definition, classification and mapping across jurisdictions.
- Of TECs that were nationally listed as threatened prior to the 2019–20 wildfires, three had > 40% of their distributions burnt, and another three had 20–40% of their extent burnt. Of a broader group of 92 fire-impacted ECs, including many listed as threatened by state jurisdictions, five had more than 90% of their extent burnt and 26 had more than half of their extent burnt.
- The impacts of fire on ECs are diverse, but not always negative, and consequences can include changes in species composition (including reduced abundance of foundational species), vegetation structure, ecosystem functions, resource availability and incidence and extent of other threats.
- The interval between successive fires is critical to community persistence, with irreversible changes ('ecosystem collapse') to disequilibrium states likely in some ECs, especially if inappropriate fire regimes disrupt life-cycle processes or transform habitats of key species.

Main findings

- Priority management responses needed to recover fire-affected ECs, and reduce the likelihood of further loss in future fires, include post-fire control of introduced herbivores; control of disease; protection of unburnt refuges from

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fire; protection of burnt areas from further fire; and protection of hydrological integrity.

- Major knowledge gaps (including the mechanisms of threats, their interactions and effective control methods) constrain effective management needed for recovery.
- Underlying these threats is a more pervasive need to reduce anthropogenic climate change. If this cannot be achieved, there will be ongoing diminution at least of rainforest, montane ash, peatland and montane heathland ecosystems.

Introduction

The 2019–20 wildfires of southern and eastern Australia burnt extensive areas of eucalypt open forests, and a wide range of environments including rainforests, eucalypt woodlands, alpine and coastal heathlands, and peatlands, with impacts extending also to aquatic and marine environments (Table 8.1; Chapters 6 and 7).

Ecological communities (ECs) are typically described at a finer scale than major vegetation groups, and are the main focus of this chapter. As defined broadly under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), ECs are assemblages of native species that inhabit a particular area in nature. They may be characterised by species composition, structure, habitat features, distribution, biological interactions and ecosystem function (Keith 2009); and include a biotic component as well as the physical environment supporting that biota. ECs can be listed as threatened (TECs) under the EPBC Act, and ~90 are so listed (as of 2021). TECs are also listed in most states and territories; and ecosystems can also be listed as threatened at a global level through the IUCN Red List of Ecosystems (Keith *et al.* 2013). The listing and protection of TECs provides a

Table 8.1. Major Australian vegetation groups (as defined by the National Vegetation Information System, NVIS version 5) and their proportion burnt in the 2019–20 wildfires (from Gallagher *et al.* 2021).

Note: All other vegetation groups had < 1% of their national extent burnt.

Major vegetation group (MVG)	Total area burnt (km^2)	% of total area of MVG burnt
Eucalypt Tall Open Forests	12 016	33.8
Eucalypt Open Forests	35 695	15.7
Heathlands	1894	12.2
Cleared, modified, aquatic, unclassified	11 909	11.6
Rainforests and Vine Thickets	2562	7.1
Eucalypt Low Open Forests	746	6.7
Eucalypt Woodlands	23 847	2.8
Mallee Woodlands and Shrublands	5644	2.7
Other Shrublands	1670	1.4
Low Closed Forests and Tall Closed Shrublands	225	1.2
Other Forests and Woodlands	522	1.2
Callitris Forests and Woodlands	369	1.1
Casuarina Forests and Woodlands	156	1.0

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complementary and more inclusive conservation focus to listing of individual threatened species, as it allows more opportunity to consider and manage ecological processes, and recognises the critical interactions among species. Furthermore, listing of TECs also provides a mechanism to safeguard many species, including poorly known species, that may not be individually eligible for listing because of critical knowledge gaps.

Many Australian ECs are in decline, with declines driven by multiple threats and their interactions. Fire has a complex impact on ECs. Individual fires – and the fire regimes in which they are embedded – may sustain, threaten or have negligible effect on the diversity and function of ECs. Such variable responses are associated with the inherent characteristics and pre-fire state of the EC, and of features of the fire, or fire regime, itself, as well as effects of fires on other threatening processes (Keith *et al*. 2021). In some ECs, such as rainforests, fire is an exceptional event, capable of causing long-lasting impacts, whereas it is an integral and necessary part of the ecological fabric for other ECs.

Changed or inappropriate fire regimes are causing major detrimental impacts for some ECs. Such impacts occur especially where fires recur at intervals that are too short to allow for continuation of critical life-cycle processes, such as development of habitat resources, maturation and accumulation of seed banks and development of fire-resistant organs – in such cases of 'interval squeeze', the EC may be transformed irretrievably (Enright *et al*. 2015). In some such cases, the ecological community may collapse irrevocably to a degraded state in which it has lost key defining features (including foundational species) and functions (Bergstrom *et al*. 2021). In some cases, this change is self-reinforcing as the degraded state has structural and fuel load characteristics that render future fire more likely or more severe (Camac *et al*. 2017). Individually, and within the context of their increasing frequency, recent severe wildfires, including the 2019–20 wildfires, are driving or contributing to such collapse for some Australian ecological communities including montane ash forests (Burns *et al*. 2015), conifer forests (Holz *et al*. 2020) and some heathlands (Barrett and Yates 2015).

In this chapter, we summarise the outcomes of a post-fire vulnerability assessment for ECs (Keith *et al*. 2021), providing case studies to highlight the impacts of the fires and interacting threats on some highly vulnerable TECs. The assessment built on an initial spatial assessment of nationally threatened ECs (DAWE 2020), by combining fire severity mapping with a broader range of distributional data for listed and unlisted ECs, as well as consideration of threats that interact with fire (Keith *et al*. 2021). The objective was to identify fire-affected ECs that were consequently priorities for national listing and management to support recovery. The approach was further developed by Keith *et al*. (in press) to consider a suite of 15 interactive threat types, categorised into four major groups (Table 8.2). These threat types mediate the pre-fire susceptibility of an EC to impacts from wildfire, the likelihood of compounding impacts of that fire with other threats, and the factors likely to constrain recovery. Consideration of these threats and their interactions is necessary to guide recovery efforts.

There are some noteworthy caveats on the assessments. First, their ambit has been restricted to terrestrial ECs, and no comparable assessment has yet been completed for freshwater ECs (but see Chapter 6). Second the current state of listing of Australian ECs is suboptimal, as many ECs likely to be eligible for national listing have not yet been assessed and, as of 2017, less than one-third of listed TECs were systematically monitored (Keith *et al*. 2018). Within Australia, the legislation of some jurisdictions (South Australia, Northern Territory) does not yet provide for listing TECs; there is inconsistency across jurisdictions in TEC definition and classification; and mapping of many ECs (including TECs) may be imprecise and inaccurate to varying degrees (Nicholson *et al*. 2015). As

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Table 8.2. A categorisation of 15 fire-related threats to ecological communities, and the ecological mechanisms by which they may affect community structure, function and composition (modified from Keith *et al.* in press).

Threat type	Mechanism
A. *Fire regime components*	
A1. High fire frequency	Disrupts life-cycle processes for some organisms, such as seed bank accumulation, development of habitat structures and resources
A2. High fire severity	Causes long-term disruption to ecosystem structure and function; alteration to habitat suitability by limiting resources; or causes long-term population declines in species that cannot compensate high mortality with reproduction or immigration
A3. Out-of-season fires	Disrupt phenological processes, limit population turnover or expose organisms to risks of mortality
A4. Substrate fires	Consume organic substrates and cause long-term alteration to ecosystem structure and function, destroy regenerative organs and propagules, and alter habitat suitability, given long timeframes required for peat accumulation
B. *Fire-environmental interactions*	
B1. Fire–drought interactions	Drought before or after fires imposes additional stress on plants and animals, by depleting resources or health or limiting resources to support post-fire recovery.
B2. Fire–hydrological change	Fire may increase impacts of hydrological change by accelerating ecosystem adjustments to new stable states under altered water availability, with consequent changes to ecosystem structure and function.
B3. Post-fire erosion, sedimentation or pollution	Fire may increase risks of erosion and sedimentation by intense rainfall or wind events in the early post-fire period, causing long-term changes to ecosystem structure and function.
B4. Fire–climate change	Climate change may drive many of the above mechanisms, and may also alter bioclimatic habitat suitability for invasive species.
C. *Fire-biotic interactions*	
C1. Post-fire interactions with invasive herbivores	Herbivores may concentrate in post-fire regrowth, limiting survival and growth of post-fire seedlings and resprouts, and may degrade ecosystem function by reducing plant biomass and litter, and disrupting soil structure.
C2. Post-fire interactions with invasive predators	Predators may concentrate and hunt more efficiently in burnt areas, causing selective declines in faunal components of ecosystems.
C3. Fire–disease interactions	Fires accelerate or amplify impacts of disease, by increasing the invasiveness and infectiousness of the disease or by increasing susceptibility of affected organisms; this interaction may have severe impacts on foundational plant species that contribute to ecosystem structure and function.
C4: Fire–invasive plant interactions	Fires may promote invasion by introduced plants by increasing availability of nutrients, light and soil water; weed invasions may then competitively exclude some native plant species and reduce habitat suitability for some animals.
D. *Fire–human disturbance interactions*	
D1. Fire–logging interactions	Legacies of past timber extraction and post-fire disturbance (e.g. salvage logging) may disrupt post-fire regenerative processes.
D2. Fire–fragmentation interactions	Fragmentation decreases effective population sizes, and post-fire recolonisation, reducing diversity and function.
D3. Fire–human access interactions	Legacies and post-fire disturbance associated with human use may disrupt post-fire regenerative processes, with associated declines in ecosystem structure and function.

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such, a comprehensive assessment of the impacts of the 2019–20 wildfires was constrained and charting post-fire recovery similarly challenged. Last, given the timeframe required to support emergency recovery decisions, the vulnerability assessments of most ECs were desktop based (see also Chapter 9). Some on-ground assessments have now been conducted, and here we present some initial findings from the case studies. With further monitoring, we expect more clarity on the impacts of this fire event.

Findings

Summary of impacts of the 2019–20 wildfires

Of TECs that were nationally listed before the 2019–20 wildfires, Keith *et al*. (in press) reported that three had > 50% of their distributions burnt (Upland Basalt Eucalypt Forests of the Sydney Basin Bioregion; Temperate Highland Peat Swamps on Sandstone; Eastern Stirling Range Montane Heath and Thicket), and another four had 20–40% within the fire footprint (New England Peppermint (*Eucalyptus nova-anglica*) Grassy Woodlands, Aquatic Root Mat Community in Caves of the Swan Coastal Plain, Alpine Sphagnum Bogs and Associated Fens, and Natural Temperate Grassland of the South Eastern Highlands). Two of these seven TECs that are currently listed as Endangered are now likely to be eligible for up-listing to Critically Endangered status. The highest priority for formal reassessment of conservation status is for the Eastern Stirling Range Montane Heath and Thicket. An additional six nationally listed TECs, including Lowland rainforest of subtropical Australia, had more than 10% of their distributions burnt and major susceptibility to at least one fire-related threat (Keith *et al*. 2021).

These TECs formed part of a larger group of 92 ECs recognised by state, territory or Commonwealth authorities that occurred within the 2019–20 fire footprint. Five of these had more than 90% of their extent burnt in the 2019–20 fires, 25 had more than half of their extent burnt and 55 had more than 10% of their extent burnt (Keith *et al*. in press). Very few of these fire-affected ECs are currently listed as threatened at national level: however, as at February 2022, 16 fire-affected ECs are under formal assessment for such listing. The most affected ECs ranged from rainforests to peatlands, and included some, such as heathlands and sclerophyllous eucalypt forests, which are traditionally regarded as fire-prone and fire-adapted.

All of the ECs affected by the 2019–20 wildfires face a mix of individual and interactive threats, many of which compound, and are compounded by, the impacts of fire (Table 8.1; see also Chapters 17–19). Three fire-related threat types posed the most severe threats to large numbers of ECs: high-frequency fire (short fire interval); pre-fire drought; and post-fire invasive predator activity (Keith *et al*. in press). Given their variety and complex interactions, and the likely variable response of the constituent species in any community to threats and associated actions, management needs to address these threats in a strategic, integrated manner (Keith *et al*. 2021).

Temperate Highland Peat Swamps on Sandstone

Four peatland ECs are currently listed as threatened under the EPBC Act. In addition to fire, peatlands are subject to a range of threats, including changing climate, introduced herbivores, erosion and sedimentation, weed invasion and longwall mining.

The nationally listed Temperate Highland Peat Swamps on Sandstone TEC includes three state-listed communities, of which two were extensively burnt: Newnes Plateau shrub

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Fig. 8.1. Collapse of a Newnes plateau shrub swamp peatland ecosystem caused by the combined effect of fire and hydrological disruption (due to underground longwall mining). (Photo: David Keith)

swamps (99% burnt) and Blue Mountains swamps (56%) (Tozer and Keith 2021). Approximately 20–30% of the burnt area of the TEC experienced high-severity fire (Keith *et al*. in press), as widespread drought resulted in low fuel moisture before ignition (Nolan *et al*. 2020). The responses to fire were notably affected by interactions with other threats. The hydrology of many peatlands has been disrupted by underground long-wall coal mining, leading to draining of the perched aquifer necessary to sustain the peatland community. Sampling after the 2019–20 wildfires revealed marked disparities in the impact and extent of recovery among burnt swamps, depending on whether prior underground mining had affected hydrology. Whereas many swamps recovered vigorously post-fire, in swamps where underground mining had led to substantial reduction in water retention, the fires consumed peat, killed plant regenerative organs and destroyed seed banks (Fig. 8.1). At such sites, recovery was largely subverted and the EC had collapsed, with almost no regrowth of the constituent species within a year after fire, but rather incursions of eucalypt seedlings into the drier soil, resulting in transformation from peatland EC to species-poor eucalypt thicket (Tozer and Keith 2021).

Upland bogs in the Australian Capital Territory

Nationally listed Alpine Sphagnum Bogs and Associated Fens include upland bogs in the Australian Capital Territory. They support distinct fauna and flora, including the Critically Endangered northern corroboree frog (*Pseudophryne pengilleyi*) and the Vulnerable

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broad-toothed rat (*Mastacomys fuscus*). Bogs intercept, filter and store large volumes of water that is slowly released into streams and rivers.

The bogs in this region are impacted by feral animals, weeds, pathogens, recreation, development, and climate change, as well as altered fire regimes, including an expected increase in peat fires. Post-fire recovery of bogs could be slowed or prevented if they are disturbed by introduced ungulates, burnt frequently over relatively short timeframes or affected by peat fires (Walsh and McDougall 2004). After being burnt, bogs can transition into grassland or heathland ecosystems (McMahon *et al*. 2015).

Upland bogs in the Australian Capital Territory are at the northern edge of the distribution of the nationally threatened EC, and have encountered three severe wildfires over the last 40 years. The most recent fire in 2020 burnt 86% of known bog sites in the territory, which completely removed all vegetation except for bleached *Sphagnum* moss and rare small unburnt patches (Fig. 8.2). Vegetation surveys conducted 9–13 months afterwards found that burnt sites on average had significantly more bare ground (43% burnt *v.* 0% unburnt) and less vegetation cover and complexity (summed cover index of 58% burnt *v.* 117% unburnt). This dramatic loss of vegetation is highly detrimental to bog fauna: sampling reported that broad-toothed rats were missing from five of six burnt survey sites, despite being found there before the fires. Further work is needed to distinguish long-term trends in these attributes from short-term fluctuations in the system as it responds to fire cycles.

After fires in 2003, Hope *et al*. (2009) inferred that re-wetting of degraded bogs was a critical priority to help ensure function and facilitate recovery. The main method used to

Fig. 8.2. Snowy Flats bog after fire showing mostly bare ground with burnt and bleached *Sphagnum* moss mounds. (Photo: Nathan Kay)

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Fig. 8.3. Coir log damming the stream channel to slow and spread water throughout the peat soil, at Rotten Swamp in the Australian Capital Territory. (Photo: Nina McLean)

achieve this is the installation of leaky weirs (typically coir logs) in stream channels. Consequently, following the 2019–20 fires, the ACT Parks and Conservation Service installed leaky weirs in nine priority bogs (Fig. 8.3) with the aim to prevent and reduce erosion or incision in the event of surface disturbance (e.g. by ungulates) and heavy rains; increase peat wetness; and promote vegetation recovery. A long-term project has now been established to assess their effectiveness by tracking vegetation recovery, soil moisture, watertable depths and streambank stability at sites with and without constructed leaky weirs, with results from this monitoring contributing to potential improvements for future post-fire management.

Montane ash forests

Successive wildfires from 1998 to 2020 have occurred throughout the montane forests of Victoria. Of particular concern is that 87% of Victoria's alpine ash (*Eucalyptus delegatensis*) dominated forests (see Fig. 8.4) have fallen within these overlapping fire extents. In New South Wales, alpine ash forests have been similarly exposed to high-frequency fire, with large areas burnt in successive fires during 2003 and in 2019–20. Nationally, some 48% of mainland alpine ash forests has experienced at least two canopy fires in the past 50 years (Keith *et al*. in press). The impact of two or more high-severity fires in quick succession has led to concerns about the loss of alpine ash from these ecosystems (Bowman *et al*. 2014; Fairman *et al*. 2016) and the implementation of post-bushfire recovery and regeneration programs that sow alpine ash seeds into multiple burnt sites (Bassett *et al*. 2015). The 2019–20 wildfires led to many fire-impacted areas of *E. delegatensis* (and mountain ash (*E. regnans*)) forest across the Australian Alps being impacted by short-interval fires with ~11 500 ha reseeded to prevent the loss of these species. In Victoria, ~23% of the alpine ash has remained unburnt for many decades, 32% has burnt at low or moderate severity (on multiple occasions in some places), 39% has had a single high-severity fire while 7% has been impacted by two (5.7%), three (1.5%) or four (0.001%) fires. Given this complexity of

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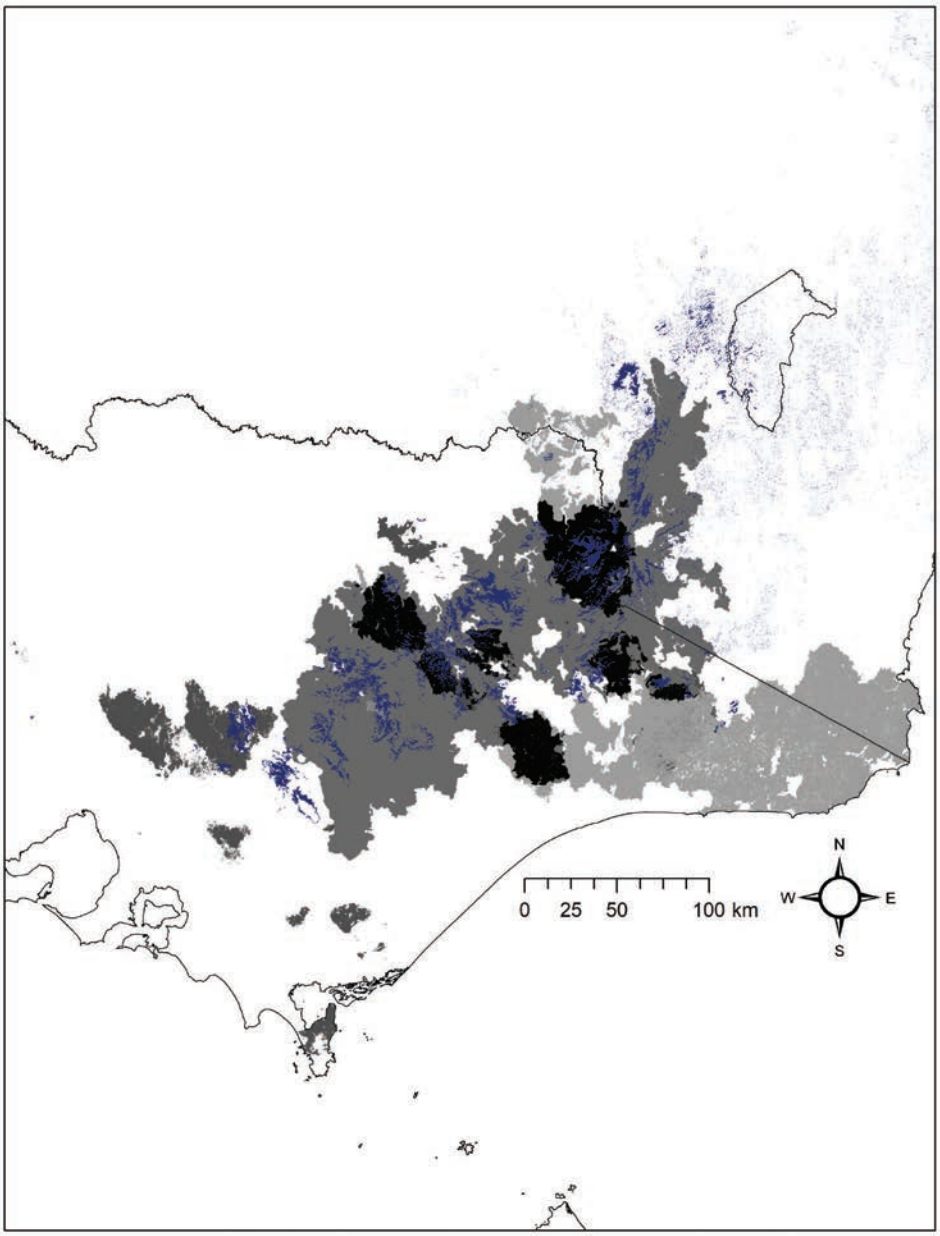

Fig. 8.4. Alpine ash extent in south-eastern Australia (dark blue) showing areas burnt by wildfires in the periods 1998 to 2018 (dark grey), 2019–2020 (light grey) and where the 2019–2020 fires overlapped with 1998 to 2018 fires (black).

fire occurrence, ~23% is at risk if a fire occurs in the near future and 7% has already been exposed to short-interval fires. This means that fires have occurred when the immaturity risk (i.e. no or limited seedbank) of these forests was high (McColl-Gausden *et al.* 2022) with ~23% of the alpine ash forest extent currently within this immaturity risk window following the 2020 bushfires. The high-risk window for complete loss of the structural

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Fig. 8.5. Surviving alpine ash among standing and fallen fire-killed saplings at a site burnt by three high-severity fires (2007, 2014, 2019). Dead *Acacia obliquinervia* are prominent as is the amount of coarse wood debris from fallen ash killed in previous fires. Epicormically resprouting *E. dalrympleana* are in the background. (Photo: Craig Nitschke)

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dominant of the community is likely to last for 15–20 years (McColl-Gausden *et al*. 2022). However, some alpine ash individuals have been found to produce viable seed at 8–9 years (Doherty *et al*. 2017). Nonetheless, substantial reductions in tree density and large structural changes can occur if forests are burnt in their early developmental stages.

Prior to the 2020 fires, multiple fire events had already impacted forests dominated by alpine ash and snow gum (*E. pauciflora*) and high elevation mixed eucalypt species forests. The impacts of short-interval fires have led to changes in forest structure in snow gum and mixed species forests (Fairman *et al*. 2017, 2019), a change in understorey composition in snow gum forests (Fairman *et al*. 2017) and changes in carbon stocks across all forest types (Bowman *et al*. 2014; Fairman *et al*. 2017). Assessments of the impacts of the 2019–20 wildfires in alpine ash forests have found a reduction in alpine ash abundance, reduction in standing carbon stocks, reduced sapwood area, reduced litter depth, increased coarse woody debris, increased flora species richness, and changes in species composition in areas impacted by multiple fires (Fairman *et al*. 2022). A decline in *Acacia* species in areas subjected to multiple fires has been documented, indicating that the hypothesised increase in *Acacia* dominance after multiple fires (Lindenmayer *et al*. 2011) may not be supported under scenarios involving multiple fires in montane forests. These changes may be shifting ecosystem functioning. However, there are some hopeful signs: reproductive ash as young as 7 years old have been found in burnt areas and seedlings from these trees (7–14 years old) found in recently burnt areas (Fig. 8.5). Another positive sign is the abundance of alpine ash in areas subjected to resowing. Notwithstanding these promising signs, climate change will increasingly place these montane landscapes at risk from more frequent fires. Species may persist in these landscapes but their dominance will shift; this will lead to changes in structure, composition, age distribution and availability of resources, such as tree hollows, that will influence ecosystem functioning at broader spatial scales over time.

Eastern Stirling Range Montane Heath and Thicket

The Eastern Stirling Range Montane Heath and Thicket EC occurs within the floristically diverse South-west Australian Floristic Region. It was assessed as Critically Endangered using IUCN Red List criteria for ecosystems (Barrett and Yates 2015) and is currently listed as Endangered under national legislation. The EC is geographically restricted and the impact of *Phytophthora* dieback in combination with recent wildfires has led to extensive changes in the EC (Department of Parks and Wildlife 2016). Of particular concern were wildfires in 1991 and 2000 that resulted in some 74% of the 322 ha EC experiencing a fire interval of 9 years, within the threshold for collapse for this EC (Barrett and Yates 2015).

A wildfire in autumn 2018 burnt up to 74% of the EC, and in December 2019 a second fire burnt 43% (Fig. 8.6). This habitat had been previously burnt in either 2000, 1991 or was long unburnt; therefore the shortest fire interval preceding the 2018–19 fires was 18–19 years. However, it is estimated that up to 15% of the EC burnt in both the 2018 and 2019 wildfires.

Monitoring commenced after the 2018 fire and was extended to areas burnt in 2019. There has been more abundant seedling emergence of some key *Phytophthora*-susceptible species compared with after the 2000 fire, plausibly associated with the longer fire interval. An initial analysis of long-term data suggests that species not susceptible to *Phytophthora* are relatively resilient to the recent fire regime. While the impact on the EC in areas that burnt in 2018 and 2019 is still being assessed, there has been a detrimental impact on seedlings of serotinous species such as the mountain dryandra (*Banksia montana*) that

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Fig. 8.6. Eastern Stirling Range Montane Heath and Thicket TEC, autumn 2020. Habitat burnt in 2019 and 2018 shown on right and left sections of image, respectively. (Photo: Sarah Barrett)

germinated in 2018 and were burnt in 2019 (Chapter 9). Seedling densities of species with soil-stored seed such as the iconic mountain bells (*Darwinia* spp.) are also lower where the two fires overlapped. High levels of browsing of shrub species (Proteaceae, Fabaceae and Myrtaceae) has been documented in association with significant activity of the quokka (*Setonix brachyurus*), a threatened native macropod (Rathbone and Barrett 2017). Drought in the summer of 2019–20 was associated with elevated seedling mortality on shallow soils. The overall impact of *Phytophthora* dieback had been relatively low until spring 2021, when high disease impact on vulnerable juvenile plants became apparent after very wet conditions in winter and spring.

This EC is also considered in Chapters 11 and 34, in the context of the extinction of an invertebrate species narrowly endemic to the community. The example demonstrates that although ECs are often defined by plant species, ECs may also be characterised by strong interactions among constituent plant and animal species.

Gondwana rainforests

Rich in diversity and deep time paleo-history, parts of the Gondwana Rainforests of Australia World Heritage Area (GRAWHA) were severely impacted by the 2019–20 wildfires (Kooyman *et al*. 2020; Ward *et al*. 2020). The Gondwana rainforests of the south-east Queensland and northern New South Wales bioregion represent one of the three most biodiverse areas in Australia. These forests occur on a range of soil types and across elevations from near sea level to more than 1200 m. The wide range of environmental

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conditions produce mosaics of different rainforest types, including lowland warm subtropical, cooler upland subtropical, warm and cool temperate, and several dry rainforest types (Fig. 8.7). In combination these forests provide a diverse range of habitats for flora and fauna species that represent lineages with Gondwanan and Indo-Malesian origins (Kooyman *et al*. 2014, 2019).

For millions of years the locations that now form part of the GRAWHA reserves have acted as a refuge for ancient lineages (Kooyman *et al*. 2014; Rossetto and Kooyman 2021). In 2019–20, a combination of factors including catastrophic fire weather, a prolonged drought, and the likely influence of past land management including intensive logging of areas adjacent to rainforest, resulted in major impacts to some rainforest areas in the Nightcap Range in New South Wales (Kooyman *et al*. 2020; Lindenmayer *et al*. 2020). National Park agencies in Queensland and New South Wales commenced monitoring impacts immediately after the fires (Fig. 8.8). Targeted surveys were undertaken for threatened species such as Nightcap oak (*Eidothea hardeniana*) and long-nosed potoroo (*Potorous tridactylus*). The results have shown significant areas of important rainforest refugia survived the fires, but confirmed that many thin-barked rainforest trees are very susceptible, even to low-severity fire, with high mortality (up to 85% of standing tree stems), a feature of the most fire-affected rainforest areas. After 3 years of monitoring these sites, many dead tree stems are now falling, creating another round of forest disturbance and potentially adding to future fire risk associated with the accumulation of ground fuels and maintenance of a more open structure that promotes fuel drying. Some

Fig. 8.7. Border Ranges region with a transition from lowland to upland rainforest ECs. (Photo: Justin Mallee)

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Fig. 8.8. Canopy image on permanent plot showing fire-impacted warm temperate rainforest (coachwood (*Ceratopetalum apetalum*)-dominated) with ca. 85% rainforest tree mortality. (Photo: Robert Kooyman)

rainforest species showed strong resprouting from the base despite the above-ground portion of the trees being killed, but this effect appeared to be related to the degree of basal smouldering. In these stands the impacts largely reflect changes in forest structure rather than major shifts in floristic composition. It is likely that re-establishment of canopy structure and the associated microclimate will take many decades, assuming future fires can be excluded. Regeneration trials show sometimes prolific natural rainforest regeneration from seed of a few species. However, areas of burnt warm-temperate rainforest formerly dominated by coachwood (*Ceratopetalum apetalum*) are now being dominated by the regeneration of tens of thousands of wattles (*Acacia* species), which could increase future fire risk and compete for space with the regenerating rainforest. Trials have now been implemented to both monitor and control the *Acacia* regeneration and investigate the effects of such control efforts. The interventions to protect priority (threatened) species rainforest habitats are ongoing and are a critical component of securing conservation outcomes for target taxa in the long term.

Detailed monitoring and ecological research are helping to guide decision making in these complex settings and inform management actions and fire planning to improve resilience and reduce future impacts.

Warm temperate rainforests in Victoria

Around one-third of Victoria's warm temperate rainforest and more than three-quarters of similar rainforests in south-eastern New South Wales were burnt at high severity during the 2019–20 fires (DELWP 2020); this was of great concern given the sensitivity of many rainforest species to fire and the strong influence of fire on rainforest distribution.

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Post-fire sampling showed recovery of both canopy and understorey species was closely associated with local fire severity (Tolsma in press). Under low-severity fire, the rainforest canopy species lilly pilly (*Syzygium smithii*) was resprouting vigorously from buds on the trunk and branches. In contrast, under high-severity fire, resprouting was restricted to the very base of the trunk, or was absent altogether as trees were killed. The opening up of the canopy by fire has led to prolific germination of short-lived fire response species, such that the understorey is now often dominated by species that are substantially less common in unburnt rainforest, including kangaroo apple (*Solanum aviculare*), Indian weed (*Sigesbeckia orientalis*) and incense plant (*Calomeria amaranthoides*) (Tolsma in press; Fig. 8.9).

An immediate threat to burnt rainforest is invasion by eucalypt seedlings. Seedlings were establishing in rainforest stands to a distance approaching the height of the surrounding mature eucalypts, with higher seedling density closer to the original rainforest edge (Tolsma in press). Successful establishment and growth of eucalypts is likely to change the overstorey structure of severely burnt rainforest stands, especially small stands that may already be marginal. Eucalypts are predicted to increase with each successive fire in warm temperate rainforest (Chesterfield *et al*. 1990) until they eventually dominate through feedbacks in which fires promote eucalypts and eucalypts promote fires, a process known as a 'landscape trap' (Lindenmayer *et al*. 2011).

Climate change poses a longer-term threat to the extent and condition of rainforest, through its effects on direct drivers of species occupancy and its interactions with other

Fig. 8.9. Regrowth in the understorey of Warm Temperate Rainforest near Martin Creek, Victoria, currently dominated by Kangaroo Apple, a short-lived fire response species. (Photo: Arn Tolsma (DELWP 2020))

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threats, particularly fire (Riddington 2014; Enright *et al*. 2015; Mariani *et al*. 2019). Warm temperate rainforests in Victoria might remain within the thresholds of their annual rainfall requirements and might be less impacted by climate change than cool temperate rainforest (Riddington 2014), but impacts will still be felt through increased frequency and intensity of fire. A self-perpetuating cycle of sclerophyll expansion and rainforest attrition will place severe limitations on the ability of rainforests to expand again to occupy their climatically- and edaphically-determined niches (Chesterfield *et al*. 1990), as those niches contract under a changing climate, and indeed limits their ability to persist in anywhere near their current (already depleted) extent.

Conclusions

The 2019–20 wildfires had major impacts on some nationally listed TECs and on many ECs not yet nationally listed. While the acute impacts of the 2019–20 Australian wildfires are significant conservation concerns, far-reaching ecological effects are best identified and understood by placing such single events in the context of fire regimes and interacting threats. In contrast, a disaster approach to conservation that has a more singular focus – on fire impacts and recovery from the fire event itself – runs the risk of focusing management responses on the treatment of those symptoms without addressing the full suite of their underlying causes.

Global climate change will drive an increase in the incidence and severity of wildfires, rendering some ECs likely to undergo continuing decline or, in some cases, collapse.

Recommendations

- Impacts of any fire event, even a catastrophic megafire, should be considered systematically within a broader context of interacting and compounding threats, with such information necessary to guide risk assessment, proactive management and post-fire recovery. Such a mechanistic understanding of fire-related risks to ecosystems needs to be built into planning and capacity building for future contingencies.
- For ECs affected by the 2019–20 wildfires, strategic and integrated management of significant threats (additional to fire) is required to support recovery and reduce susceptibility to future fires.
- For at least some ECs affected by the 2019–20 wildfires, more effective and targeted management is required to protect unburnt areas from future fire, to identify the locations and safeguard any refugial areas, and to seek to avoid the recurrence of fire until burnt areas have recovered sufficiently.
- National and state/territory processes should be undertaken to list (or up-list) as threatened the ECs for which the 2019–20 wildfires, and compounding factors, have resulted in losses and other impacts that meet assessment criteria. Moreover, more consistency among Australian jurisdictions in the classification, mapping and listing of ECs are required to enhance assessment of their national status and coordination of their conservation.
- Major knowledge gaps constrain assessments of the impacts of the 2019–20 wildfires, will hamper assessment of the conservation status of fire-affected ECs, hinder recovery efforts, and subvert preparedness for future wildfires. There is a need to undertake research to understand the fire regime requirements of different ECs, to complement spatial assessments of overlap with on-ground research and sampling to verify threats and impact, and to identify and refine priority management actions needed for recovery.

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- A systematic monitoring program should be expanded to encompass all TECs – one that can provide a benchmark against which to measure impacts of future fires, help chart post-fire recovery, assess the effectiveness of threat management, and provide early warnings of undesirable trajectories.
- The ongoing decline of ECs that are highly susceptible to the increasing trend of more, and more severe, fires (e.g. rainforests) should be highlighted, and areas with these ECs should be recognised as critical heritage assets for protection in fire planning and operations.
- The most effective and immediate risk-reduction strategy for fire-impacted ECs is to reduce the extent and/or severity of future fires, where possible through reducing the rate of ignitions, early fire suppression and strategic fuel management within or in proximity to the ECs.
- The longer-term imperative is to constrain global climate change. If this cannot be done, the corollary of more frequent and severe droughts and fires will render Australia increasingly unsuitable for the persistence of, at least, rainforest and peatland ecosystems across large areas of their current range (Keith *et al*. 2021).

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