Frequently Burnt Subtropical Eucalypt Forest Is More Resilient to Wildfire Than Rarely Burnt Forest

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Abstract

Open eucalypt forests with a grassy understorey are becoming rare in the volcanic landscapes on the Queensland–New South Wales border, as woody plants thicken with the cessation of regular planned burning. Whether previous planned burning reduced the impact of the 2019 unplanned wildfires on forest condition is debated. We evaluated the role of planned burning on the condition of a subtropical eucalypt forest following a wildfire in 2019. Two years after a wildfire at Mt Lindesay, a section of forest that had been frequently burnt was in better condition than adjacent rarely burnt forest. Specifically, there was significantly greater cover of kangaroo grass and a lower density of tree saplings in frequently burnt forest. The canopy of rarely burnt forest showed more signs of dieback. The pattern of healthier eucalypt forest with frequent burning was observed at other South East Queensland sites, Mt Gillies and Spicer's Gap. These observations suggest long-term frequent burning under mild conditions with good soil moisture maintains grassy eucalypt forest that is resilient to occasional intense wildfires during drought, such as seen in late 2019.

Keywords: planned burning, frequent fire, wildfire, overabundant saplings, kangaroo grass

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Introduction

Eucalypt forests are the predominant vegetation type of the coast and ranges of subtropical eastern Australia. The understorey beneath the trees ranges from low, open and grassy, to a dense subcanopy of trees and shrubs. On the fertile volcanic soils of South East Queensland and north-eastern New South Wales (NSW), tall, straight-trunked eucalypts overtop what was once an understorey of robust native tussock grasses and herbs (Butler et al., 2014; Stone et al., 2018). Cessation of Indigenous fire management has resulted in the thickening of plants promoted by occasional high-intensity fires, especially wattles, and the encroachment of semi-mesic woody plants into these formerly open landscapes, with succession to rainforest possible (Butler et al., 2014; Stone, 2018; Baker et al., 2020). This trend prevails to the point where open eucalypt forests with a grassy understorey are becoming hard to find (Kington et al., 2021; Stone et al., 2022). Encroachment of woody vegetation into once-grassy landscapes due to loss of Indigenous fire management has been documented across Australia (Stanton et al., 2014; Fletcher et al., 2021; Roberts et al., 2021; Chevis et al., 2022; Mariani et al., 2022). Loss of open grassy ecosystems in tropical and subtropical landscapes is a conservation issue deserving of much greater recognition than it currently receives (Parr et al., 2014; Bond, 2019). The scarcity of these iconic landscapes is a shame in itself and is also associated with a decline in fauna that use grasses for foraging and shelter (e.g. Stone et al., 2022).

Indigenous fire management in grassy ecosystems generally involved frequent, low-intensity fire, and continues to do so where practised today (Mariani et al., 2022; Steffensen, 2020). Australian ecosystems are also burnt by non-Indigenous Australians, primarily to reduce fuel loads for the protection of life and property, to encourage green pick for stock (Jarman et al., 1987), and for conservation purposes. Planned burning (also called prescribed burning) has been shown to reduce the extent and impact of wildfires, both in Australia (Boer et al., 2009; Price et al., 2012) and overseas (Hunter & Robles, 2020; Santos et al., 2021), although its capacity to do so depends on a variety of factors, including ecosystem type and condition, as well as time since previous fire (Storey et al., 2016). However, the capacity of planned burning to mitigate the effects of wildfire on conservation-related parameters has received little attention.

Large areas of eastern Australia were burnt in unplanned, high-intensity wildfires between August 2019 and February 2020 (Adams et al., 2020; Collins et al., 2021; Smith et al., 2021; Baker et al., 2022). High-intensity wildfires can damage the canopy and kill eucalypt trees which normally survive lower-intensity fires (Williams et al., 2020). They can also promote dense germination of trees and shrubs because the elevated heat penetration into the topsoil breaks the dormancy of hard-seeded species such as wattles and damages roots, promoting stem propagation via root suckering (Williams et al., 2004; Palmer et al., 2018).

Excessive sapling density smothers grasses and herbs in subtropical eucalypt forest (Kington et al., 2021; Lewis & Debuse, 2012; Baker et al., 2020), and it is grasses and herbs that provide the bulk of species diversity in these forests of South East Queensland (Ryan, 2012). The loss of native grass cover reduces the capacity of land managers to implement low-intensity fires under mild conditions, because fire carries through a continuous grass layer while there remains good soil moisture early in the dry season but is less capable of spreading through a ground layer of predominantly leaf litter until soil and fuel dry out (Baker et al., 2021). A forest cluttered with tree saplings has very high to extreme elevated fuel that can increase the intensity of a fire and create a ladder of fuel that burns into and damages the canopy (Barker et al., 2022).

In this study, we investigated whether the impact of a wildfire on a subtropical eucalypt forest could be minimised by prior frequent planned burning. Specifically, we examined adjacent areas of forest with contrasting fire histories, two years after both areas were burnt in the 2019 wildfires, comparing them on the following indicators of forest condition: native grass cover, species richness, density of tree saplings, and canopy health.

Methods

Mt Lindesay

The primary study site lies on the western foot slopes of Mt Lindesay, in Mt Barney National Park, less than 1 km north of the Queensland–NSW border. The vegetation is subtropical eucalypt forest, dominated by *Eucalyptus propinqua* and *E. microcorys*. This forest is classified as Regional Ecosystem 12.8.8a, which has an 'Of Concern' Queensland *Vegetation Management Act 1999* status (Queensland Herbarium, 2021). The broad landscape surrounding the site has a long, continuous history of frequent burning under mild conditions. For four generations the Hardgrave family have implemented a frequent low- to moderate-intensity burning program under mild conditions on their cattle grazing property, part of which became Mt Barney National Park (S. Hardgrave, pers. comm., 6 September 2021); i.e. a continuous frequent burning program has run for more than a century. According to the landholder, this regime continued the regular burning practices of the Indigenous people of the area (S. Hardgrave, pers. comm., 6 September 2021).

Surveys of the influence of frequent burning on the vegetation response to the 2019 wildfire were undertaken on either side of the Mount Lindesay Highway (28.3343°S; 152.7069°E). At this location, the ‘highway’ is a narrow, winding road running roughly south. The wildfire in late 2019 burnt both sides of the Mt Lindesay Highway in this area, during drought conditions. Due to the highway and another fire break, the western side of the highway had not been burnt for at least 20 years prior to 2019 (D. Kington, pers. comm., 6 September 2021). In contrast, the eastern side of the highway received frequent fire (i.e. every few years) up until 2012, after which there was a hiatus in burning prior to the 2019 wildfire (S. Hardgrave, pers. comm., 6 September 2021). This difference in fire regime and the resulting vegetation condition on either side of the highway have been observed and discussed by two of the authors (D. Kington and P. Watson) for two decades.

On 6 and 7 September 2021, two years after the wildfire, six transects were surveyed: three on the frequently burnt, eastern side of the highway; and three on the rarely burnt western side. As the area of frequently burnt forest was small, the transect positions were not selected randomly but spread out across a 250 m stretch of forest on each side of the highway. In each transect, all woody plants were counted and allocated to size classes, and the percentage cover of grasses and herbs was estimated within 10 evenly spaced 1 m^2 quadrats. The three transects in the frequently burnt area were 50 m long by 4 m wide. The three transects in the rarely burnt area were half that length (i.e. 25 m × 4 m), due to the high density of saplings and tangle of native vines. The woody plant counts in the 25-m long transects were doubled to allow comparison with counts from the 50-m long transects.

The statistical significance of differences between fire histories was assessed using an ANOVA for the density of shrubs and saplings, the percentage cover of native grasses, and species richness per 1 m^2.

Consistency in Vegetation Patterns

Observations were also made at the nearby Mt Gillies section of Mt Barney National Park (28.3057°S; 152.7433°E). This eucalypt forest has received a continuous program of burning every few years for over a century but was not burnt in the 2019 wildfire. This site provided a background example of forest condition with regular burning, in the absence of the 2019 wildfire.

To check the consistency of vegetation response to the 2019 wildfire between frequently burnt and rarely burnt forest, observations were also made in *Eucalyptus dunnii* forest (Regional Ecosystem 12.8.11) at the Spicers Gap section of Main Range National Park (28.081°S; 152.4099°E). Regional Ecosystem 12.8.11 has an ‘Of Concern’ Queensland *Vegetation Management Act 1999* status (Queensland Herbarium, 2021). This area was a known eastern bristlebird (*Dasyornis brachypterus*) site until a few decades ago.

Results

Mt Lindesay

The frequently burnt eucalypt forest on the foot slopes of Mt Lindesay had an open mid stratum of saplings, with a dense continuous ground layer of native grasses. In contrast, the rarely burnt forest had limited grass cover and excessive saplings after the 2019 wildfire (Figures 1 and 2). Sapling density (<2 m tall) was significantly lower in the frequently burnt than rarely burnt forest ($F_{1,4}$ = 14.16; P <0.02; Figure 3), as was combined sapling density up to 6 m tall ($F_{1,4}$ = 9.155; P <0.04). The most common saplings in both frequently and rarely burnt forest were *Acacia maidenii*, *Allocasuarina torulosa*, *Corymbia intermedia*, *Eucalyptus propinqua*, *Lophostemon confertus*, *Polyscias elegans* and *Trema tomentosa*. The canopy of the rarely burnt forest was observed to clearly have a greater abundance of dead branches than the frequently burnt forest, although this was not quantified.

The cover of the native kangaroo grass (*Themeda triandra*) was significantly higher in the frequently burnt forest ($F_{1,4}$ = 9.622; P <0.04; Figure 4). Blady grass (*Imperata cylindrica*) was more abundant in the frequently burnt forest (mean 15.9% cover in frequently burnt vs 6.4% in rarely burnt forest), and bracken ferns (combined cover of *Calochlaena dubia* and *Pteridium esculentum*) were more common in the rarely burnt forest (2.5% cover in frequently burnt vs 9.1% in rarely burnt forest). However, the differences in blady grass and bracken fern cover between regularly and rarely burnt forest were not statistically significant ($F_{1,4}$ = 62.172; P >0.2 and $F_{1,4}$ = 63.866; P >0.3, respectively). Average species richness per 1 m^2 was similar between fire regimes (6.8 in frequently burnt vs 6.1 in rarely burnt forest, $F_{1,4}$ = 0.395 P >0.5).

FIGURE 1. Frequently burnt eucalypt forest at Mt Lindesay, two years after a 2019 wildfire.

FIGURE 2. Rarely burnt eucalypt forest at Mt Lindesay, two years after a 2019 wildfire.

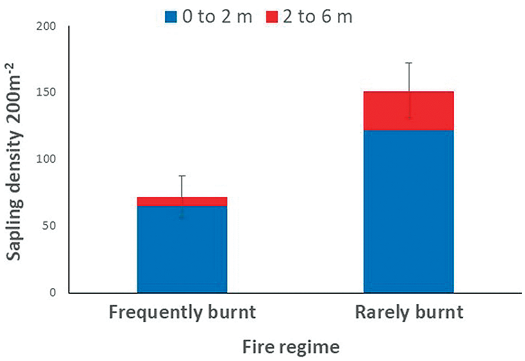

FIGURE 3. Mean sapling density across 200 m^2, at two years after a 2019 wildfire, in frequently and rarely burnt eucalypt forest at Mt Lindesay. Size classes of saplings are shown (0 to 2 m and 2 to 6 m). Error bars are one standard error of the mean, for all saplings combined.

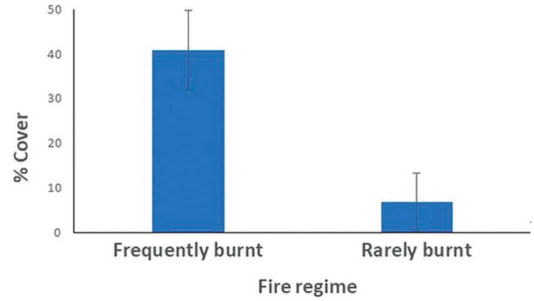

FIGURE 4. Mean percentage cover of kangaroo grass (*Themeda triandra*) in frequently and rarely burnt eucalypt forest at Mt Lindesay. Error bars are one standard error of the mean.

FIGURE 5. Frequently burnt eucalypt forest at Mt Gillies, dominated by kangaroo grass.

Consistency in Vegetation Patterns

The eucalypt forest on nearby Mt Gillies, which has been frequently burnt for at least a century, had a dense cover of kangaroo grass in the ground layer, an open mid stratum with scattered saplings, and a healthy canopy (Figure 5).

Following the 2019 wildfire, the frequently burnt eucalypt forest at Spicer's Gap in Main Range National Park resembled that of Mt Lindesay, in having fewer saplings and a greater cover of native grasses (*Poa labillardierei*, *Sarga leiocladum* and *Themeda triandra*) compared with adjacent rarely burnt forest (Figures 6 and 7).

FIGURE 6. Frequently burnt eucalypt forest at Spicer's Gap, burnt in 2019 wildfire.

FIGURE 7. Rarely burnt eucalypt forest at Spicer's Gap, burnt in 2019 wildfire.

Discussion

The data set in this study, of six transects at a single location plus visual observations at secondary locations, is limited. The study should thus be seen as an initial exploration of the influence of pre-wildfire fire regime on forest resilience. In this discussion, we will refer to our findings as observations. We consider our conclusions tentative pending further empirical investigation.

The Mt Lindesay transect data and observations at Spicer's Gap provide examples where frequent burning under mild conditions has maintained a healthy, grassy subtropical eucalypt forest that was more resilient to the 2019 wildfires than rarely burnt forest. A long history of regular burning appears to have limited the excessive post-wildfire sapling recruitment seen in rarely burnt forest. Frequent burning also maintained a healthy, dense native grass layer. The observed condition of the vegetation at Mt Gillies and Spicer's Gap was consistent with our findings at Mt Lindesay.

An overabundance of native saplings, especially wattles and eucalypts, is a recognised indicator of unhealthy subtropical eucalypt forests (Williams et al., 2020; Virkki et al., 2021). High-intensity fires promote abundant recruitment of some woody species, especially wattles, other legumes and some rainforest trees (Morrison, 2002; Lewis & Debuse, 2012; Williams et al., 2012; Collins, 2020; Baker et al., 2022). The risk of high-severity fire increases with high elevated fuel loads (Furlaud et al., 2021). For example, in Warrumbungle National Park, the abundance of *Acacia* species increased four-fold after a high-intensity wildfire, with their density positively correlated with fire severity (Gordon et al., 2017; Palmer et al., 2018). The increase in sapling density causes a positive flammability feedback, whereby intense fires promote dense sapling recruitment which, in the absence of regular fire, grows into the mid strata, increasing elevated fuel loads and subsequent fire intensity. This feedback loop has recently been documented in eucalypt forests in Victoria (Karna et al., 2021), providing a mechanism for the recently recognised tendency for high-severity fire to beget further high-severity fire (Barker & Price 2018; Barker et al., 2022).

High sapling density, particularly of nitrogen-fixing wattles, increases soil nitrogen levels, promoting the young, soft eucalypt foliage targeted by psyllids, which is correlated with Bell miner associated dieback of subtropical eucalypt forests (Wardell-Johnson et al., 2005). Excessive sapling density also corresponds with a loss of native grasses and herbs in subtropical eucalypt forests (Baker et al., 2020; Williams et al., 2020). The maintenance of a dense native grass cover, especially of *Poa* spp. and *Themeda triandra*, is critical for fauna such as the northern population of the eastern bristlebird (Stone et al., 2018) and the Hastings River mouse (*Pseudomys oralis*; Tasker & Dickman, 2004). Grass abundance is also essential for maintaining the capacity to implement low-intensity fires that carry patchily through the landscape under mild conditions, while good soil moisture remains following the wet season (Simpson et al., 2016; Prior et al., 2017; Padullés Cubino et al., 2018).

In the frequently burnt grassy forest at Mt Lindesay, the lack of a dense mid-storey meant that the flammable understorey was separated from the eucalypt canopy many metres above, reducing the possibility of crown fire. The value of frequent planned burning in reducing both the intensity and the spread of wildfires has been demonstrated across Australia. For example, prescribed burning at intervals of up to five to seven years can minimise wildfire occurrence in eucalypt forests of southern Australia (Volkova et al., 2021). Planned burning under mild, early dry season conditions in northern Australia has successfully reduced the extent of late dry season, high-intensity fires across a vast landscape (Edwards et al., 2021). A study of 52 years of fire history in southern Western Australia found that regular prescribed burning markedly reduced the incidence and extent of wildfire, particularly large fires, and especially in the 1960s when prescribed burning activity was at a maximum (Boer et al., 2009). These results also support the conclusion of a recent international review that regular planned burning lowers the intensity of subsequent wildfires (Hunter & Robles, 2020).

Although the density of saplings in the regularly burnt forest at Mt Lindesay was only half that in the infrequently burnt area, quite a number of saplings were present nevertheless. The seven-year interval before the wildfire had likely allowed some build-up of shrub and tree propagules, which were then triggered to germinate by the wildfire. This area would likely benefit from follow-up fires at intervals shorter than seven years, to ensure mid-storey density does not continue to increase, to the detriment of the grassy understorey. In South East Queensland, current recommended frequency for these very productive forests is 3 to 5 years (Kington et al., 2021).

We conclude that these observations suggest long-term frequent burning in subtropical grassy eucalypt forest, under mild conditions, promoted and maintained a healthy understorey of grasses and herbs, together with scattered saplings. This forest appeared resilient to the damaging effects of the 2019 wildfires. In contrast, adjacent forest that had not received regular fires was damaged by the 2019 wildfires. Thus, these observations suggest regular burning in these grassy forests is not only beneficial for maintaining forest structure and health, it also minimises the impact of wildfire if one does occur during drought conditions.

Further research is required to expand on these observations to better quantify the influence of frequent burning on the condition of grassy eucalypt forests after wildfire. Further investigation would ideally assess pre- and post-wildfire sapling density and tree canopy health, as well as grass abundance and vigour.

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Dave Kington is a fire ecologist with extensive experience in fire management within South East Queensland forests.

Eleanor Collins is an ecologist interested in fauna and flora management, including suitable fire management.