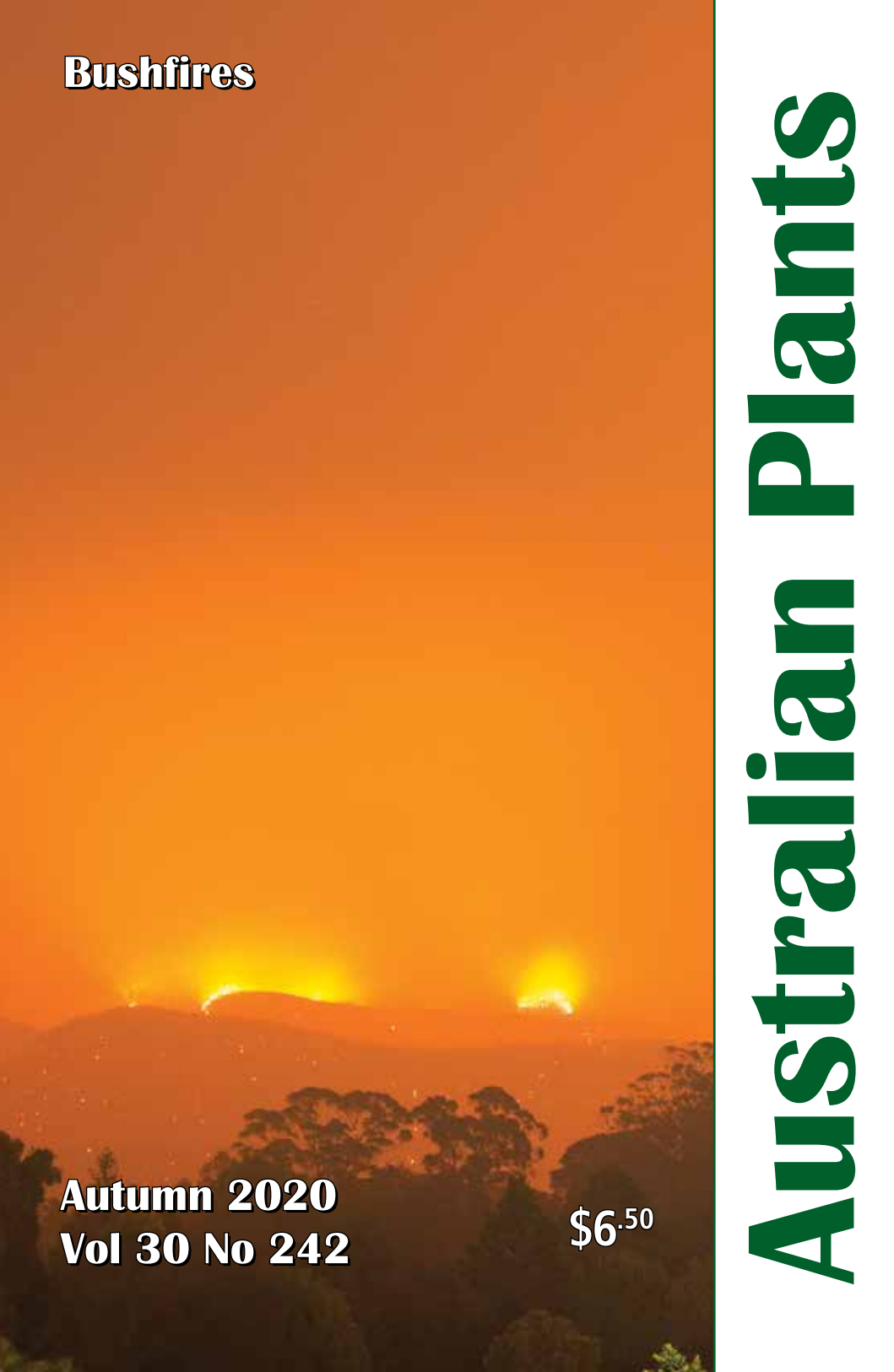




Bushfires

**Autumn 2020
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Australian Plants

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Covers: front – Gospers Mountain fire from the Blue Mountains Botanic Gardens, Mt. Tomah, NSW; back – Eucalypt on fire, Berambing Fire, Blue Mountains, NSW. Both photos by Greg Bourke, 15 December 2020.

Note: Photos were taken by the authors unless specified otherwise.

Australian Plants articles

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Erratum

Australian Plants Vol 30 No. 241 Summer 2019/2020

On page 183 the captions for *Callistemon* "Violaceus" and *Grevillea* "Superb" have been reversed.

Editorial

John Aitken and Merle Thompson OAM, Editors *Australian Plants*

The theme for this issue of *Australian Plants* had been decided in early 2019. Little did we realise the catastrophe that was going to hit many parts of Australia later in the year. During the 2019–20 summer, later to be called 'Black Summer', most Australians and indeed the world were horrified by the ferocity of the fires that swept many parts of Australia and in particular Queensland, NSW, Victoria and South Australia.

For weeks on end our news bulletins and emergency broadcasts were dominated by the fires – where they were, who was in danger and what had been lost. We grieved about lives lost and shared the distress of those who had lost their homes. Two of our contributors to this issue, Margaret Baker and Greg Bourke, have had to defend their homes from the ravages of fire on two occasions; Margaret in 1994 and 2013 and Greg in 2013 and on 15 December 2019. Many of us saw Greg, who is Curator Manager at the Blue Mountains Botanic Garden, being interviewed on the ABC 7.30 Report, 16 December 2019, following his success to save his home. This interview can be seen at: www.abc.net.au/7.30/out-of-control-backburn-destroys-20-buildings-in/11804868

And, of course, the impact was not just on people, their homes, infrastructure and services. We despaired about what has happened to our environment. The media commented on the speed of regeneration and recovery of some species. They also noted that many species needed fire to reproduce and that some might even be found which have not been seen for years. But there is the other side of the story. What plant species with a limited range or with specific habitats were destroyed? Or those with associations with insects, birds and other fauna for pollination which have lost these essential elements? What fauna have lost their only food sources? And what topsoil loss has there been with the subsequent rains while the ground was bare?

This issue does not concentrate on the cause of the fires, although a number of the authors briefly discuss probable factors. The main purpose is to discuss the impact of fires on our Australian native flora and the ways in which it recovers post fire. The theoretical became experiential. We delayed preparing this issue to enable it to reflect recent experience.

The first two articles by Tina Bell and Brett Summerell give a professional summary of the effects of fire and recovery of plants. The following three articles by Margaret Baker, Dan Clarke and Dick Burns discuss their personal experiences with the effect of fire in their local area and post fire regeneration.

Responses of Australian native plants to bushfires

Tina Bell

Tina Bell is an Associate Professor of Fire Ecology at the University of Sydney. Throughout a research career spanning 25 years she has studied the response of plants to fire in heathlands, woodlands and forests across southern Australia. Her current research investigates the impact of fire on vegetation at a landscape scale. She can be contacted by email at tina.bell@sydney.edu.au.

Bushfires during the summer of 2019–20, a period now known as the 'Black Summer', burnt more than 12.6 million hectares in Australia. More than 5.6 million hectares were burnt in New South Wales and 1.5 million hectares in Victoria and there were significant areas burnt in southern Queensland and South Australia. Tragically, lives were lost, and it has been estimated that insurance claims for damaged property will be more than \$2 billion. Extended drought conditions leading up to the Black Summer fires were in effect in Queensland, New South Wales, Victoria and in some areas of South Australia and record high temperatures of more than 45°C were recorded on the worst of the fire days. The debate about the role of climate change in the fire season this summer and in future years continues.

Regular, recurrent fires have been part of the Australian environment since at least the early Quaternary (2.6 million years ago) and possibly since the late Cainozoic (5 million years ago). Sclerophyllous vegetation (plants with small, hard leathery leaves) in temperate regions of Australia has evolved against a background of frequent fires coupled with low nutrient soils and seasonal summer drought. As a result, contemporary floras in areas that burn regularly have developed to a point where they require fire for regeneration and renewal.

The Australian flora has traditionally been classified according to whether it can survive fire or is killed by fire. 'Sprouters' or 'resprouters' can regrow foliage from buds and living tissue protected from heat by a thick layer of bark or underground by soil. Soil has amazing insulating properties – a layer as thin as 5 cm can be enough to prevent underground plant material (roots, tubers, stems, seeds) from heating to a point where plant tissues are killed (which generally happens at about 60°C). Soil has even better insulating properties when it is moist because the energy generated by a fire must first be used to heat any water held in the soil to 100°C to allow it to 'boil' and evaporate before the soil can get any hotter. By the time the soil water has been removed,



Left: Young epicormic sprout on lower trunk of eucalypt tree. The bark has been burnt but was sufficiently thick and contained enough moisture to protect underlying shoot buds from conducted heat.

Right: Regrowth of rhizomatous plant after bushfire. In this case, the soil layer protected underground buds from heat.

the fire front has often moved on and taken the heat it generates with it. Tree bark is also a superb insulator and some types of bark can withstand temperatures of up to 750°C bark surface temperature for more than a minute and a half before underlying tissue reaches a lethal temperature.

The other broad category of plant response to fire describes plants that do not survive if more than about 60–70% of an individual is burnt. These are often called 'seeders', 'obligate seeders' or 'reseeders' and, as the name suggests, they recover in the months after fire from seed. Most species store their seed in soil as part of the 'soil seed bank', but other species such as banksias and casuarinas can store their seed in woody cones.

This condition is called serotiny. The heat generated as the outside of the cone burns (dead florets are often retained on the cone to purportedly increase its flammability) is enough to melt the resins holding the woody follicles together and, with the death of the stem supporting the cone, the turgor pressure holding the follicles closed is released. These two actions allow follicles to open after fire so that the seed falls to the ground and can germinate. In Western Australia, 20–30% of heathy floras are serotinous and 5–10% of species in east coast dry heath display this feature.

A more common trait for seeder species is to have soil-stored seed. Seed may be transient and remain viable for only a year or two or may be persistent and live in the soil for many years. For heathy vegetation in eastern Australia, 40–80% of seeder species have a persistent seed



Left: Cone of *Banksia* sp. with five closed follicles, each containing a single seed, and remnant flower parts that increase flammability.

Right: Opened follicles of Banksia cone after it has been burnt allowing the seed to be released.

bank and 10–35% of species have a transient seed bank which needs to be replenished annually.

Regardless of the longevity of seed, seeder species often have what is called a 'mass germination event' after fire as hundreds and thousands of individual seeds respond to stimuli during fire such as heat and smoke and favourable post-fire conditions such as reduction of competition for space, light and water (see image of young eucalyptus seedlings on opposite page). Because of this, seeder species are vulnerable after disturbance since, once the current crop of seed has germinated, the soil seed bank cannot be replenished until the newly germinated plants mature and produce seed themselves. Species that require long periods of time to mature are particularly vulnerable in the years after a fire. An example is the Mountain Ash, *Eucalyptus delegatensis*, which may take tens of years from the time of germination until the first flowers are formed and substantial numbers of viable seeds are produced. Although this seems to be a risky strategy, when masses of viable seed all germinate at once, the opportunity for at least some individuals to survive is high. Many shrubby seeder species have fast rates of growth and can flower within a few years after fire.

Bushfire also stimulates flowering of some native plant species. A common sight after even the mildest fires is mass flowering of Grass

Trees, *Xanthorrhoea* sp. Some other species, particularly orchids, only flower after fire (obligate pyrogenic flowering) with Pink Beaks (*Pyrorchis forrestii*) and Red Beaks (*P. nigricans*) being the most well-known examples from Western Australia and eastern Australia, respectively.



Left: Young eucalypt seedlings after germination of seed promoted by conditions caused by the bushfire. Leaves on the ground have fallen from the surrounding trees after they were killed by rising hot air but not burnt by the fire.

Right: Precocious flowering of *Pimelea* sp. within two years after a fire.



Mass flowering of Grass tree (*Xanthorrhoea* sp.) in the first spring after bushfire.

Fire severity is defined as the impact that fire intensity has on plant communities and is measured according to the direct and indirect physical changes in an area after fire. Many studies have predicted that climate change will exacerbate the frequency (timing) and extent (size) of bushfires in Australia, and indeed worldwide, in coming years. The number of days when bushfires are more likely to occur (i.e. days with appropriate fire weather) is increasing and the periods of time when preventative action can be done, such as planned fires which are traditionally done in cooler, wetter conditions in autumn and spring, are getting smaller. Taken together, there is strong evidence that climate change will change our flora and fauna in the future.

So, as the media around the 2019–20 summer fire season goes quiet and state and federal bushfire inquiries gain momentum, the ecosystems burnt during the Black Summer will go about their business of recovery and, in many cases, rejuvenation. As long as there are good rains to follow and minimal disturbance due to continued drought, more fire, human impact and weed invasion, there is a very good chance that our native vegetation will successfully regrow and flourish and, yet again, demonstrate the resilience of Australian ecosystems.



A water-bombing helicopter releases its load in a bid to reduce the risk of the Gospers Creek fire on the Wollemi Pines, January 2020. Photo: NSW National Parks and Wildlife Service.

The impact of fires on plants in the summer of 2019–20

Dr Brett Summerell, *Chief Botanist, Australian Institute of Botanical Science, Royal Botanic Garden and Domain Trust, Mrs Macquaries Rd, Sydney NSW 2000.*

The 2019–20 fire season has seen devastating impacts on the natural world across Australia. The extent of the bushfires has been of a scale that is very difficult to make sense of. Images and footage of the immense suffering of animals have been confronting and heartbreaking. The estimate of the impact on animals has been as high as 1 billion animals killed by the fires. I keep getting asked what the impact on plants has been. Charred landscapes of immense size are of course predominantly images of burnt plants – trees and the understorey species that comprise those ecosystems. But can we state how many plants have been killed?

It is difficult to estimate the number of plants impacted by fire. Published tree densities¹ in different ecosystems range from 500 to 1,200 trees per hectare. If we multiply this by the area burnt of approximately 18 million hectares across Australia with an assumption that approximately 60% comprised natural ecosystems this could give 5.4–13 billion trees impacted, with as many again understorey plants affected. The impact on understorey species is usually much more dramatic, and final, as these species are more likely to be burnt completely.

Conditions leading up to the fires

Prior to the 2019–20 fire season much of Australia was affected by one of the most severe droughts on record. The impact on native ecosystems was extreme and large areas of bush were adversely affected. The presence of dead trees resulting from drought and heatwave conditions was common, especially throughout south-eastern Australia, and prompted the establishment of the “Dead Tree Detective” citizen science project by researchers from Western Sydney University.² Last year, 2019, was Australia’s hottest and driest year in over a century and these conditions had the effect of priming conditions for catastrophic fire events in bushland throughout Australia, even in ecosystems like rainforests which had not previously been expected to burn.

Impact on different groups of plants

Answering the question of how bad the impact on plants was is complex and needs to be quite nuanced. As readers of *Australian Plants* would well understand, the flora of Australia has evolved with fire and as

the continent has moved north and become more arid, species like eucalypts and wattles have come to predominate. These plants have numerous adaptations to cope with fire – in eucalypts epicormic buds protected by bark spring to life after a fire with amazing haste and seeds of wattles and banksias are stimulated to germinate and grow once it rains enough to allow successful establishment. In some cases, we may even see species of plants grow that have not been observed for a long time such as *Muehlenbeckia* sp.



Muehlenbeckia sp (sometimes known as *M. costata* but not formally described as yet), Mt Norman, Bald Hill National Park, NSW. Photos: Gavin Phillips, Australian Botanic Garden, Mount Annan

We are already starting to see ecosystems start to recover and display the type of resilience the Australian bush is well known for. Certainly, some species of eucalypts (*Eucalyptus*, *Angophora* and *Corymbia*) are sprouting epicormic growth from trunks and lignotubers, some *Banksia* species are growing from epicormic buds and a range of Proteaceae species are growing from lignotubers.



Banksia serrata regenerating from epicormic shoots (far left) and lignotuber.

As would be expected, there are seedlings of a diversity of species, especially eucalypts, *Acacia* species and other Fabaceae such as *Indigofera* and a diversity of other species. The success of establishment will depend on a great many factors and will not necessarily be clear for some time.



Seedlings of *Banksia serrata* (left) and an *Acacia* species (above) emerging after the fire event at the Tomah Spur conservation area at the Blue Mountains Botanic Garden, Mount Tomah.

For some *Eucalyptus* species that are obligate seeders a mass mortality of mature trees will occur, and the next generation will depend on a viable crop of seed and consequent seedlings being present. For species like Mountain Ash and Alpine Ash this is the case but, concerningly, in many locations the ecosystems dominated by these species are experiencing multiple fires over only a few decades, or even less. In these circumstances it is unlikely that these forests will survive intact as there is not enough time for trees to reach maturity and produce viable seeds before another fire moves through the area.

The extent of recovery will depend on the intensity of the fire – lower intensity fires do not substantially damage eucalypts and will stimulate germination of seed of a range of species. If the fire is high intensity, we see trees killed and an almost sterilisation of the forest floor. In these situations, the loss of plant diversity may well be profound.

In ecosystems that are not adapted to fire the losses can be much higher. The other factor is the frequency of fire – we are already seeing fires in some areas at a too frequent rate and the climate models indicate that this will be the future scenario faced in far too many of these ecosystems.

Rainforests

This fire season was remarkable for the extent to which areas of rainforest burnt, particularly in southern Queensland and in northern New South Wales. In NSW 35% of rainforest vegetation burnt and 54% of Gondwanan rainforest world heritage area was burnt. This extent of rainforest burning was unprecedented and, given the high biodiversity



values and the extent of unique endemic lineages, of substantial concern. Rainforests have not evolved to cope with dry conditions or fire. The trees in these forests are often thin-barked and easily killed by the heat of bushfires and when these habitats burn the outcome is poor.

An unidentified strangler fig (*Ficus* sp.) on a Tallowwood (*Eucalyptus microcorys*) impacted by fire at Nightcap National Park.
Photo: Dr Maurizio Rossetto.

Threatened species

Modelling of the distribution of the fire affected ecosystems in NSW with the locations of listed threatened species indicates that 367 species of threatened plants have had their distribution impacted. Of these, 163 species had 20% of their habitat impacted and 46 species had 90% of their habitat burnt. Similar scenarios have been observed in other jurisdictions. The impact of fire on threatened species of plants will be variable – it will depend on the distribution and intensity of fire and local conditions. It will take a long time to assess the situation across ecological communities around the country. Monitoring the impacts and responses will be critical and it cannot be assumed that because a species has had all of its range impacted by fire that it will be a terminal outcome. There is of course the scenario where exposure to fire will have a positive impact on a threatened species, stimulating flowering and consequent seed production providing the opportunity for an increase in recruitment.

Wollemi pines

One of the most notable occurrences of the fires was the impact on the Wollemi pine populations in Wollemi National Park. The Gospers Creek fire burnt through most of Wollemi National Park eventually impacting the Wollemi pine populations in January 2020. Extraordinary efforts were made to protect the Wollemi pines with specialist remote area firefighting teams deployed to minimise the chance of the pines igniting. While many of the trees were scorched to some extent, the impact was not substantial, and certainly less than what may have been expected if the trees were not so rigorously protected. The Wollemi pine has been shown to be reasonably resilient to the impact of fire.³ In experimental work and observations to date of planted and translocated trees affected by fire support those findings. The long term impact on the wild populations will take some time to understand fully, requiring detailed assessments of the populations by researchers.



Wollemi Pines following the Gospers Mountain megablaze that spread into the Wollomi National Park. 9 January 2020. Photo: John Spencer, NSW Dept. of Planning, Industry and Environment.

Other complications

The impact of invasive species on fire ravaged vegetation can be expected to be devastating. Management of invasive plants will be a critical issue with the potential for weedy species to overwhelm native species regeneration. Equally invasive pathogens like myrtle rust and

Phytophthora can be expected to limit regeneration. Myrtle rust prefers young host tissue in susceptible species and so new growth and seedlings are likely to be heavily infected, especially now that warm, humid weather following extensive rain events will favour infection. Phytophthora is not adversely affected by fire, surviving underground, sometimes at depth. It can be easily spread in fire affected areas as there is no leaf litter to buffer the contact between footwear and infested soil so that it is easier for the infective elements (zoospores and chlamydospores) to be spread.

It is critical that when we visit fire affected (in fact all) ecosystems that we take precautions to minimise the likelihood of introducing weed seeds, infested soil and fungal spores. The use of 70% methylated spirits sprays for footwear is strongly encouraged and bushwalkers should launder clothes before visiting these ecosystems which are much more fragile than normal.

Conclusion

The 2019–20 fires have raised questions about the role, extent and frequency of hazard reduction burning and the potential role in decreasing or increasing the likelihood and intensity of fire. This subject will be debated as state and federal inquiries and commissions take place. This type of impact and the expectation that climate change will continue to facilitate fires in the future highlights the importance of ensuring that we preserve plants in seed banks and botanic gardens and understand the response of plants to a changing climate. We need to make substantial progress in collecting as many of the species of plants that occur in Australia to be sure of preserving them into the future. This needs to be combined with programs to recover threatened species and restore species in the wild.

Plants are vital for life. These fires highlight how much more research is needed to ensure their, and our, survival.

Further reading

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Regenerating bushland, Mt. Wilson, Blue Mountains, 8 weeks after the megafire in December 2019.
Photo: Heather Miles

Pyrophilous fungi, *Laccocephalum sclerotinium*

John Aitken, co-editor Australian Plants



Laccocephalum sclerotinium is a small species developing pored mushroom-like fruitbodies up to 30mm diameter. These are produced by marble-sized underground sclerotia, which are stimulated by fire to produce fruiting bodies.

Laccocephalum sclerotinium, fruiting,
Blue Mountains Botanic Garden.
Photo Brett Summerell.

Resilient plants survive tough times

Margaret Baker

Margaret is a member of the Blue Mountains Group of the Australian Plants Society NSW. She has been a TAFE Head Teacher of landscape interpretation and native plant studies and has co-authored books on native plants. Margaret was awarded the Blue Mountains Environmental Citizen of the Year in 2020.

Blue Mountains World Heritage Area, NSW – the worst fire season in living memory

Blue Mountains plants have experienced challenging growing conditions in recent years. Temperatures that have soared to unprecedented highs of 40° to 48°C over many days, lower than average rainfall and months of strong drying winds in each of the last few years have taken a toll on plants and their communities. Some places, including my family's bushland property, have not had a reasonable spring flowering for at least two years. By late 2019 there were reports of widespread tree death that had become so bad in places that it has been called 'canopy collapse'.¹ Many individual plants in the shrub layer were also succumbing to the tough conditions as soil water and seepages were depleted to nothing. Then in late October 2019 fire was added as the ultimate challenge to plant survival.

As followers of the NSW Rural Fire Service app *Fires Near Me*, we know a fire was started by lightning on 26 October 2019 in the headwaters of Running Stream about 5 km to the west of Gaspers Mountain, north-east of Lithgow.² At the same time lightning fires dotted the Kanangra-Boyd National Park south of Lake Burragorang. These fires seemed quite remote from most of us until in late November another lightning strike apparently ignited Ruined Castle in the Jamison Valley just south



Moderate burning of Tall Open Forest with rainforest understorey at Mount Wilson, December 2019^{AP}



Severe burning of Open Forest near Mount Wilson Road, December 2019^{MWB}

of Katoomba. Under the conditions outlined above many stressful weeks followed as all fires massively increased in size and penetrated deep into our national parks, back burns became uncontrollable, blazes encroached on towns and villages in our region and an inconceivable amount of bushland was incinerated.

Dr Peter Smith has compiled an excellent document of statistics and maps to show the unprecedented extent of the combined fires in the Greater Blue Mountains World Heritage Area.³ In the Blue Mountains National Park alone Peter estimated that 188,237 ha or 70% of the total vegetation cover was burned with at least 15% of the national park experiencing severe fire and the complete loss of canopy. Such areas were marked by ash-grey bare earth and blackened sticks that were once trees. How do plants ever recover from fires of such intensity?

Is the bush 'adapted' to recover from fire?

It is very frequently said that the Australian bush is 'adapted to' and is capable of recovering quickly from bushfires. However, this does depend on the antiquity of the plants that were growing in the bush at the time of the fire. Australian plant communities could be simply divided into those dominated by ancient plant groups that evolved 60–70 million years ago or very much earlier when fire was less frequent and intense than today. These older groups include the rainforests of the Blue Mountains that occupy the most sheltered, dampest and fire-protected micro-environments. The remote canyon complex in the Wollemi National Park that houses the very ancient Wollemi pine is one such example. Such communities can recover from fire but generally only if it is less



frequent and severe than occurs today. The 2019–20 summer fire season will provide answers to questions about whether rainforest can survive 'modern' fire regimes since more of these communities than ever before have been incinerated for the first time in living memory.

Back burning of Mount Wilson Warm Temperate Rainforest, December 2019^{AP}

A turning point in the make-up of our plant communities came at about 50 to 60 million years ago when Australian climates began to become drier and hotter, and fire increased in intensity and frequency. Ancient plants gave way to newer families of flowering plants and the vegetation overall shifted towards sclerophyllous (hard-leaved) types that were dominated by the eucalypts. Within these ‘modern’ communities many plants have an inbuilt resilience that usually allows for regrowth following fire events and other disturbance though it is not quite that simple. The degree of recovery and the type of regeneration after fire depends on many factors including the species make-up of the community, the store of seeds in the soil and on plants, nearby unburned vegetation with available seed, the fire regime (intensity, frequency and timing), and growing conditions prior to the fire and weather conditions following it.

A mosaic of burning occurred within the *Eucalyptus*-dominated communities across the Blue Mountains in the summer of 2019–20. Some places burned more intensely than others and some burned for the second or even third time in 20 years or less. Large areas of bushland had been more seriously affected than others by drought before the fires, and after the fires parts of the region achieved astonishing amounts of rain while others had more moderate totals. Temperatures post-fire were very hot in some places while others headed into autumn. There is no one hard or fast rule as to the speed of regeneration or even of its nature. We know quite a lot about plant recovery post-fire in a general sense but sometimes the specifics vary from one plant species and community to another and from one fire to another.



A mosaic of burning – Narrow Neck Katoomba after the Ruined Castle fire, December 2019 ^{MWB}

Post-fire recovery in eucalypt-dominated communities

How then does recovery generally occur after fires in a eucalypt-dominated plant community be it Tall Open Forest, Woodland or Heath with mallee eucalypts? Any answer to this question must acknowledge that each plant is different in their response to fire. Some plants are killed outright, others are stimulated to regrow and/or flower, while some may be quite fire-dependent. Not surprisingly there will then be a spread of regeneration types. Overall, the sequence and type of recovery through the Blue Mountains after the 2019–20 fires has been as follows.

1. The Bare Earth

The bush may appear to be lifeless for some weeks after a fire but there is usually activity on bare surfaces and within the soil itself. For example, ants emerge from underground burrows and spread out to gather seeds that have escaped incineration or which have fallen from fruit that opened after the fire has passed. Ants are especially interested in seeds that have elaiosomes or fleshy nutritious appendages. Ants carry the seed back to their nests where the elaiosome is eaten and the seed discarded in underground middens safe from predators and available for later germination. This important function of seed dispersal by ants is called myrmecochory. In the Blue Mountains bushland species of *Acacia* and members of the Pea family that have elaiosomes on their seeds are preferentially dispersed by ants.



Above: a Green-headed Ant carrying an *Acacia* seed that has an edible elaiosome ⁴

Left: *Cortinarius sublargus* (Dumpy Webcap), a large fungal species that forms mycorrhizal relationships in eucalypt forests; photographed post-fire in Blackheath, February 2020 by local fungi expert Liz Kabanoff ^{LK; 5}

Fungi are also busy underground spreading mycelium (fine thread-like growth) within the newly burnt soil. One group of fungi, the arbuscular mycorrhizal fungi that exists in a symbiotic relationship with plants, has a significant role in post-fire recovery.⁶ Its mycelium penetrate plant roots through fine root hairs and grow microscopic branched structures called arbuscules inside the cortex. The mycelium then harvest plant nutrients from the soil and transfer them via the arbuscules to the plant's vascular system; the fungi receive sugars in return. Seedling growth following fire may also require the presence of the fungal mycelium. Species of terrestrial orchids in our region have a close relationship with mycorrhizal fungi. Genera including *Genoplesium* that grow and flower quickly after fire are dependent on fungi for seed germination. It is imperative that after fire the fungi-plant relationship is re-established



to enable healthy plant growth but that process may be slow if near-surface fungi are killed by severe fire. Following the 1994 Grose Valley fire, fungal regeneration was quite evident on our property; the remnant ashy soil became soft and puffy as the mycelium expanded and large fruiting bodies (the reproductive spore-bearing structures of fungi) were abundant. I did not see such a proliferation of fungi following the 2019–20 fires but a range of species was evident and photographs are available online.⁷

Genoplesium orchids have a close association with fungi and fire ^{MWB}

2. New plant growth returns to the bush

There are a number of ways in which plants recover or grow anew after fire:

- (a) **Resprouting** is the first, most common and obvious form of regrowth. It occurs in plants that may appear to have been completely burned or badly scorched but where in fact the fire has not fully penetrated into all the living tissue. Using resources (sugary sap and water) still available within the plant new growth quickly appears to re-establish photosynthesis. Resprouting occurs from either above or below ground growth nodes.

Many plants resprout aurally anywhere from large branches to the base of the trunk. Visitors to burnt bushland are particularly attracted to the red and purple-coloured clusters of new eucalypt foliage. The colour comes from a leaf pigment called anthocyanin that acts to protect the tender new shoots from insect predation and from damage that could result from excess near-infrared radiation.



Colourful epicormic growth on a Mount Wilson eucalypt, February 2020 ^{MWB}

It has long been assumed that all aerial resprouting of Australian plants comes from the growth of dormant epicormic buds that are held just beneath the outer bark of the trunk. Encouraged by hormonal changes within the plant caused by disturbances such as fire, the buds, that should not have survived burning, spring into life to produce the fuzz of new leaves encountered on many eucalypts. However recent research has indicated that the concept of ready-formed buds so close to the surface of the trunk is not accurate for many Australian trees especially those of sclerophyll forests; it may in fact be largely

an incorrect assumption based on the presence of such buds in trees from the Northern Hemisphere. Geoff Burrows from Charles Sturt University has shown that for a range of eucalypts (*Eucalyptus* and *Angophora* genera), there are no ready formed buds but rather they have epicormic strands of meristematic growth tissue⁸ arising from the vascular cambium (that produces new xylem and phloem) below the bark and it is from these that new growth bursts forth.⁹ The origination of such tissue is well away from the surface of the trunk thus minimising growth tissue damage and maximising the possibility of new epicormic shoots after fire.

Grass trees (species of *Xanthorrhoea*) produced amazing displays of new aerial growth almost immediately after the fires. Even if the individual plant was burnt to ground level or a taller trunk stood



Xanthorrhoea resinosa at MtWilson ^{MWB}

totally blackened the tightly packed base of the leaf tufts and the high resin content of the trunk resisted fire penetration and the leaves continued to grow.

A range of other shrubs in the Blue Mountains fire-affected bushland have also recovered by aerial resprouting. These include *Persoonia levis*, *Banksia serrata* and *Leptospermum trinervium*. I am unable to say whether these plants have actual epicormic buds or whether new growth develops from epicormic strands as outlined above, but it could be the subject of future research.

- (b) **Resprouting also occurs from below ground storage organs** that include rhizomes, tubers, corms and bulbs. Each structure contains growth nodes that are protected by the soil from the fire and promptly resprout soon after fire passes provided the fire has not penetrated too deeply into the soil. Examples of under-ground resprouters in the eucalypt-dominated communities include *Entolasia stricta*, *Gahnia microstachya*, *Patersonia sericea*, *P. longifolia* and *Pteridium esculentum*.



Epicormic growth of *Persoonia levis* – Mount Wilson, February 2020 ^{MWB}

An underground survival structure adopted by many Australian plants is the lignotuber. This is a thickened woody stem (or stem extension) that contains nodes from which new growth in the form of multiple branches can emerge after disturbance. Following fire protected underground buds within the lignotuber awaken from their dormancy and new growth quickly develops into the characteristic branches of species that had, by March 2020, included *Allocasuarina nana*, *Banksia spinulosa*, *Brachyloma daphnoides*, *Eucalyptus stricta*, *Hakea laevipes*, *Isopogon anemonifolius* and *Lambertia formosa*. Eucalypts with lignotubers are called mallees and other lignotuberous species are said to have a mallee-like form.



Eucalyptus stricta: a mallee with a lignotuber. ^{MWB}



Lambertia formosa: mallee-like a with a lignotuber. ^{MWB}

- (c) **Seed germination** is a familiar means of regrowth used by all flowering plants. It becomes critically important for species survival if a plant is completely incinerated by fire and dies with no chance of recovery by any of the vegetative means outlined above. Some plants go a step further and only reproduce by seed; they are referred to as obligate seeders and include most of the Fabaceae family (Acacias and pea flowers), *Actinotus helianthi*, *Allocasuarina distyla*, *A. littoralis*, *Banksia ericifolia*, *B. marginata*, *Callitris muelleri*, *Epacris pulchella*, *Grevillea phyllioides* and *Petrophile pulchella*.

Information about plant renewal from seed following fire often depicts the process as being fairly straightforward – fire reduces the vegetation to nutrient-rich ash, it opens hard woody fruit held on many plants and the seed drops onto the ash bed or fire breaks the dormancy of seed within the soil, rain occurs, the seeds germinate and seedlings grow in the nutritious ash uninhibited by shade and competition from other plants. Sometimes recovery does happen like that, however the real-life situation is much more complicated than this with many variables needing to be negotiated to achieve successful seedling establishment.



Above: *Hakea pachyphylla* sheds its seed onto the ash bed; note heavy rain erosion of soil, ash and seed ^{MWB}

Left: Seedling and adult leaves of *Acacia ulicifolia* that are starting to appear across the Blue Mountains fire grounds ^{MWB}

There is a substantial body of research information available about seed germination of individual species following fire that indicates that the variables likely to affect the process include: the fire regime (intensity, frequency and season), the availability of seed on the plant or in the soil, the presence of the ash bed, chemical content of smoke, the survival of fungi and the amount and intensity of follow-up rain. Very intense fires diminish the ash bed and its nutrients; fruit and seeds may be incinerated both on the plant and in the soil, and near-surface fungi may not recover. Low intensity fires on the other hand might not be hot enough to open fruit or to break seed dormancy. Plants that are slow to regrow are disadvantaged by frequent fire. An obligate-seeding species like *Banksia ericifolia* may take 15 to 20 years to produce enough seed in its slow-developing follicles to sustain new growth so a fire frequency of 8 to 10 years will eliminate this plant from a heathland community. Heavy rain following a fire, particularly in areas of steep slopes, may cause significant loss of soil, ash and seed. Climate change is still the wild card variable in understanding seed germination and seedling survival.

Each of the above scenarios has played out in the Blue Mountains in the 2019–20 bushfire season. It is likely that some eucalypt-dominated plant communities may experience a significant change in the species reliant on seed for regrowth. As of my last foray into the bush in early March 2020, very few seedlings had appeared but it is early days yet.

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- (d) **A combination of regeneration types:** Just depending on seeds for regrowth can be risky because, as noted above, a range of conditions have to line-up for the seeds of any particular species to successfully germinate. It is advantageous for any plant in a fire-prone environment to use a range of survival techniques from resprouting to seed germination. Most Blue Mountains plants are, wisely, optional seeders. Fire provides the cue for adult plants to quickly resprout and for seeds stored on the plant or in the soil to germinate.



Top left: *Eucalyptus racemosa*: epicormic shoots from branches to trunk base and copious seed ^{MWB}

Top right: *Allocasuarina nana*: multiple branches from a lignotuber and copious seed stored on the plant ^{MWB}

Left: *Leptospermum trinervium*: lignotuber, epicormic shoots and seed stored in the ground. ^{MWB}

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Conclusion

Eastern Australia had an exceptionally challenging fire season in 2019–20 and the Blue Mountains was no exception. Climate change has brought hotter, drier and windier conditions all year round and fires are increasing in frequency, intensity and area burned. Plants of the Blue Mountains eucalypt-dominated communities have developed a range of techniques to assist each species recover from fire and examples of these outlined indicate that those species that resprout aurally and/or by underground vegetative means are regenerating across the region. In March 2020, new seedling growth had just commenced so there is an expectation rather than a reality in comments about the survival of those species that rely on seed germination. Being just a few months after the cessation of the blazes it is too early to tell how successful the combined regeneration will be. The mosaic of fire types from very intense to light, and fire intervals from decades to 4 or 5 years, set against climate change provides an opportunity to reconsider fire regimes and appropriate fire management to retain maximum biodiversity.

Photographic credits: AP Alan Page; LK Liz Kabanoff; MJB Margaret Baker; MWB Mark Baker (principal photographer).

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The recent bushfires in NSW – Impacts and plant responses

Dan Clarke

Dan is a botanical consultant in the NSW ecological consulting industry and a conservation and land management teacher at TAFE NSW. He is the Conservation Officer for Australian Plants Society NSW.

Bushfire impacts

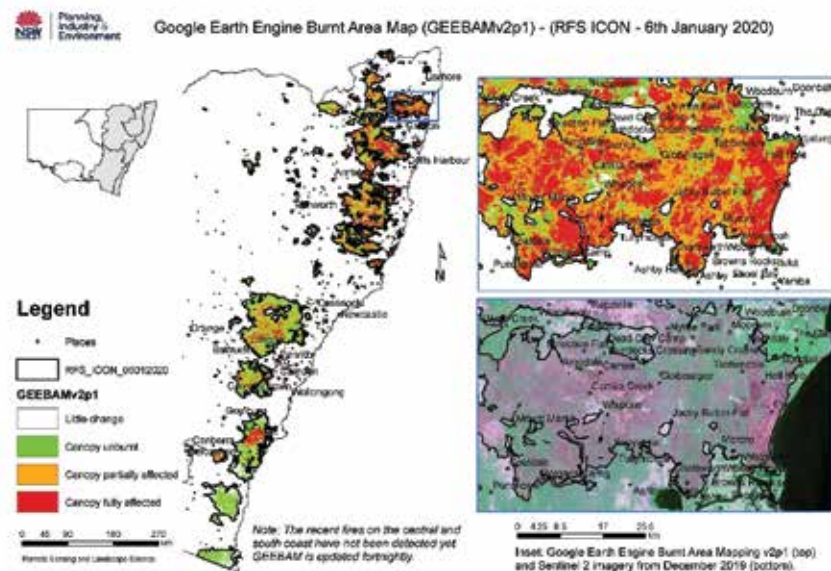
In the forefront of many people's minds in recent times would undoubtedly have been the extensive and intense bushfire events across NSW. The bushfires, occurring from June 2019 to January 2020, were on such a large scale that it is now documented in Wikipedia¹.

While most of the impacts occurred in New South Wales, the ACT and Victoria, areas of South and Western Australia, and Tasmania, were not spared.

The NSW Department of Planning, Industry and Environment has developed a website *Understanding the effects of the 2019–20 fires*², which reports statistics about areas burnt in NSW, as well as the broad vegetation classes affected. While the statistics may be limited and likely subject to change, the website does provide a baseline reference point for the scale of the event across NSW. It is reported that 5.3 million hectares (6.7% of NSW) had been burnt, 2.7 million hectares of which was national parks estate (37% of the total estate).

Obviously, our primary sadness is the tragic loss of 34 human lives, which reflected the severity of the disaster. However, we also remain concerned about the impacts to bushland and biodiversity. Of particular concern is that 80% of the Greater Blue Mountains Area and 54% of the Gondwana Rainforests of Australian World Heritage have been reportedly affected. The burning of the Gondwana rainforest, in a wide range of locations between Newcastle and the Gold Coast, is distressing to many ecologists and naturalists as such areas are very sensitive to fire events and are not usually prone to burning. We need to pay strong attention to what ecologists and other experts say about these areas going forward.

Many readers would likely recall several bushfire events in NSW over their lifetime and some of us, rightly or not, may think it is “*business as usual*” and “*to be expected in hot and dry Australia*”. I recall the substantial event of 1994, when firestorms destroyed properties in southern Sydney, which resulted in loss of life and property in my own local Sutherland Shire area.



Google Earth Engine Burnt Area Map (GEEBAM) showing extent of 2019–2020 bushfire event in NSW. NSW Department of Planning, Industry and Environment.

As a botanical consultant, I have heard a range of views from my colleagues, which have varied from positive feelings regarding some areas that had not burnt for several decades to deeply concerned views about the intensity and extent of the burns in other areas. These concerns relate to impacts on threatened species; impacts that have likely been compounded when tied to processes such as vegetation clearing, pest and weed invasion. However, we cannot help but think more and more about how climate change is affecting fires in the Australian bush. The fires did arrive after at least 18 months of generally very dry conditions on the NSW east coast. Climate scientists are telling us that we are moving towards a hotter and drier climate, with less rainfall predicted through time, coupled with rising temperatures. This is leading to a positive feedback loop of heat, drought and fires, all of which are predicted to be of greater intensity. The long term impacts of this will impose selection pressures on flora and fauna species, predicted to result in the loss of some species from our local bushland ecosystems. In early 2020, a substantial rain event in the form of an east coast low has affected much of NSW. We now wait with some concern to see how our bushland species will respond and evolve into the future.

One aspect that deserves some attention is the variety of fire behaviours and intensities that occur. Referring back to the NSW *Understanding of the effects of the 2019–20 fires* website, it is interesting to view the Google Earth Engine Burnt Area Map (GEEBAM). This map, reproduced on the opposite page, albeit most likely preliminary, has categorised burnt areas in terms of: *Little change*, *Canopy unburnt*, *Canopy partially affected* and *Canopy fully affected*. While a lot of “red” for *Canopy fully affected* is shown on the map, it does indicate that fires behave differently in different areas. Fire behaviour is affected by different topographies, terrains and weather conditions. A hot topic of debate is also *in situ* fuel loads and their role in the recent event. Such variation in fire behaviour is a primary driver for how the bushland responds post-fire. Fire can create a mosaic-like result in the landscape with areas burnt unevenly.

We would expect that severe and intense fires of higher temperatures would result in a slower response and regeneration time in that bushland, especially where canopy eucalypts and rainforest species have been killed outright, and where the ground layer may have been subject to high heat.

Although I am not a fire ecologist, I have always found that the best approach to gauge the intensity of a fire is a bushwalk in your local area. This approach will give insight into the amount of “doom and gloom” in your favourite area, if it has been affected. You can observe how the bushland is responding and make notes of which plants are the first to appear. I have been interviewed recently by groups such as mountain bikers and orienteering clubs who are making their own observations in their locally burnt patches.

One word of warning: do be very mindful of unstable trees and falling branches in burnt bushland and do not enter closed areas.

Bushland responses

The questions always arise: “*Why doesn’t the bushland die? How is it able to regrow and burn again in years to come?*” I have heard this regularly, and in fact, even during this recent event.

The Australian bushland has evolved with periodic fire, likely over a period of millions of years. There is much historic debate amongst academics regarding the mechanisms of the evolution and the amount of fire. This debate also focuses on Indigenous Australians’ burning practices over the last 70,000 years and how this may have altered the Australian flora. I believe that Australian bushland has always experienced wildfires, due to drought periods combined with

lightning strikes, especially in areas of inaccessible terrain that First Nations people were not inhabiting. Undoubtedly, deliberate burning by Indigenous Australians would also have taken place, most likely in favoured areas. However, it is debated how large an area and at what frequencies this may have occurred.³

General ecological consensus is that many Australian vegetation types require periodic fire. Fire regenerates the landscape in terms of reducing fuel loads and creating an open ash bed on the ground layer. This ash bed, which has elevated levels of carbon-base compounds and minerals such as potassium, combined with increased sunlight, creates a medium for seed to germinate. Usually, this is seed that has fallen from burnt fruits such as woody follicles, pods and capsules along with a variety of .

Some species are lost from bushland patches in periods of long term absence of fire, with prime examples being fragmented and isolated sandstone bushland patches in the Sydney urban landscape, which are never likely to be burnt again. Species such as wattles and peas depend on periodic fires as many are short lived species and require a fire to allow seeds to heat up and create the next renewed generation.

Conversely, plant species can be put at risk from fires that occur too frequently, as insufficient time is given to allow enough flower and fruit set to replenish the species. Some ecosystems do not respond favourably at all to fire and are likely to suffer severe detriment, such as the Gondwana rainforest areas. I have included some references on this subject for further reading.

The bottom line is we can easily observe our bushland areas regenerating after a bushfire event. Although the regeneration may take time and works at different speeds, most of us have likely continued to observe or monitor an area after a fire event. We have watched it evolve, to a point where 15 or 20 years later, it may be hardly evident that a fire took place.

Now that substantial rain has fallen over much of the east coast of NSW and further inland, regeneration of some areas is well and truly underway.

My own observations for this article do not come from any area affected in 2019–20, but from areas in the Royal National Park (RNP) in southern Sydney over many years. Approximately 2000 hectares of bushland was burnt in the park in January 2018 which I have been visiting regularly. The regeneration results have been incredibly interesting, shown in the photographs.



A mosaic of burnt and unburnt areas above Garie Beach, RNP, 2018.

The responses of Australian plants to fire can generally be grouped into the following three categories:

1. **Obligate seeders:** This group of species basically has no other mechanism available other than to regenerate from seed. Plants will usually be killed by fire and will regenerate either from the soil seed bank or from seed released from burnt fruits after fire. Heat usually plays a role in the germination success of these seeds. Plants in this group include many dicotyledonous angiosperms such as many wattles and peas (Family Fabaceae subfamilies Mimosoideae and Faboideae), as well as species such as *Actinotus helianthi* (Flannel Flower). Recently on the Wallumarra Track in the Royal National Park, I observed a meadow of *Mitrasacme polymorpha*, a common white-flowered herb. Some of these plants will respond more quickly than others. Some of these species will not make a show until at least 12 months after the fire with growing anecdotal evidence that species of *Prostanthera* behave as such. *Banksia ericifolia* (Heath-leaved Banksia) is an obligate seeder in the Proteaceae family. Some Australian conifers such as *Callitris* and *Podocarpus* fall into this group.

In some areas, I have observed species such as *Acacia falcata* (Hickory Wattle) and *A. suaveolens* (Sweet Wattle) create dense,

almost impenetrable screens, after fire. This gives insights into the early vegetation structures that fire may create in some areas. Some people may have also observed stunning meadows of flannel flowers in coastal heath after fire growing along with large numbers of *Blandfordia* and *Pimelea linifolia*.

Some eucalypts also fall into this category, with one example being Australia's most grandiose species *Eucalyptus regnans* (Mountain Ash).

2. **Plants with epicormic shoots, lignotubers and general stem/root suckering:** These plants are also mainly dicotyledonous angiosperms and include many members of the Myrtaceae (*Eucalyptus* spp., *Corymbia* spp., *Angophora* spp., *Leptospermum* spp., *Melaleuca* spp. etc); Proteaceae (*Banksia* spp., *Lambertia formosa*, *Hakea* spp., some *Persoonia* spp.), and species such as *Glochidion ferdinandi* (Cheese Tree) which exhibits suckering growth from the stem/root interface or zone. Epicormic growth appears from buds which are unburnt below the bark surface. These shoots will emerge along the entire length of stem and can readily be seen in many eucalypts, angophoras and persoonias. We can also see this happening in plants such as *Exocarpos*



Epicormic growth of *Angophora costata*, 4 weeks after fire, Garie area, RNP, 2018.



Angophora hispida regenerating from a lignotuber, 3 weeks after fire, Walumarra Track, RNP, 2018

cupressiformis and *Ceratopetalum gummiferum* (NSW Christmas Bush). The epicormic growth of many eucalypts and angophoras often starts red in colour and is termed juvenile foliage. In some cases, the growth is known to contain high levels of secondary metabolites such as cyanide in order to protect it from herbivores.

Many species of *Eucalyptus*, *Corymbia*, *Banksia* and *Hakea* have a lignotuber. This is a swollen woody root, storing reserves of sugars and starch. The structure is protected underground and is relatively insulated from hot fires. The lignotuber produces vertical shoots very quickly after fire, also typically red in colour. What always strikes me about this is that while the above ground parts of plants may be killed, the roots continue to reshoot over and over again. Some of the root systems of species such as *Corymbia gummifera* (Red Bloodwood), which grows up and down the entire NSW coast, are most likely several centuries, or more, in age!

Taxonomically, plants with lignotubers warrant separating as a distinct species, with the splitting of *Hakea laevipes* from *Hakea dactyloides* a good example. Plants in this category can also regenerate from seed as well. Common sense suggests that plants in Category 2 have an ecological advantage over those in Category 1.



Xanthorrhoea resinifera regenerating 4 weeks after fire, near Garie, RNP 2018.

- 3. Plants which reshoot from rootstocks, rhizomes/stolons and non-woody tissue:** I tend to place many species in this generalised category for ease of reference. It includes many monocotyledonous angiosperms with a great example being *Xanthorrhoea* spp. (grass trees). I am frequently amazed how much growth grass trees can put on after a fire with shoots emerging from burnt “trunks” and the basal zones. I have observed approximately 80 cm of growth on species *X. arborea* and *X. resinifera* four weeks after a fire. Many Australian native plant enthusiasts are familiar with the spectacular flowering of grass trees after fire.

Other species that will reshoot from ground level from either rhizomes or subterranean stems include *Macrozamia* species, *Lomandra* species and *Doryanthes excelsa* (Gynea Lily). Many tussock grasses likely have an ability to regenerate from seed, but often it seems that the burnt tussocks or buried rhizomes simply reshoot. This occurs in species such as *Microlaena stipoides* (Weeping Meadow Grass) and *Austrostipa* species. *Dianella* species (Flax Lilies) also appear to send up rhizomatous growth. And, we have likely all observed how species such as *Pteridium esculentum* (Bracken Fern) and *Calochlaena dubia* (Rainbow Fern) are strongly favoured by fire, simply reshooting from unburnt rhizomes and quickly colonising the ground layer, possibly to the detriment of other species.

There are many other species not mentioned but many of them display a fire coping mechanism. Species that also deserve our focus are our listed threatened plants. Many of these will germinate from seed and “explode” through the landscape after a fire event. However, they might last only one generation and then rapidly disappear. Other threatened species will not respond favourably to fire at all and I have heard anecdotes of some particular species that have suffered severe detriment in a bushfire. Other species that come to mind are orchids, and how fire influences the success of these over time.

Many scientific studies have been carried out on fire ecology with data presented for factors such as ideal fire periods for different vegetation types and how different species respond to different fire intervals. Yet, general documented categorised response mechanisms to fire for Australian plants are not easily found through general website browsing. I believe you will learn the most by simply getting out there in the field. Coastal heaths and shrublands make very good study areas and are likely much safer than burnt woodlands and forests.

Hopefully, a lot of post-fire ecological monitoring data can be collected to provide a picture of how vegetation is responding over the long term. I remain concerned about the future of the Gondwana rainforest. The timing of the 2019–20 fires may well serve as a catalyst to expand and continue the NSW government Saving our Species program, which is due to conclude in 2021.



Resprouting Gynea Lily, 4 weeks after fire, Garie area, RNP, 2018

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Regrowth, three months after the Berambing fire, Blue Mountains, NSW, 19 December 2019.

Above: *Kennedia prostrata* seedlings

Left: *Lomatia silaifolia* Proteaceae

Photos: Greg Bourke

Burning the Tasmanian Wilderness

Dick Burns OAM

Dick is a Life Member of APS Tasmania, and was recently placed on the honour list of the Friends of Cradle Valley. He has bushwalked in the Cradle Mountain area since 1970, as he has for much of the Tasmanian Wilderness World Heritage Area (TWWHA). He has been involved with several groups concerned with the care and conservation of Cradle Mountain, the whole TWWHA and other parts of Tasmania's natural environment. Dick's articles on Tasmania's rainforests (Australian Plants 29, 234, pp. 227–231) and montane vegetation (Australian Plants 29, 231, pp. 68–74) appeared in recent issues of this journal.

Tasmania, along with all of southern Australia, is the driest and most fire hazardous region of the world. When the right conditions prevail, bushfires become savage and uncontrollable; large conflagrations result. This is of particular concern for the Tasmanian environment. Our mountainous terrain with its wide range of rock types, from nutrient-poor and weathering-resistant quartzite to nutrient-rich easily weathered basalt, led to a most diversified vegetation. Tasmania is home to special floras, including cool temperate rainforests, extensive montane and alpine flora and a rich remnant of plants descended from those of the supercontinent Gondwana. These floras have not evolved to cope with fire. Some 10% of Tasmania's flora is endemic to the island. Most of the Gondwanan and alpine flora is contained within the Tasmanian Wilderness World Heritage Area (TWWHA), in the west to southern part



Montane vegetation Mt Anne, South West Tasmania.

of the island and encompassing over 20% of Tasmania. Much of the rest of the island has fire-adapted vegetation.

The TWWHA is an agglomeration of State reserves including national parks and conservation areas with some contributions from the Tasmanian Land Conservancy, a not-for-profit organisation supported by private donations and volunteers. The world heritage concept is controlled by UNESCO; to be accepted as a world heritage area, a place must satisfy at least one of ten criteria. The TWWHA satisfies seven of these ten, the most of any area in Australia.

The gravity of the effect of fires on Tasmania's natural environment is compounded by climate change. The book, *Vegetation of Tasmania*, published in 1999, states on p. 34: "Lightning induced fires seldom burn large areas" because of the relatively high rainfall. But many of the bushfires in the TWWHA through the summer of 2018–19 were started by dry lightning storms, an uncommon phenomenon twenty years earlier.

In the past

Tasmanian Aboriginal people used fire to clear travel routes and to promote fresh greenery for their herbivorous prey. In doing so they gradually increased the occurrence of fire-adapted communities. Temperate rainforest is the climax vegetation for much of Tasmania and it has been calculated that rainforest is not as widespread as it should be, a phenomenon attributed to Aboriginal practices. European explorers followed these traditional clearways, but when they had to enter rainforest, the explorers did not have the wondrous experience that we do. Henry Hellyer, the first explorer to venture away from the north west coast, wrote of rainforest:

This is a horrid place to be living in; neither Sun nor Moon to be seen; no part of the sky visible being completely darkened by dripping Evergreens (quoted in *Henry Hellyer's Observations*, p. 91).

In the nineteenth century, other explorers and mineral prospectors burnt the South West to clear their way and to expose likely prospects.

From 1803, when the first Europeans came, settlers have faced a series of devastating fires. In 1854, the colony enacted a Bush Fires Act to control when people lit fires. Despite this, fire has destroyed property ever since. In 1897–98 fire swept through the lower Midlands to south of Hobart and destroyed some of the convict buildings at Port Arthur. The devastating Hobart fires of 1967, when 62 people were killed and 1400 homes burnt down, were preceded by fires in the Derwent Valley in 1933–34. In 1981, severe fires threatened the west coast town of

Zeelan. Various parts of Hobart and surrounding areas were affected by fires in 1982, 1993, 1998, 2003 and 2006. In 2013, fires flared up across the island, and much of the town of Dunalley on the Forestier Peninsula was destroyed. TV documentaries have covered the day of the fire and the recovery of Dunalley. The bushfires of the 2018–19 summer threatened towns near Mt Field, Geeveston and in the Huon Valley, severely damaging two timber mills.

Many out-of-control fires started from human action, either accidental or deliberate. Almost all accounts of fires are, like the preceding paragraph, accounts of property loss or loss of life. The change from reporting economic and social damage to focusing on environmental harm occurred with the fires of 2016.

Fires in the wilderness

In January 2016, over seventy bushfires broke out in the Central Highlands, the South West, western and north-western Tasmania. The main causes were either lightning or arson. This time, there was no significant property damage, yet the fires received widespread, even international, coverage. There were shocking TV images of burnt cushion plant communities, blackened trunks of conifers (some estimated to be over 1000 years old) and destroyed sphagnum moss bogs. The photo below of the late Mary Hancock, member of the Australian Plants Society NSW, sitting among highland vegetation including the cushion plants *Pterigopappus lawrencei* (sage green) and *Abrotanella forsterioides* (bright green), was taken near Lake Mackenzie. These communities were lost in the 2016 fires.



Mary Hancock sitting among highland vegetation near Lake Mackenzie.

Public awareness of Tasmania's natural values has increased significantly and there is a strong emphasis on this in Tasmania's tourism promotions. At the same time government funding has dropped for employment of Parks and Wildlife Service rangers and the routine upkeep of State reserves and the TWWHA – maintenance of a world heritage area is a joint state–commonwealth responsibility. The Tasmanian Premier stated that the burning of only 1.2% of the TWWHA in 2016 was “not significant” and it “could have been much worse”. Ecological experts disagree, noting that some of the burnt communities will take centuries to recover, even if seed sources are available and if climate change does not interfere.

A problem with fighting bushfires in the Tasmanian wilderness is the rugged nature of the island, making access for firefighters difficult; the 2016 fires continued to burn until autumn. Because the average temperature in Tasmania is relatively lower and moisture levels higher, dead plant material does not always decompose completely, causing a build-up of peat in the soil. Once a fire gets into peat, the burning will continue for a prolonged time, spreading underground. The camping area at Lake Pedder (not the water impoundment that now covers the lake) was in a low forest growing on peat. There was a series of round pits in the peat where campers had set up their campfires. This effect in peat is the main reason for the whole TWWHA being a fuel-stove only



area. Other reasons for the ban on open fires are to preserve dead wood (always a home for other creatures) and to prevent careless escapes of campfires.

One of the rare plants in the sand dunes of the far South West is the tall shrub *Persoonia muelleri* subsp. *densifolia*, shown on the left. Having set up camp at Coxs Bight some years ago, the author was enjoying a cuppa while leaning against a substantial tree, when he realised that the purple fleshy fruits littering the ground were of *Persoonia*: the tree must have been hundreds of years old. A few years later he was in the area again so went looking for this

wonder. The whole campsite and surrounds were burnt and the tree of *Persoonia muelleri* subsp. *densifolia* was dead. There are many plants in the South West that are rare and centuries old; they require a proper commitment to the TWWHA from the politicians who allocate funds.

The fires of 2018–19

Throughout the 2018–19 summer, the media were continually reporting on bushfires across Tasmania. Towns were threatened and the natural environment suffered. This time, 6% of the TWWHA was burnt, much of that being button grass plains and eucalypt communities, all of which are fire-adapted. This time the Tasmanian Parks and Wildlife Service was somewhat prepared, installing sprinkler systems to protect special plants in the South West. This included *Lomatia tasmanica*, a plant over 40,000 years old which is proving difficult to propagate and keep growing outside its unique natural environment. Specialist remote area firefighters had to be flown in from interstate, a role once taken by Tasmanians, one of the consequences of budget cuts. The Tourist Industry Council of Tasmania, representing tourist companies and recognising the importance of the TWWHA to tourism, called on the federal government to increase funding to the world heritage area so it could prepare for future fires. The relevant minister refused to even consider extra money beyond the \$5 million allocated for the year.

Recovery from fire – two case studies

In the morning of 21 November 1966, men clearing vegetation under power lines in the Nelson Valley on the Lyell Highway east of Queenstown used the standard practice of the time and lit a fire to burn the low vegetation. By the afternoon the fire had spread to a nearby hill. It rapidly developed into a raging inferno, sweeping over mountain ranges and jumping across river valleys to Frenchmans Cap, a well-loved icon for bushwalkers about 10 km south. Within days soaking rain had quenched the fires. Much of the unique vegetation around Frenchmans Cap was destroyed including stands of King Billy Pine, *Athrotaxis selaginoides*. Members of the Australian Plants Society Tasmania (then known as SGAP) banded together with bushwalkers and other conservationists to propagate plants sourced from nearby, and planted them around the verges of Lake Tahune, at the foot of Frenchmans. Natural recovery of the forests is slowly occurring. A more easily visited recovery site is Cradle Mountain.

In the decades around the turn of the 19th and 20th centuries, a series of fires swept through the Cradle Mountain area. A photo taken in the 1920s shows a patchwork of remnant and recovering vegetation. A



Frenchman's Cap walk fire damage



Gustav Weindorfer on Perrys Peak

group of people are on top of Perrys Peak with the entrepreneur and promoter of Cradle Mountain, Gustav Weindorfer, in the straw boater on the left (AP, 24, 193, pp. 156–160 for the story of Weindorfer).

Dove Lake sits below the mountain. On the far left is a triangle of rainforest not burnt by the fires; the Dove Lake Circuit now passes through this. The wooded spur that juts into the lake from the right hides another patch of remnant rainforest that includes Ballroom Forest and trees of King Billy Pines, some over 1000 years old. Perrys Peak is now covered by low eucalypt forest.

On his first exploration of the Cradle Mountain area in 1909, Gustav Weindorfer set up base camp at Crater Lake; he commented that tent erection was easy because of the recent burning. By the 1970s, when the author first walked to Crater Lake, any flat ground was hidden by the growth of *Leptospermum* species, *Nothofagus cunninghamii*, *Phyllocladus aspleniifolius*, etc. Even in this montane habitat, regrowth can be rapid as the two views of the Crater Lake boatshed show.



Crater Lake boatshed, 1975



Crater Lake boatshed, 2003

The Dove Lake Circuit walk starts off from the Dove Lake carpark in regrowth button grass, *Gymnoschoenus sphaerocephalus*, and montane shrubbery. One can see the patches of remnant rainforest spreading, with young trees of *Athrotaxis selaginoides* and *Richea pandanifolia* encroaching on shrubbery, button grass and cutting grass, *Gahnia grandis*.

In these examples from Frenchmans Cap and Cradle Mountain, fires had limited effect because of the fire-quenching rain or the patchwork nature of the burns, leaving seed sources in close proximity. But the 2018-19 summer conflagrations are a permanent threat to the unique Tasmanian environment.

Tasmania was not as affected by the conflagrations of 2019–20 on mainland Australia. However, the two prime dangers to the Tasmanian wilderness are:

- climate change and
- lack of effective concern by the succession of governments.

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Blechnum cartilagineum,
two months after the
Berambing fire in December
2019 Photo: Greg Bourke

The amazing red and purple leaves of resprouting eucalypts

Margaret Baker

Once the smoke has cleared after a bushfire new life bursts forth to clothe the alien sculptures of blackened trees. The appearance and colour of the post-fire growth on many eucalypts always fascinates bushland visitors. New leaves may appear as fuzzy clusters from epicormic shoots on branches and trunks of tree species or as new limbs from the underground lignotubers of mallees. Normally we would expect this new growth to be green but a wow moment comes when someone spots red to red-purple leaves standing out from black backgrounds. But aren't leaves meant to be green? How can they be red and purple too?



Stunning red foliage on *Eucalyptus sieberi*, Mount Wilson, February 2020. Photo Mark Baker)

Leaves are not just green. Leaf colour comes from pigments contained in different cells within the leaf structure. These variously coloured pigments collect light at different wavelengths and perform different functions. Most familiar are chlorophyll (usually green) that everyone knows is essential for photosynthesis, and carotenoids (yellow) that are antioxidants preventing oxygen damage to chlorophyll molecules in the presence of light.¹ The colour we see is not the colour absorbed by the

pigment but the colour that is reflected by that pigment. So what colours new leaves red to purple?

The answer to the leaf colour puzzle lies in the concentration of a water-soluble red to purple pigment called anthocyanin in newly emerging growth. This seems to occur because abundant carbohydrates stranded



Both photos: Red leaves changing to green as chlorophyll gradually replaces the anthocyanin in the foliage of a range of eucalypts at Mount Wilson; the fire occurred in mid-December 2019. Photos: Mark Baker, 5 February 2020

within the plant by the sudden fire-loss of foliage favour anthocyanin formation.²

Studies of the benefits of having extra anthocyanin in new leaves of resprouting eucalypts and other genera suggest that it provides significant protection against being eaten by insects (insect herbivory).³ Such protection is very important when competition for scarce plant resources intensifies after a fire, especially as local insect populations re-establish. The red pigment protects plants against insect munching in three ways:

- A red leaf is less easily seen than a green one by photoreceptive foliage-eating insects; however some species of psyllids do prefer the red leaves.
- Insect camouflage is reduced by the red colour making potential leaf chewers more obvious to their predators.
- The higher concentrations of anthocyanin and other phenolic compounds in new red leaves may directly deter insects because of their astringent taste.⁴

Another advantage of red new leaves is that the colour provides protection from sun damage. Red leaves strongly reflect excess near- infrared light thus markedly reducing structural damage to the developing chloroplasts needed to re-establish photosynthesis.⁵ This is a significant protective role for plants that have no shade in a burnt plant community. Anthocyanin may also provide UV-B protection but recent research suggests this may be less important than once thought.⁶

The attractive new foliage doesn't stay red or purple for long. As more leaves grow and mature the extra anthocyanin is metabolised, chlorophyll that is required for photosynthesis becomes the dominant pigment and the leaves gradually turn a familiar green.

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