NSW Forest Monitoring and Improvement Program

Summary paper: Koala and habitat response after the 2019-20 wildfires in north east NSW

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Acknowledgement of Country

The Natural Resources Commission acknowledges and pays respect to traditional owners and Aboriginal peoples. The Commission recognises and acknowledges that traditional owners have a deep cultural, social, environmental, spiritual and economic connection to their lands and waters. We value and respect their knowledge in natural resource management and the contributions of many generations, including Elders, to this understanding and connection.

List of acronyms

ANU	Australian National University
Coastal IFOA	Coastal Integrated Forestry Operations Approval
DPE	Department of Planning and Environment
DPI	Department of Primary Industries
FCNSW	Forestry Corporation of NSW
FMIP	Forest Monitoring and Improvement Program
FPCs	Formylated phloroglucinol compounds
NSW	New South Wales
UBFs	Unsubstituted B-ring flavanones

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Cover images clockwise from top left:

1. Burnt forest at Bril Bril State Forest (November 2019), image courtesy of Dr Brad Law, DPI
2. Koala at Kiwarrak State Forest, image courtesy of Dr Brad Law, DPI
3. Acoustic recorder set up in the field

Table of Contents

Executive summary

The NSW Forest Monitoring and Improvement Program (FMIP) funded researchers from the Australian National University (ANU) and Forest Science Unit, NSW Department of Primary Industries (DPI) to co-investigate the impact of the 2019-20 wildfires on koalas and their habitat at research sites in north-east NSW.

The research used existing pre-fire data and analysis combined with targeted sampling after the wildfires to opportunistically address knowledge gaps around the impacts of fire on:

- koala density (site scale)
- koala occupancy (regional scale)
- nutritional value of trees and sites for koalas.

This synthesis report presents the findings from the research and opportunities to improve knowledge and management for north coast koala populations. The research, while robust, had limited sample sites and further on-going monitoring is required to confirm the conclusions.

Severe fires impacted koala populations, but local recovery is evident in some locations

For local koala populations, the research found that areas with a greater extent of medium or high fire *severity* (degree of canopy scorch) experienced larger declines in koala density than areas with only low severity fire. Koalas were temporarily absent in some areas where high fire severity dominated the landscape, but return of koalas had begun after a year. In contrast, in unburnt or predominantly low fire severity areas, koalas continued to be widespread, with little to no signs of decreased local population density.

At the regional scale, there was no overall decline in post-fire koala occupancy (2019) detected for the north-east NSW metapopulation compared with trends pre-fire, between 2015 and 2018. However, while the occupancy of a metapopulation can be stable overall there may be increasing and decreasing subpopulations, whereby populations that are temporarily absent because of disturbance can be recolonised where connected over time.

As such, local or regional extinctions are unlikely in these hinterland forests where connectivity and refugia remain. However, predicted increases in fire frequency and intensity pose a risk to these habitat features. **Section 2.1.2** notes other potential impacts to koalas from wildfires.

Key koala browse species offer improved nutritional quality after fire

The epicormic growth post-fire of some species was found to have higher nutritional quality than mature leaves from the same trees pre-fire. These included species of the subgenus *Symphyomyrtus*, also known as “symphyomyrtle” species (many of which are preferred koala browse species, such as Sydney blue gum, small-fruited grey gum, northern grey ironbark and red mahogany), as well as tallowwood from the subgenus *Alveolata* (another preferred browse species). In these species, regenerating foliage had higher levels of protein (digestible nitrogen) and higher moisture content.

While some increases in protein and moisture content may be due to drought recovery over the study period, leaf type was found to be a primary factor determining leaf nutritional quality. This is because the difference between the levels of protein in epicormic growth and pre-fire mature leaves is far greater than for mature leaves before and after fire.

In contrast, the nutritional quality of species of the subgenus *Eucalyptus*, also known as “monocalypts” (such as blackbutt, white stringybark, and broad-leaved white mahogany, which are typically not preferred browse species) decreased after fire, with lower protein availability in the epicormic regrowth.

At a site level, habitat nutritional quality is determined by tree species composition as well as the types of leaves available. Following a fire, increased epicormic growth at sites with a greater abundance of preferred koala browse species (mostly symphyomyrtles and tallowwood) has the potential to improve habitat nutritional quality for koalas. However, for sites with a greater abundance of non-preferred species (often monocalypts), habitat nutritional quality for koalas would be further reduced with a higher proportion of epicormic growth. These findings indicate that forests with a high abundance of symphyomyrtle koala browse species and tallowwood, from the subgenus *Alveolata,* may be particularly important for maintaining koala habitat nutritional quality following wildfires.

Ensuring koala populations remain resilient in future

This research indicates koala populations at these sites have been relatively resilient following the 2019-20 wildfires. However, previous research suggests future fires may lead to more significant adverse effects as habitat quality, connectivity, and refuge areas may decrease and koalas may have less opportunity to recolonise between fire events. Wildfire frequency has been found to have a strong negative correlation with koala habitat suitability.

Future opportunities include:

- reviewing the browse species classification of species with high post-fire nutritional value
- monitoring and managing regeneration areas to ensure koala browse species are present
- continuing to monitor koala recovery at sites impacted by fire
- exploring management practices that could reduce fire severity, along with further research on the impact of low severity fire to koalas to ensure such approaches deliver the expected outcomes.

1 Understanding post-fire koala and habitat responses

In August 2020, the NSW Forest Monitoring Steering Committee approved funding under the NSW Forest Monitoring and Improvement Program (FMIP) to investigate the impact of the 2019-20 wildfires on koalas and their habitat. The research capitalised on a unique opportunity to use data collected before and after the wildfires to assess the impact of fire on:

- **local koala density** – using acoustic array surveys, each spanning around 400 hectares, and scat DNA analysis
- **regional koala occupancy** – using annual passive acoustic monitoring (see **Figure 7** for locations of burnt sites)
- **nutritional value of trees and sites for koalas** – based on analysis of leaf samples.

The local koala density and regional koala occupancy analysis[1,2] was led by Dr Brad Law (DPI – Forest Science group), while the nutritional analysis[3] was led by Dr Karen Ford (ANU). The research results are summarised here. The full research reports are available on the Commission's website.

1.1 Building on existing data to gain new insights

The data sources for this research are set out in **Table 1**. Pre-fire data was obtained from existing sources, including from the Commission's Koala Research Program and annual koala monitoring carried out by DPI. Comparable post-fire data was collected using the same survey and sampling methods. This allowed for rapid and cost-effective research into the impacts of the unprecedented 2019-20 wildfires on koalas.

Table 1: Data sources

Research	Pre-fire data	Post-fire data
Local koala density	Existing Koala Research Program data and DPI survey data	Acoustic array[4] surveys for koala density were repeated, in part immediately after fires at two sites, and then in full around one year post-fire at three sites subject to different fire severity: ▪ **Bril Bril State Forest** – low severity fire in August 2019 ▪ **Kiwarrak State Forest** – moderate severity fire in November 2019 ▪ **Bellangry State Forest** – high severity fire in October 2019. Fire severity is determined by the degree of canopy scorch, based on fire extent and severity mapping (FESM V3) or, where this is not available, from rapid assessment of fire impact on timber (RAFIT), as well as pyrodiversity.[5]

1 Law, BS., et al. (2021) *Foundational Monitoring Project: Effects of 2019 Fires on Koala Occupancy Monitoring at the Regional Scale and Koala Density at the Local Landscape Scale*, report for the Natural Resources Commission by NSW Primary Industries Forest Science and Forestry Corporation of NSW

2 Law, B.S., et al. (2022) Fire severity and its local extent are key to assessing impacts of Australian mega-fires on koala (*Phascolarctos cinereus*) density. *Global Ecology and Biogeography*, 31(4): 714-726. https://doi.org/10.1111/geb.13458

3 Marsh, K.J.; Youngentob, K.N.; and Clark, R.G. (2021) *Determining the effects of forest harvesting on habitat nutritional quality for koalas*. Report for the Natural Resources Commission by Australian National University.

4 An acoustic array comprises 25 acoustic recorders set up in grid formation across a 400 hectare site

5 Fire severity categories are outlined in Law, B. S., Gonsalves, L., Burgar, J., Brassil, T., Kerr, I., O'Loughlin, C. (2022) Fire severity and its local extent are key to assessing impacts of Australian mega-fires on koala (*Phascolarctos cinereus*) density, *Global Ecology and Biogeography*, 31(4): 714-726. https://doi.org/10.1111/geb.13458

Research	Pre-fire data	Post-fire data
		Surveys were also undertaken at reference unburnt control areas (Bago Bluff, Kumbatine and Ulidarra National Parks), which had previously been surveyed as part of the Koala Research Program. Scats were collected at the Kiwarrak State Forest site for DNA analysis to identify individuals and their sex to confirm a 1:1 sex ratio.
Regional koala occupancy	Annual passive acoustic koala occupancy monitoring for 2015-2018	Passive acoustic koala occupancy monitoring was carried out by FCNSW and DPI staff at 50 sites immediately after the 2019-20 wildfires – including 16 burnt sites across state forests, national parks and private property (10 high severity and 6 low severity) – and at further sites in spring 2020. The 16 burnt sites represent 33 percent of the full sample surveyed, which is equivalent to the proportion of koala habitat burnt across the region. **Note:** at present, only results from 2019 immediately following the fires have been analysed for occupancy. Recordings from 2020 will be analysed for occupancy together with further data from 2021 when these are available.
Nutritional value for koalas	Existing Koala Research Program data	Leaves were resampled in February 2021 for nutritional analysis from 150 previously sampled trees across six sites that burnt in 2019, and six paired unburnt sites, all located in state forests

2 Research findings

2.1 Koala response to wildfire at local and regional scales

Most (69.5 percent) of the 1.65 million hectares in north-east NSW identified as moderate- or high-quality koala habitat remained unburnt after the 2019-20 bushfire season[6]. The remaining habitat experienced a range of fire severities (**Figure 1**).[7] Figures presented here are largely consistent with earlier assessments of fire severity in high-suitability koala habitat.[8,9] Where habitat was burnt, there was typically a mosaic of fire severity and extent, including unburnt refuges. High severity fire impacted over 10 percent of moderate- and high-quality koala habitat.

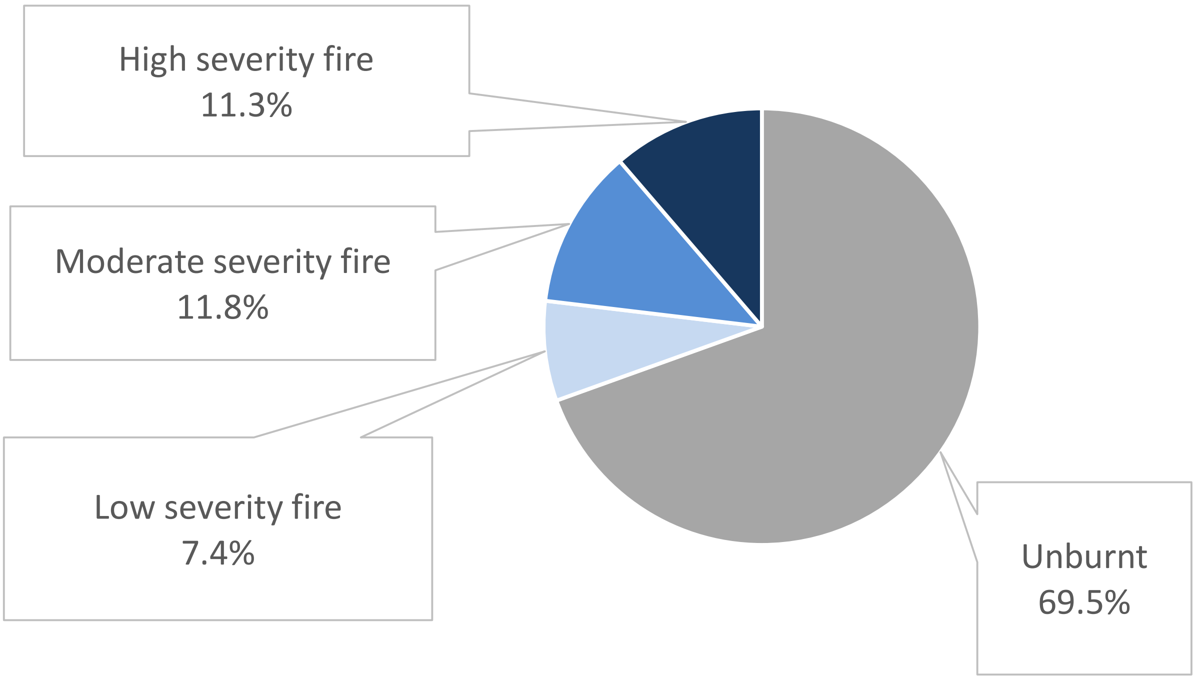


Figure 1: Proportion of moderate and high-quality koala habitat in north-east NSW impacted by the 2019-2020 wildfires

[6] Law, B. S, *et al.* (2022). Fire severity and its local extent are key to assessing impacts of Australian mega-fires on koala (*Phascolarctos cinereus*) density. *Global Ecology and Biogeography*, 31(4): 714-726. https://doi.org/10.1111/geb.13458

[7] Law, B. S, *et al.* (2022). Fire severity and its local extent are key to assessing impacts of Australian mega-fires on koala (*Phascolarctos cinereus*) density. *Global Ecology and Biogeography*, 31(4): 714-726. https://doi.org/10.1111/geb.13458

[8] DPIE (2020). *NSW Wildlife and Conservation Bushfire Recovery – Medium-term response plan.* State of NSW and Department of Planning, Industry and Environment, Parramatta. Available at https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Parks-reserves-and-protected-areas/Fire/nsw-wildlife-and-conservation-bushfire-recovery-medium-term-response-plan-200478.pdf

[9] DPIE's figures on fire severity in high suitability koala habitat from 2020 were used in the Commission's Koala Research Program report published in September 2021 - *Koala response to harvesting in NSW north coast state forests.* At that stage, the figures from Law *et al.* (2022) were not available.

Where high severity fire dominated in the study areas, there was little unburnt forest, including in gullies.[10,11] The drought preceding the 2019-20 wildfires reduced vegetation moisture to extremely low levels and led, in some cases, to the fires penetrating moist environments that typically do not burn, such as riparian vegetation in gullies and rainforest.[12] Given the scale and intensity of these wildfires, it was anticipated that some local populations of koalas would be severely impacted, especially where moderate- and high-severity fires were more extensive. This component of the research looks at the impacts of these fires on local koala density at both burnt and unburnt sites, and on the regional koala population across north-east NSW.

2.1.1 Local koala population density declines linked to higher fire severity

The research confirmed that greater extent of high-severity fire correlated with a greater decline in male koala density, and in unburnt or predominantly low fire severity areas, no detectable change in koala density was recorded as pre- and post-fire uncertainty intervals overlapped (**Figure 2**).

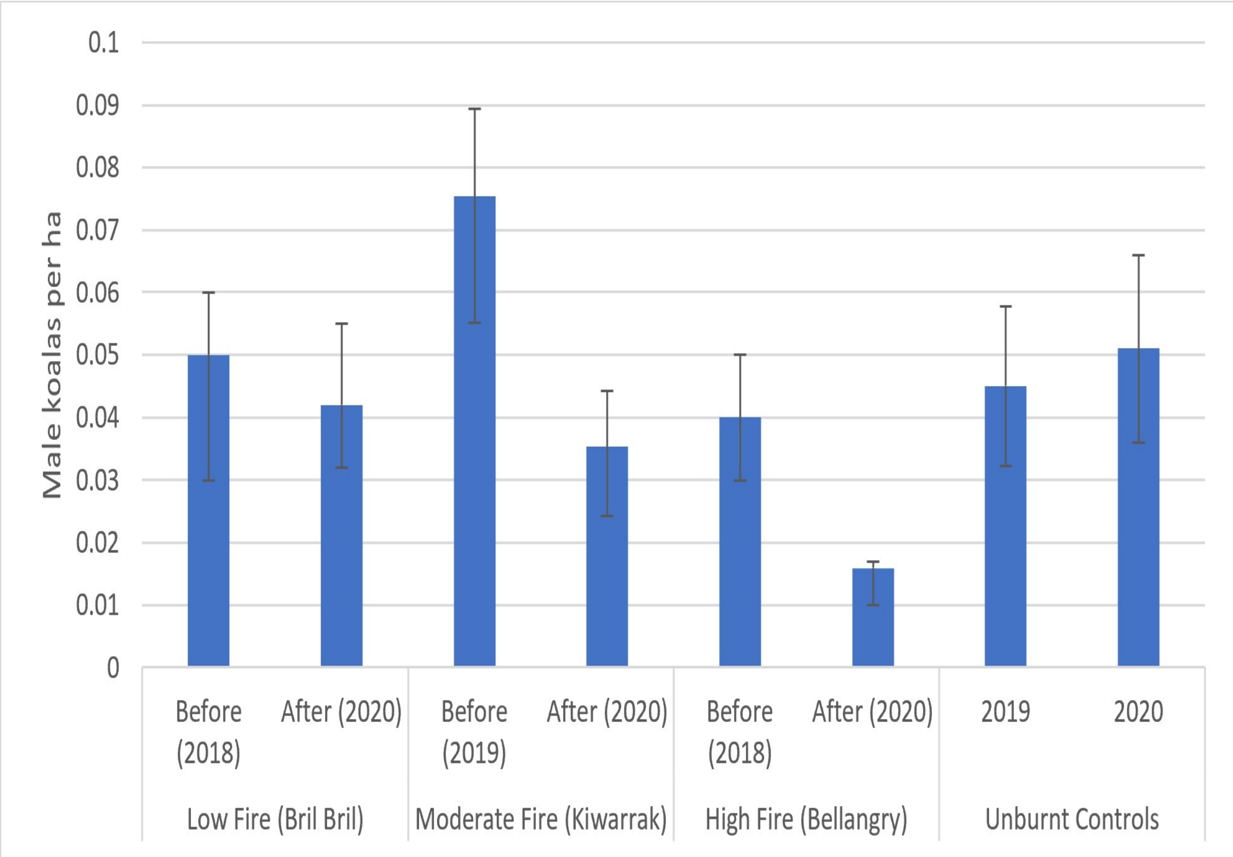


Figure 2: Mean male koala density (± 50% BCIs), as estimated by acoustic arrays before (2018, 2019) and after (2020) fires at the three study areas with different severity and unburnt controls (plotted as mean of three control areas ± SE)

10 ....Law, B. S, *et al.* (2022). Fire severity and its local extent are key to assessing impacts of Australian mega-fires on koala (*Phascolarctos cinereus*) density. *Global Ecology and Biogeography*, 31(4): 714-726. https://doi.org/10.1111/geb.13458

11 ....Bradstock. R, Bedward, M., & Price, O. (2021), *Risks to the NSW Coastal Integrated Forestry Operations Approvals Posed by the 2019/2020 Fire Season and Beyond*, Centre for Environmental Risk Management of Bushfires, University of Wollongong and the NSW Bushfire Risk Management Research Hub, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

12 ....Law, B. S, *et al.* (2022). Fire severity and its local extent are key to assessing impacts of Australian mega-fires on koala (*Phascolarctos cinereus*) density. *Global Ecology and Biogeography*, 31(4): 714-726. https://doi.org/10.1111/geb.13458 and references within.

At 1–2 months post-fire, koalas were temporarily absent in surveyed areas where high fire severity dominated the landscape (see **Figure 3** and **Figure 4** for examples of a forest burnt with high severity fire). Some localised recovery was evident at these sites after a year, although local population density was still estimated to be 60 percent lower one year after the fires despite epicormic regrowth being available on burnt trees at the time of the surveys (see **Section 2.2**).

Post-fire surveys from this study suggest that in these north coast hinterland forests with high connectivity koala declines are unlikely to result in long-term local extinction. Similarly, where fire severity was moderate-high, surveyed koala density was reduced by about 50 percent within one year, but koalas remained widespread throughout the burnt area. Further monitoring of these sites is needed to confirm the long-term trends and impacts. Additional surveys should also occur following future wildfires to confirm these findings and to complement broader landscape monitoring.

High rainfall occurred following the wildfires weakening drought conditions across much of eastern NSW.[13] Koala population recovery could have been impacted by prolonged food shortages if the north coast remained in drought conditions after the wildfires. It is uncertain to what extent koala numbers will build back up prior to the next significant bushfire season. For this given event, there have been at least three consecutive years of above average rainfall, which has accelerated forest canopy recovery.

Figure 3: Example of high severity fire that burnt the entire canopy across most areas of Bellangry, except very small refuges in some sheltered gullies[14]

13 .... NSW DPI. *NSW State Seasonal Update - February 2020.* Available at: https://www.dpi.nsw.gov.au/climate-landing/ssu/february-2020#:~:text=The%20NSW%20DPI%20Combined%20Drought,improving%20conditions%20in%20eastern%20NSW.

14 .... Photo sourced from: Law, BS., *et al.* (2021) *Foundational Monitoring Project: Effects of 2019 Fires on Koala Occupancy Monitoring at the Regional Scale and Koala Density at the Local Landscape Scale*, report for the Natural Resources Commission by NSW Primary Industries Forest Science and Forestry Corporation of NSW

Figure 4: Example of high-severity fire in Kiwarrak State Forest[15]

Within the survey areas that were dominated by moderate- or high-severity fire, there were patches of both low- and high-severity fire. Koala density was reduced within both low- and high-severity fire patches in these areas. This may indicate that within areas that experienced more severe burns, patches of low-severity fire were less effective as refugia, potentially due to overwhelming heat generated by severe fires over a large area.[16] Alternatively, landscapes with more high severity fire have fewer surviving koalas to use the patches burnt by low severity fires, or there were just fewer refugia.

In contrast, the acoustic surveys found that in areas dominated by low-severity fire, pre- and post-fire koala density did not significantly change (**Figure 5** provides an example of an area subject to a low-intensity burn). Similarly, the unburnt control sites also showed little change in density following the fires.

Koala detection dogs were used to collect scats at Kiwarrak State Forest for researchers to assess koala sex ratios at the site. This forest was impacted by fire classed as medium severity. This analysis found a 1:1 ratio between sexes (49 percent - female koalas and 51 percent male koalas). This is consistent with a similarly sampled unburnt forest on the mid-north coast of NSW (Kalateenee State Forest).[17]

15 .... Photo sourced from: Law, BS., *et al.* (2021) *Foundational Monitoring Project: Effects of 2019 Fires on Koala Occupancy Monitoring at the Regional Scale and Koala Density at the Local Landscape Scale*, report for the Natural Resources Commission by NSW Primary Industries Forest Science and Forestry Corporation of NSW

16 .... Law, B. S. *et al.* (2022). Fire severity and its local extent are key to assessing impacts of Australian mega-fires on koala (*Phascolarctos cinereus*) density. *Global Ecology and Biogeography*, 31(4): 714-726. https://doi.org/10.1111/geb.13458

17 .... NRC (2021) Research Program – Koala response to harvesting in NSW north coast forests – final report – September 2021.

Figure 5: Low severity fire that burnt ground cover, understorey and occasionally scorched the canopy at Bril Bril State Forest[18]

2.1.2 Overall koala occupancy at the regional scale appears stable post-fire

The research found that at the regional scale, across 50 sites, the probability of occupancy by koalas in north-east NSW was stable after the 2019-20 wildfires.

In the period prior to the 2019-20 wildfires (2015 to 2018), koala occupancy in north-east NSW (that is, the regional metapopulation) was assessed as being stable based on modelled occupancy which accounts for the influence of elevation and habitat suitability of monitoring sites. No signal of a decline in koala occupancy was identified either in 2018 during drought conditions, or immediately after the wildfires in 2019 (**Figure 6**). Koala occupancy remained high throughout this period, with at least one bellowing koala occupying about 68% of survey sites.

However, the stable occupancy of a metapopulation can include increasing and decreasing subpopulations. For example, where fire severity was mostly moderate, density was reduced by about 50 percent within one year of the fire, but with koalas detected on all sensors across that study area.[19] These findings regarding local koala population density are described in **Section 0**.

[18] Photo sourced from: Law, BS., et al. (2021) *Foundational Monitoring Project: Effects of 2019 Fires on Koala Occupancy Monitoring at the Regional Scale and Koala Density at the Local Landscape Scale*, report for the Natural Resources Commission by NSW Primary Industries Forest Science and Forestry Corporation of NSW

[19] Law, B. S, *et al.* (2022). Fire severity and its local extent are key to assessing impacts of Australian mega-fires on koala (*Phascolarctos cinereus*) density. *Global Ecology and Biogeography*, 31(4): 714-726. https://doi.org/10.1111/geb.13458

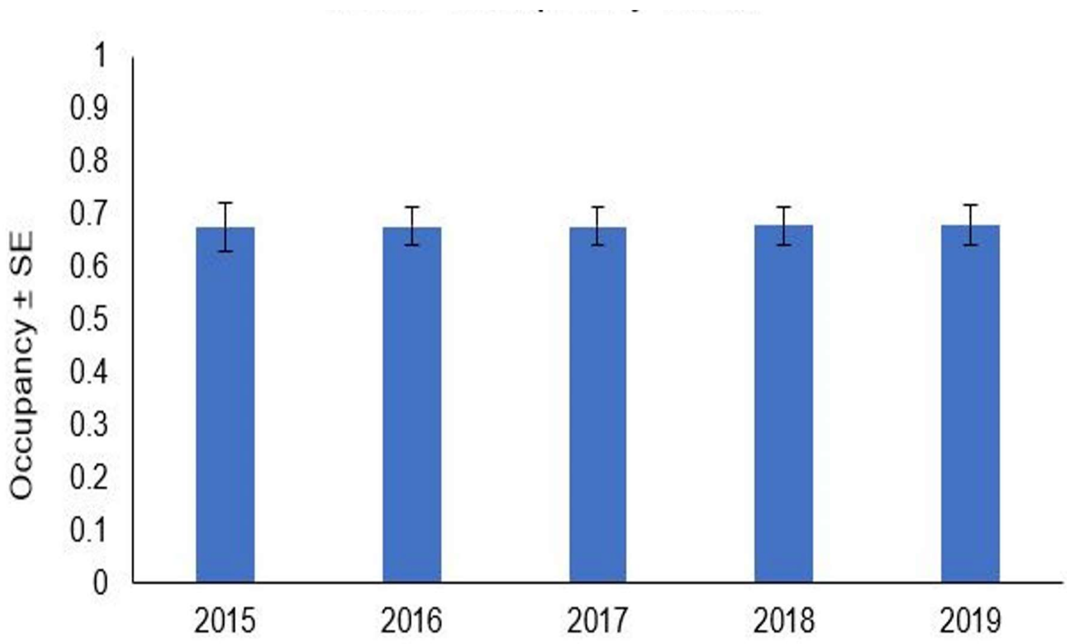


Figure 6. Koala occupancy trend in north-east NSW from 2015 to 2019

Note: estimates for each year assume median values for elevation (756 m ASL) and habitat suitability (0.56)

The sites surveyed after wildfires in 2019, were chosen to be representative of the fire extent on koala habitat. Given about 30 percent of modelled koala habitat burnt on the north coast, koalas were surveyed at 16 burnt sites (33 percent of all sites surveyed in 2019), with varying degrees of fire severity and extent. These were sampled across 11 state forests, four national parks and one private land location (**Figure 7**). Koalas were detected at 13 of the 16 burnt sites (81 percent). This was equivalent to the detection rate at unburnt, but drought afflicted sites in 2019. Analysis of the data from 2020 will provide further important information on the continuing trends at sites impacted by fire.

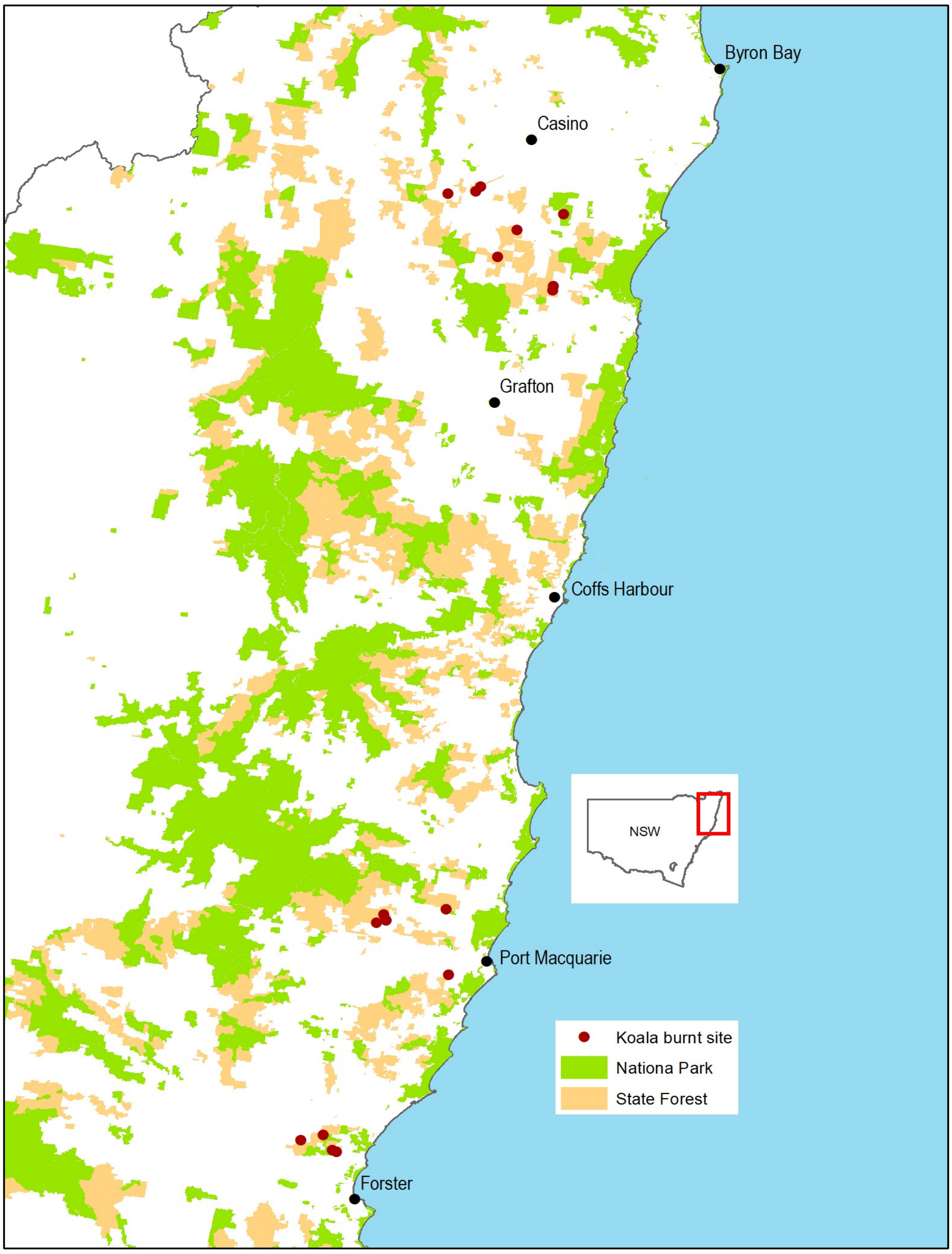
The three burnt sites with no koala detections[20] all experienced high-severity fire over more than 50 percent of their surroundings. At the other burnt sites where koalas were detected, high-severity fire affected less than 50 percent of the surrounding landscape, which meant that more refuge areas were available and/or fire severity was lower.

In 2020, the Department of Planning and Environment (DPE) carried out post-fire koala surveys at 441 sites sampled across 15 study areas in national parks.[21] They used koala detection dogs to detect koala scats and found post-fire koala detection rates in the study areas ranged from 3 percent to 69 percent of sites. On average 38 percent of all sites surveyed recorded post-fire scats. A direct comparison to results from the acoustic surveys above is not appropriate given the different methods of detection used, and acoustic surveys sample much larger areas than scat searches and are, therefore, more likely to detect koalas.[22] However, it is important to note that both surveys show koalas are less likely to be found at sites with higher fire severity.

20 .... Two in Kiwarrak State Forest and one in Bellangry State Forest.

21 .... NSW Department of Planning and Environment (2022). *Post-fire koala surveys in north-east NSW 2020. A Saving Our Species* project. Environment and Heritage. Available at: https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Animals-and-plants/Threatened-species/post-fire-koala-surveys-north-east-nsw-2020-220184.pdf

22 .... Scat surveys are site-based with detection dog surveys covering about one hectare per site, whereas acoustic recorders sample koalas over a much larger area (about 30 hectares each) and so may be more likely to encompass fire refuges – from Law, B. S, *et al.* (2022). Fire severity and its local extent are key to assessing impacts of Australian mega-fires on koala (*Phascolarctos cinereus*) density. *Global Ecology and Biogeography*, 31(4): 714-726. https://doi.org/10.1111/geb.13458



Document Path: U:\MXDS\FORESTS\Koala research\Draft maps\Draft Map 004 - Koala sites - June 2022.mxd

Figure 7. Location of burnt sites sampled for koala occupancy post-fire

While wildfire may not lead to local or regional extinction, it may affect koalas in other ways, such as through physiological stress.[23] The capacity of koala populations to recover from wildfire depends on many factors, including the size of the original population in a fire-affected area, and future inter-fire intervals and associated intensities.[24]

[23] Narayan, E. (2019). Physiological stress levels in wild koala sub-populations facing anthropogenic induced environmental trauma and disease. *Scientific Reports* 9, 6031. https://doi.org/10.1038/s41598-019-42448-8

[24] Phillips, S., Wallis, K. and Lane, A. (2021). Quantifying the impacts of bushfire on populations of wild koalas (*Phascolarctos cinereus*): Insights from the 2019/20 fire season. *Ecological Management & Restoration* 22(1): 80-88. https://doi.org/10.1111/emr.12458

2.2 Changes to koala habitat nutritional quality following wildfire

This research addresses key information gaps about whether the nutritional composition of post-fire regrowth in eucalypt species is beneficial or detrimental to koalas.

2.2.1 Nutritional quality is determined by both species and leaf type

As eucalypt leaf chemistry is the main factor driving koala food choice, this research examined nutritional variables known to be important to koalas, including:

- **protein** – total and digestible nitrogen (N)
- **plant secondary metabolites** – formylated phloroglucinol compounds (FPCs) and unsubstituted B-ring flavanones (UBFs).

Forests with higher levels of digestible nitrogen in the leaves can support more koalas, while those with leaves with higher levels of plant secondary metabolites are known to deter koala browsing and support lower koala population densities.[25,26] In general, of the two major eucalypt subgenera:

- **symphyomyrtles** - those with the FPC toxin, such as the small-fruited grey gum (*E. propinqua*), forest red gum (*E. tereticornis*) and Sydney blue gum (*E. saligna)*) are listed as preferred koala browse species on the NSW north coast[27]
- **monocalypts** - those with the UBF toxin, such as blackbutt (*E. pilularis*), white stringybark (*E. globoidea*), broad-leaved white mahogany (*E. umbra*)) tend to be avoided on the NSW north coast where preferred browsing species are available.[28]

Tallowwood from the subgenus *Alveolata* is also a preferred koala browse species.[29] Recent research found this species to have medium levels of FPC toxin.[30] While koalas generally avoid toxins, they will consume them where there is high nitrogen. Other research investigating plant DNA in koala scats,[31] has shown some tree species were eaten to a greater extent than expected from their tree use classifications, while others are being avoided more than expected.

In addition to nutritional differences driven by species type, individual eucalypt trees will also contain a mix of different leaf types according to age and response to disturbances, including:

- **epicormic growth** – growth from a dormant bud triggered by light and air after damage or stress (including after a fire)
- **young leaves** – leaves in the adult phase that are not yet fully expanded
- **mature leaves** – fully expanded adult leaves.

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25 .... Au J. (2018) *Multi-scale effects of nutrition on an arboreal folivore*. PhD thesis, The Australian National University

26 .... Au J., Clark R. G., Allen C., Marsh K.J., Foley W.J., Youngentob K.N. (2019) A nutritional mechanism underpinning folivore occurrence in disturbed forests. *Forest Ecology and Management* 453:1-8. doi: 10.1016/j.foreco.2019.117585

27 .... Listed as primary or secondary koala browse species under the Coastal IFOA or ranked 1 or 2 (high preferred use or high use species) in the NSW Koala Habitat Information Base

28 .... Not listed as koala browse species under the Coastal IFOA or ranked 1 or 2 (high preferred use or high use species) in the NSW Koala Habitat Information Base

29 .... Listed as a primary koala browse species under the Coastal IFOA and rank 1 high preferred use in the NSW Koala Habitat Information Base

30 .... Marsh, K.J., Youngentob, K.N., and Clark, R.G. (2021) *Determining the effects of forest harvesting on habitat nutritional quality for koalas*. Report for the Natural Resources Commission by Australian National University.

31 .... Moore, B., Blyton, M., Law, B., Marsh, K., Gonsalves, L., Brassil, T., Slade, C., and Whale, J. (2022). *Assessing koala diet composition on the North Coast of New South Wales using molecular analysis of faecal pellets*. Report for the Natural Resources Commission by Western Sydney University.

Despite being part of the same tree, the various leaf types differ in nutritional composition. The proportion of different leaf types varies based on the season and other factors such as drought and/or damage to the tree. Importantly, fire can change the proportions of different leaf types on a given tree. Specifically, damage or loss of foliage in the crown of the tree due to fire leads to a reduction in the amount of adult leaves coupled with an increase in epicormic growth.

2.2.2 Epicormic leaves in koala browse species have higher nutritional value

This research found that the most significant changes in nutritional quality for koalas following fire are due to differing levels of digestible nitrogen, and thus protein availability, in epicormic growth compared with mature leaves (**Figure 8**). When compared with pre-fire mature leaves of the same trees, the post-fire epicormic growth of:

- **symphyomyrtle** (subgenus *Alveolata* was included with these in the analysis) species had higher digestible nitrogen concentrations
- **monocalypt** species had lower digestible nitrogen concentrations.

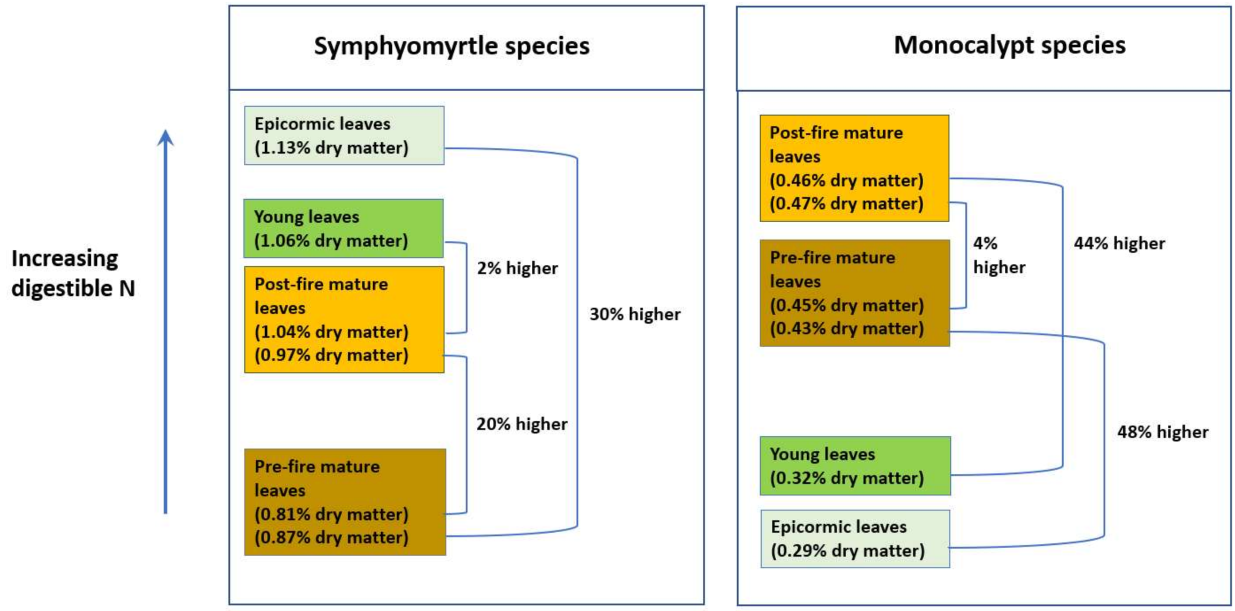

Figure 8: Percent difference in mean digestible nitrogen (% dry matter) between different leaf types. *Note that: –*

- *The analysis of symphyomyrtle species also included tallowwood from the subgenus Alveolata*
- *Digestible nitrogen in epicormic leaves is higher in symphyomyrtle species and lower in monocalypt species compared with pre-fire mature leaves of the same trees*
- *Different subsets of trees were used in different comparisons for pre- and post-fire mature leaves, so the mean values for percent dry matter differ depending on the comparison*

Some of the differences in digestible nitrogen in leaves sampled before and after the fires may be due to a break in drought conditions that occurred soon after the fires finished. In this case, the observed increase in digestible nitrogen in mature symphomyrtle and tallowwood leaves was similar at both burnt and unburnt (control) sites sampled post-fire, indicating that this change was not fire related. In contrast, the level of digestible nitrogen in the epicormic growth at post-fire sites far exceeds the level found in the mature leaves, suggesting leaf type is a factor determining leaf nutritional quality.

The research also examined leaf water content, finding that the water content was around 10-11 percent higher in post-fire epicormic growth than in mature leaves collected pre-fire from the same trees for all species. This could be partly due to drought recovery or other environmental conditions, but the difference is larger than for mature leaves before and after fire and, therefore, indicates differences between these leaf types.

2.2.3 Post-fire epicormic growth may change the habitat nutritional quality

As established in **Section 2.2.1**, the nutritional quality of sites is influenced by the type of leaves available and the combination of species. This study found that where the canopy remained intact (12 to 18 months after low severity fire) and young and mature leaves are available, leaf nutritional quality for koalas was not affected by fire. However, as described in **Section 2.2.2**, where leaf type shifts towards epicormic growth following a fire, the nutritional quality of the available koala habitat is expected to change depending on the eucalypt species composition of a site.

Figure 9 shows mean site digestible nitrogen from pre-fire mature leaves and post-fire epicormic leaves at sites from three forest types with a range of different koala browse species compositions.[32] Forest 3 was found to have a higher mean digestible nitrogen concentration in sampled post-fire epicormic growth compared to pre-fire mature leaves. It also had a higher proportion of preferred koala browse species, of which 75 percent were tallowwood and symphyomyrtle species.

In contrast, forests 1 and 2 were found to have lower mean digestible nitrogen concentrations in post-fire epicormic leaves. These forests had a much lower proportion of preferred koala browse species (all of which were tallowwood and symphyomyrtle species).

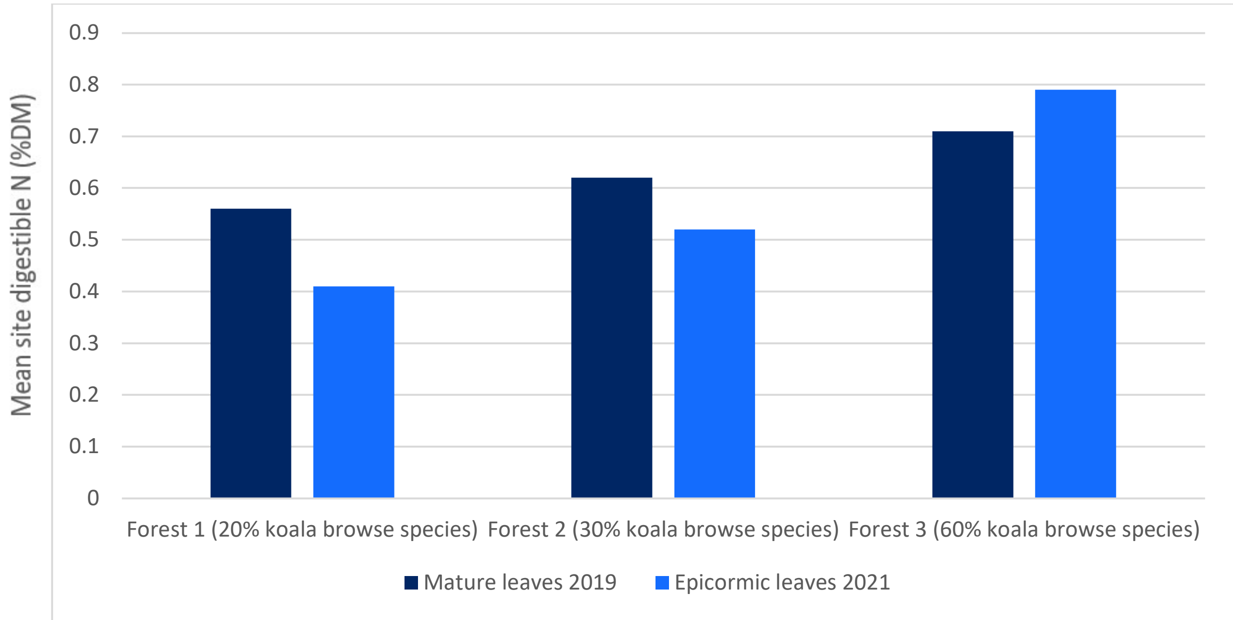

Figure 9: Effect of leaf type and species composition on mean digestible nitrogen at sites pre-fire (2019) and post-fire (2021)

Notes:

Mature leaves 2019 = sites containing mature leaves surveyed in 2019 (pre-fire)
Epicormic leaves 2021 = sites with only epicormic regrowth available sampled in 2021 (post-fire).
The Coastal IFOA koala browse species list was used to identify koala browse species.

32 ....The sites comprise common forest types found in the region. These sites were also sampled as part of the Commission's Koala Research Program.

It is likely that after a fire koalas will adjust their diet when trees are producing epicormic regrowth to make use of the highest nutritional quality browse and avoid species that become less palatable. This means that forests with a high abundance of preferred koala browse species (mostly symphomyrtle species and tallowwood) are likely to be important areas providing higher nutritional quality koala habitat following wildfires. In contrast, for sites with a high abundance of non-preferred species (often monocalypts), the already lower nutritional quality of the area is likely to decrease further after a fire due to loss of mature leaves combined with lower protein availability in the epicormic regrowth.

It is important to note that north coast forests contain a complex mosaic of different species. While results may be true of individual tree stands, landscapes will have a mix of forest types and species. For example, tallowwood typically occurs on mid-slopes, and gullies generally have a greater abundance of blue gum and flooded gum as a result of their underlying geology, rainfall patterns and topographic position compared to ridges.

Further, within the koala browse species, koalas may show a stronger preference for specific species after fire due to the nutritional quality of their epicormic leaves compared with their mature leaves. For example, forest harvesting prescriptions consider Sydney blue gum, *E. saligna,* and small-fruited grey gum, *E. propinqua,* to be secondary browse species, but this research found that these species had some of the highest nutritional quality browse after fire.

3 Improving the evidence base

3.1 Reviewing koala browse species

Aside from direct mortality, fires reduce the availability of foraging habitat for koalas. However, this is likely to be a temporary resource gap as epicormic growth in key koala browse species (specifically symphyomyrtle species and tallowwood) was found to offer higher nutritional quality leaves.

However, in some cases, the high nutritional quality of a species' epicormic growth may not be reflected in its current browse species classification (see **Section 2.2.3**). In order to ensure these post-fire browsing resources are being adequately protected in landscapes with predicted increased fire, Government could review the classification of koala browse species to reflect the new findings about post-fire nutritional value, taking into consideration how long epicormics persist for in relation to a typical and predicted wildfire cycles. This aligns with similar recommendations in the Commission's recent Koala Research Program report to review the koala browse tree list under the Coastal IFOA.[33]

In the longer term, the species composition of regeneration in areas following fires and other disturbances should be monitored and managed across the landscape to ensure adequate koala browse species are available, particularly types with high nutritional quality. It is also important to monitor the recovery trajectory of koalas post-fire, including both local density and regional occupancy.

Box 1 lists a number of other research considerations for habitat nutritional quality identified by researchers and the expert panel.

Box 1 - research considerations for habitat nutritional quality
▪ Understanding seasonal and climatic impacts on koala habitat nutritional quality (for example, drought) to assist with future habitat suitability models under various climate change scenarios
▪ Investigating whether species-based nutritional quality trends apply across a wider range of eucalypt species, and in other regions such as on the south coast of NSW
▪ Understanding differences in koala food availability in terms of volume of leaves available pre- and post-fire (not just nutritional composition)
▪ Understanding at what point epicormic leaves are accessible to koalas post-fire
▪ Assessing for other potential toxins that may impact the nutritional quality of epicormic leaves in koala browse species, for example cyanogenic glycosides
▪ Understanding at what stage epicormic growth transitions into adult leaf phases
▪ Updating statistical models that predict how changes in eucalypt species composition affect koala densities to include the effect of UBFs and thereby determine how changes in the proportions of monocalypt species, including blackbutt, affect the koala density index.
▪ Understanding the susceptibility of different browse tree species (and subgenera) to fire-induced mortality

33 Natural Resources Commission (2021). *Research program - Koala response to harvesting in NSW north coast state forests - Final report*. Delivered under the NSW Koala Strategy 2018-21 overseen by the NSW Department for Planning, Industry and Environment, Sydney, NSW.

3.2 Updating koala fire refugia mapping

This research showed recolonisation of burnt forests had begun within 12 months, consistent with other koala and fire studies,[34] and probably due to rain helping with recovery following the fires (see **Section 2.1.1**), although potential for recolonisation is limited where habitat is fragmented. Future fires may have an impact on habitat connectivity.

Existing koala habitat suitability mapping for north-east NSW[35] used in the Coastal IFOA includes frequency of previous wildfire events as a modelling covariate (amongst other covariates). Modelled higher suitability habitat will in part include fire refuges from past fires for koalas which are likely to be less fire prone due to their position in the landscape. The modelling demonstrates that koala habitat suitability is lower where there have been more frequent fire events. To better guide management in this area, mapping could be updated to include the 2019-20 fires, koala occupancy data and other relevant datasets.

3.3 Managing future risks from increased fire frequency

Following the 2019-20 wildfires, the conservation status of koalas was upgraded from vulnerable to endangered in NSW, Queensland and the ACT under the Commonwealth Environment *Protection and Biodiversity Conservation Act* 1999.[36] The fires burned across nine of the fifteen IBRA regions with known koala populations in NSW, with the south east corner (52 percent burnt), the Sydney Basin (30 percent burnt) and NSW north coast (30 percent burnt) being the most heavily impacted.[37]

Climate change is predicted to increase fire activity[38] and is expected to lead to a cumulatively greater extent of forest area being burnt annually in the future.[39] This is consequently predicted to increase fire impacts on koalas, including by reducing refuge areas and, in the short term, connectivity, which will afford koalas fewer opportunities to recolonise between fire events. In addition, post-fire forests can be more susceptible to future fires where fine fuel species such as lantana and acacia form dense thickets.[40] Forest recovery may be also at further risk from 'fire disclimax'[41] caused by repeated and more frequent fires.

This research shows that local koala populations declined more significantly in areas dominated by higher fire severity. As such, any management practices that could reduce fire severity (for

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34 .... Matthews, A., Lunney, D., Gresser, S., & Maitz, W. (2016). Movement patterns of koalas in remnant forest after fire. *Australian Mammalogy*, 38(1), 91–104. https://doi.org/10.1071/AM14010g

35 .... Law B, Caccamo G, Roe P, Truskinger A, Brassil T, Gonsalves L, McConville A, Stanton M (2017) Development and field validation of a regional, management-scale habitat model: A koala *Phascolarctos cinereus* case study. *Ecology and Evolution* 7:7475–7489. https://doi.org/10.1002/ece3.3300

36 .... Department of Climate Change, Energy, the Environment and Water (2022). *Phascolarctos cinereus (combined populations of Qld, NSW and the ACT) — Koala (combined populations of Queensland, New South Wales and the Australian Capital Territory).* Species Profile and Threats Database. Available at: https://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=85104

37 .... Department of Water Agriculture and the Environment (2022). *Conservation Advice for Phascolarctos cinereus (Koala) combined populations of Queensland, New South Wales and the Australian Capital Territory.* Available at: https://www.environment.gov.au/biodiversity/threatened/species/pubs/85104-conservation-advice-12022022.pdf

38 .... Canadell, J.G., Meyer, C.P., Cook, G.D. et al. (2021). Multi-decadal increase of forest burned area in Australia is linked to climate change. *Nature Communications* 12, 6921. https://doi.org/10.1038/s41467-021-27225-4

39 .... Bradstock. R, Bedward, M., & Price, O. (2021), *Risks to the NSW Coastal Integrated Forestry Operations Approvals Posed by the 2019/2020 Fire Season and Beyond*, Centre for Environmental Risk Management of Bushfires, University of Wollongong and the NSW Bushfire Risk Management Research Hub, commissioned by the NSW Forest Monitoring Steering Committee, Sydney, NSW

40 .... Gordon, C. E., Price, O. F., Tasker, E. M., Denham, A. J. (2017). Acacia shrubs respond positively to high severity wildfire: Implications for conservation and fuel hazard management. *Sci Total Environ*, 575:858-868. doi: 10.1016/j.scitotenv.2016.09.129

41 .... A vegetation community that is perpetually maintained at an early stage of succession through recurrent destruction by fire followed by regeneration.

example, cool, patchy burns) should be explored as soon as possible. That said, recent research indicates that the extent and severity of the 2019/20 fires was largely related to adverse fire weather driven by drought and wind conditions over the entire fire season, rather than past forest management of fire disturbance.[42] In addition, low severity wildfire still carries risk of injury or death for koalas.[43] Therefore, if fire management approaches were pursued, further research on the impact of low severity fire at additional sites would be needed to ensure this intervention approach delivers the expected outcomes for koalas.

Continuing to monitor the recovery of koalas at the research sites is also important for informing management approaches. As noted above, the recovering vegetation may be at risk of being trapped in a fire disclimax, or switch to a different structure if subject to repeated wildfire or severe drought during recovery.

The Commission notes there are currently other research projects underway that explore low-intensity fire impacts and management that may provide relevant insights or could be expanded to include analysis of koala impacts and responses.

3.4 Understanding post-fire nutritional quality for other species

This research highlights that the preferred browse species of koalas tend to deliver improved nutritional quality for koalas during the post-fire regeneration phase. However, the situation is likely to be more complex for species such as the greater glider (*Petauroides volans*) that frequently consume monocalypt as well as symphyomyrtle species.[44]

Further research is needed to identify species that may be at greater risk post-fire, and to update their relevant plans of management, species-specific protections, and/or fire management plans in key habitat areas.

[42] Bowman, D.M.J.S., Williamson, G.J., Gibson, R.K., Bradstock, R. A., Keenan, R. J. (2021). The severity and extent of the Australia 2019–20 Eucalyptus forest fires are not the legacy of forest management. *Nature Ecology and Evolution.* 5: 1003–1010. https://doi.org/10.1038/s41559-021-01464-6

[43] Lunney, D., Gresser, S. M., Mahon, P. S., & Matthews, A. (2004). Post- fire survival and reproduction of rehabilitated and unburnt koalas. *Biological Conservation*. 120 (4): 567-575. https://doi.org/10.1016/j.biocon.2004.03.029

[44] Youngentob, K. N., Wallis, I. R, Lindenmayer, D. B., Wood, J. T., Pope, M. L., Foley, W. J. (2011). Foliage Chemistry Influences Tree Choice and Landscape Use of a Gliding Marsupial Folivore. *Journal of Chemical Ecology* 37(1):71-84. DOI 10.1007/s10886-010-9889-9