Threatening Processes and the Future of Mature Red Tingle Trees (Eucalyptus jacksonii)

Final Report to the Australian Flora Foundation

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Executive Summary

This report summarises findings from an Australia Flora Foundation funded series of three linked studies. These studies were conducted as a PhD thesis which investigated the impacts of threatening environmental processes on the persistence of large (> 100 cm DBH) red tingle trees (*Eucalyptus jacksonii*). The species is a narrow range endemic confined to a high rainfall zone in southwest Australia. This work examined (1) the relationship between fire history and basal hollow development, (2) the impact of a single prescribed burn on basal hollow formation; and (3) canopy physiology under seasonal and heatwave conditions. Together, these studies indicate that both increased fire frequency and a warming, drying climate pose risks to red tingle populations due to decreased structural integrity and reduced physiological performance of mature trees.

Background

Giant trees play important social, cultural, and ecological roles worldwide, but giant tree and tall forest ecosystems are increasingly at risk from the direct and indirect consequences of climate change. Globally, warming and drying climates threat to impact plant function and are altering local fire regimes. Red tingle (*Eucalyptus jacksonii*), the focal species of this work, is a species of giant tree restricted to approximately 5,600 ha of wet eucalypt forest along a coastal high rainfall zone of southwestern Australia (Figure 1). Since the 1970s, southwest Australia has experienced considerable climate warming and drying, resulting in the area being termed a ‘canary in the coalmine’ for climate change impacts (Hawke et al 2025). Thus investigating red tingle responses to environmental pressures associated with a changing climate provides a valuable case study for other giant trees facing similar climate projections. In doing so, this project makes a new and significant contribution to scientific understanding of red tingle forest ecology and management, and to the broader knowledge base on giant tree ecology globally.

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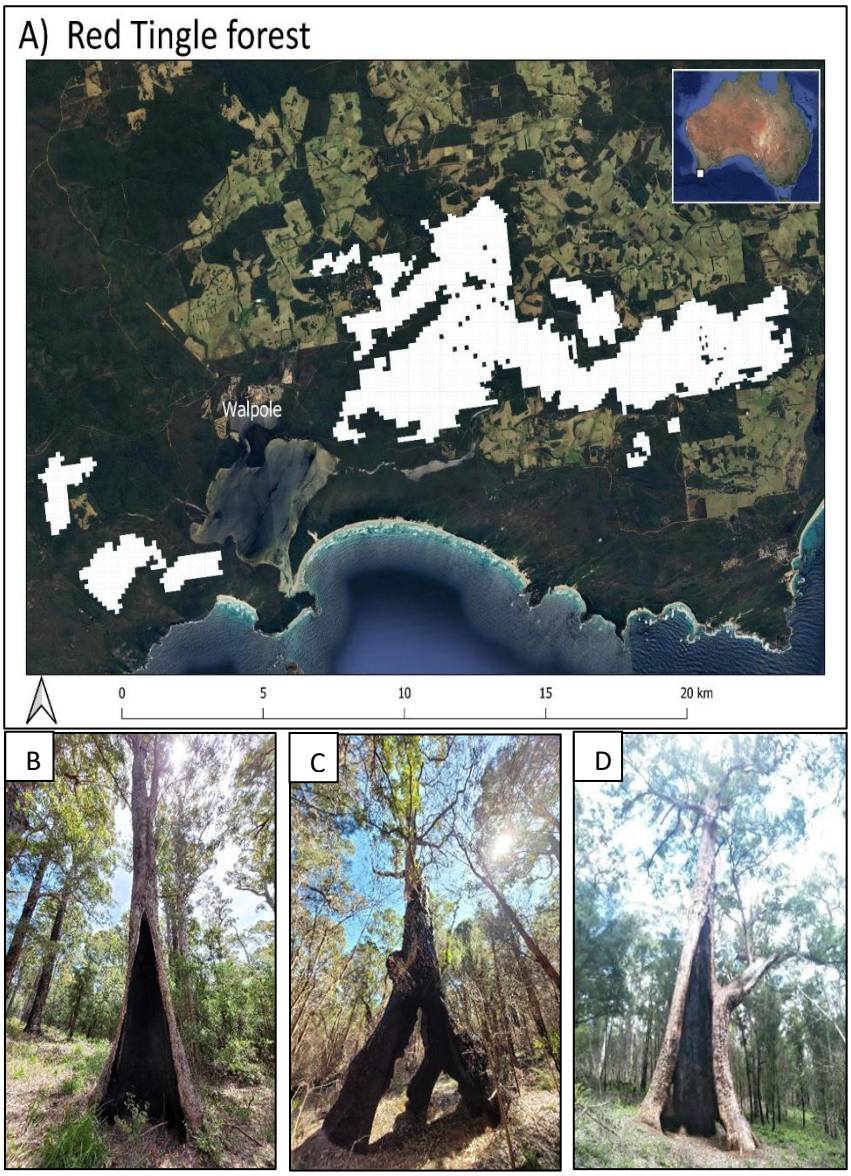

Figure 1. A) Distribution map of red tingle (Eucalyptus jacksonii); photos of red tingle with B) understorey removed by 'scrub rolling' prior to prescribed burning; C) an extensive hollow at the base of a recently burnt tree; and D) tall hollow with some understorey regrowth two years following a burn. All photos by authors.

Project Objectives

Funding from the Australian Flora Foundation supported three distinct elements of this PhD with the aims to investigate:

1. the influence of fire frequency and tree size on hollow formation in large red tingle trees
2. the impacts of a single prescribed burn on basal hollow formation and subsequent tree collapse on mature red tingle trees
3. plant-water status and physiological performance for large red tingle across seasons, including a summer heatwave

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1. Basal Hollows and Fire History[1]

Red tingle are well known for their large diameter, and their propensity to develop hollows at their base (Anderson et al. in review; see also Figure 2). These hollows create a structural vulnerability as hollows occupying more than 70% of the stem increase the likelihood of tree collapse (Mattheck et al 1994). Here we investigated the role of historic fire frequency on the development of basal hollows. To do so we stratified our sampling by fire history (1953–2021) by creating 1-ha areas of red tingle forest grouped by number of times burnt: long unburnt (0 fires), low (1–3 fires), moderate (4–6 fires), and high (7+ fires). Within each area, large tree (>100 cm diameter at breast height, DBH) density, tree diameter, and basal hollow presence and extent were quantified across and between stands (n = 622 large trees).



Figure 2. Anderson measuring the diameter at breast height of a red tingle tree (Eucalyptus jacksonii)

We developed a conceptual progression of basal hollow development to create a basal damage classification system was developed from first principles of tree wound response and decay, incorporating expected interactions with fire (See Figure 3). Trees were visually assigned a category from 0 to 5, representing the conceptual progression from an initial wound to a structurally compromising hollow: (0) no damage; (1) dry siding with no decay; (2) dry siding with decay or charring; (3) small to moderate hollow; (4) moderate to large hollow (where hollow height exceeds tree diameter, or depth exceeds 50% of the tree); and (5) extensive hollowing, with the tree effectively standing on 'legs' or riddled with holes resembling 'Swiss cheese'.

[1] This work is published and freely available for public download here: https://doi.org/10.1016/j.foreco.2025.123095

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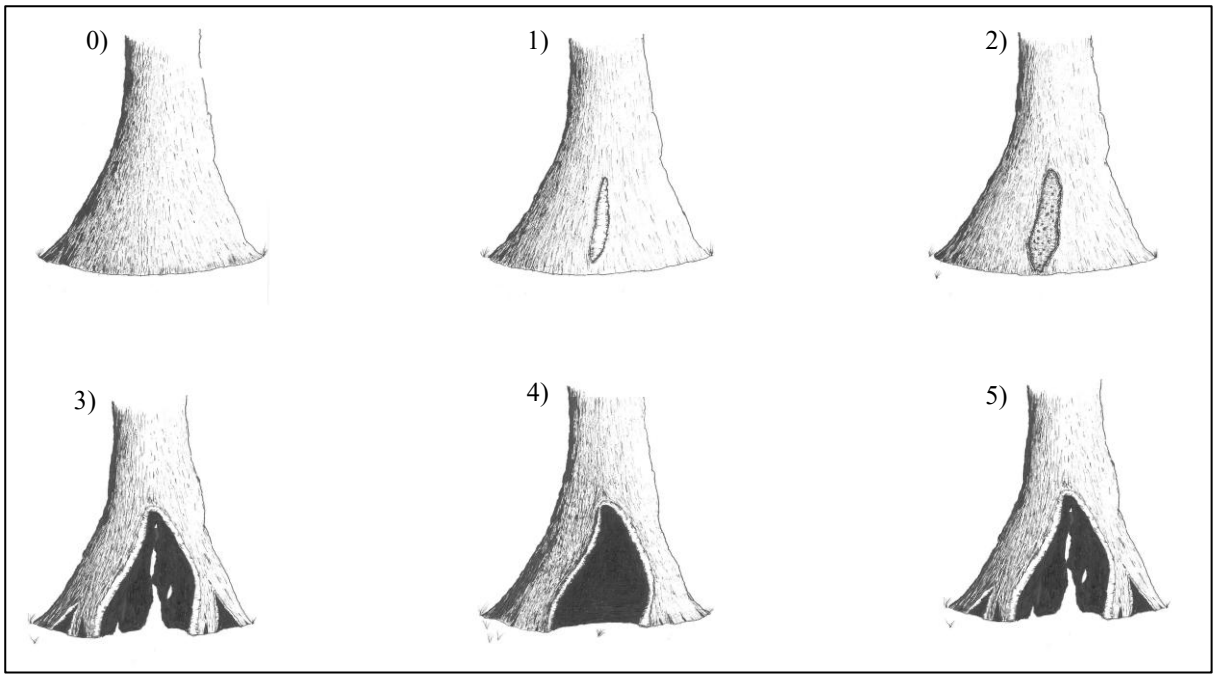

Figure 3. Conceptual progression of hollow formation in Eucalyptus jacksonii as used for visual assessment during field sampling. Categories are: 0) No visible dry siding or hollowing at the base; 1) Uncharred dry siding present, no visible hollowing present: 2) Dry siding with decay, either fungal or charring: 3) Small to moderate hollow(s) present: 4) Large individual hollow or multiple small/moderate sized hollows merging: 5) Extensive hollowing visible, tree appears to be 'standing on legs.' The conceptual progression was established by Anderson et al. (2025) to assess basal damage in red tingle trees.

Results

Across all stands the mean density of large trees (>100 cm DBH) was 15.7 ha^{-1}, with the lowest density recorded in high fire frequency stands (14.0 ± 0.8 trees; Anderson et al. 2025). Across our sampling the mean DBH of trees with basal hollows (209 ± 9 cm) was substantially higher than the mean DBH of intact trees (167 ± 5 cm). This trend was evident in all fire histories but more dramatic in the low and moderate histories (see Figure 4A). Among the smallest size class of large trees (100 cm DBH), those in high fire frequency stands were more likely to have basal hollows (31% of trees) than those in long unburnt (20%), low (17%), or moderate (21%) fire frequency stands (Figure 4C and D).

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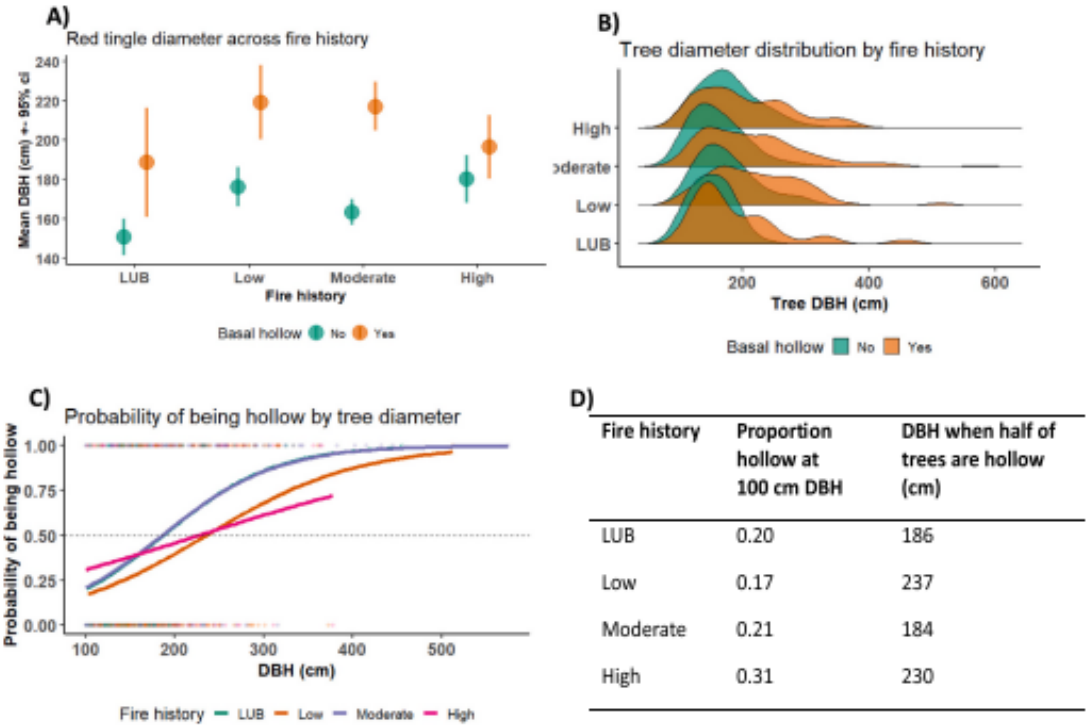

Fire history	Proportion hollow at 100 cm DBH	DBH when half of trees are hollow (cm)
LUB	0.20	186
Low	0.17	237
Moderate	0.21	184
High	0.31	230

Figure 4. A) mean tree DBH for hollow and not hollow trees in each fire history (cm ± 95 % CI) for large red tingle across all stands. Reported p values are Tukey test results for differences between trees with/without basal hollows at each fire history. B) Ridgeline plot showing the distribution of tree DBH by fire history. C) Mean tree diameter for all trees measured in each fire history. C) Logistic regression for hollow trees by tree DBH in each fire history; and D) table of key points from logistic regression.

Implications

This work demonstrates a positive association between fire frequency and the initial development of basal hollows in smaller diameter red tingle trees. Increased fire frequency may therefore be contributing to the decay of heartwood in large individuals leading to increased collapse rates which would explain the lower density of large trees in high fire frequency stands. Thus, more frequent fire may lead to a demographic squeeze in red tingle populations. Future climate and fire scenarios will require transparently weighing ecological impacts against fire risk to inform best-practice land management.

2. Basal Hollow Development During a Low-Intensity Fire Event

Building on the fire history findings, this study examined the development of new basal hollows and the expansion of existing basal hollows following a low intensity prescribed burn. Here we followed the same field protocols as above, but instead of stratifying sampling by fire history we conducted pre and post burn measurements on the same trees. We further investigated the influence of 'scrub rolling' on reducing impacts to trees. 'Scrub rolling' is a management technique that is unique to tingle forests and involves the

use of machinery to knock down vegetation prior to the prescribed burn and then leave it to dry out prior to ignition. Doing so allows the vegetation to burn more readily and creates a more complete fire edge preferred by managers. We measured trees in both the scrub rolled section (n=85) and on the interior of the forest where scrub rolling did not occur (n=194).

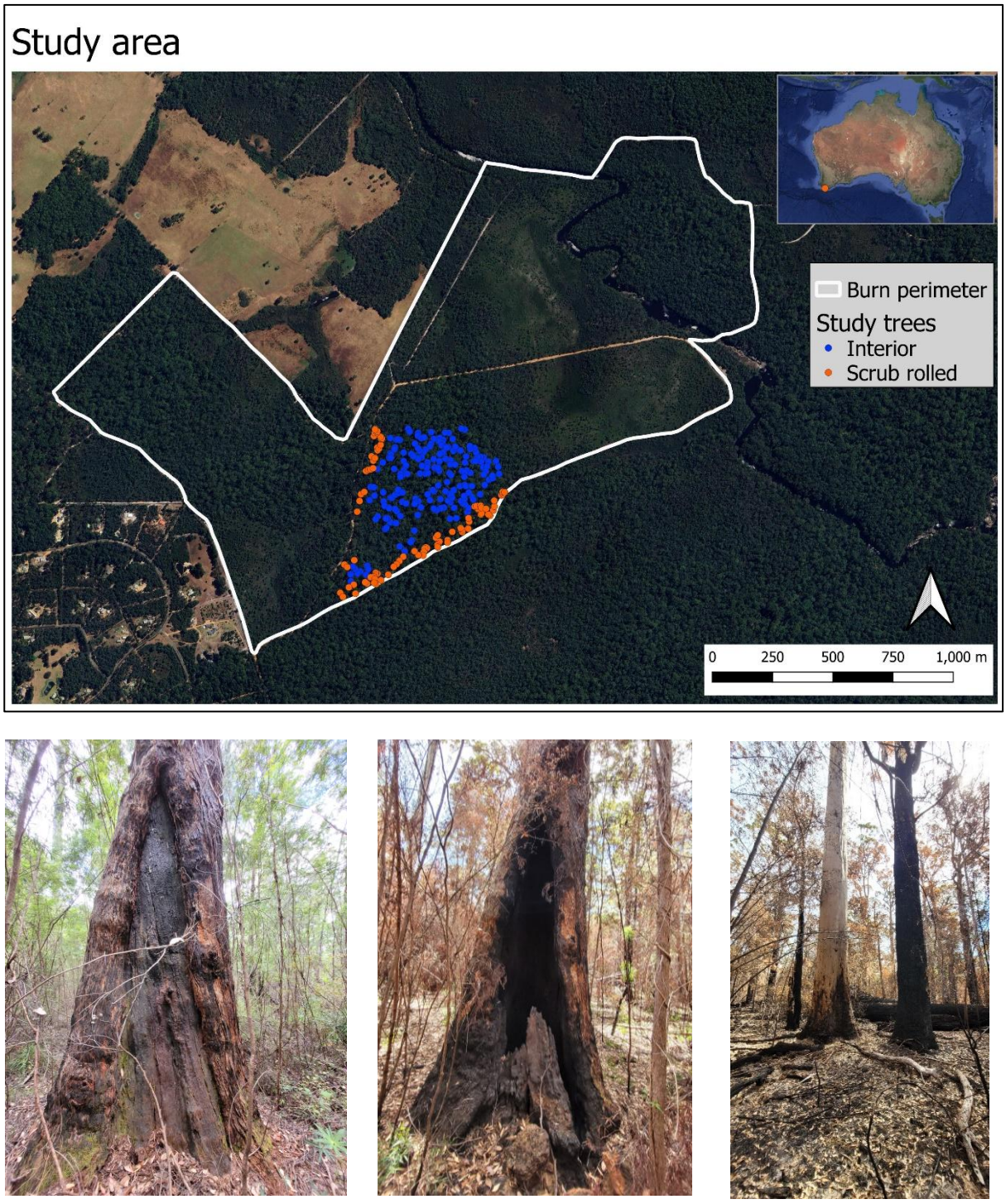

Figure 5 A) map of prescribed burn and study trees; B) pre-burn photo of tree; C) post-burn photo of the same tree; D) post-burn photos of char height in karri (Eucalyptus diversicolor, left smooth bark) and red tingle (right, thick fibrous bark).

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Results

Twenty percent of previously intact trees (no hollow) developed new basal hollows during the burn, and the overall proportion of trees with basal hollows increased from 49% pre-burn to 59% post-burn (Figure 6). Among trees with pre-existing hollows, mean hollow depth increased by 20.9 cm, with the increase in interior stands (25.7 cm) more than 1.5 times that in scrub-rolled stands (15.2 cm; Anderson et al. in prep). Of these same previously hollow trees, 12.5% had hollows expand by more than 50 cm, with a higher proportion in interior stands (14.3%) than scrub-rolled stands (9.4%). Scrub rolling did not affect tree collapse rates but was associated with reduced hollow development and expansion compared with untreated interior stands (see Figure 5B,C and 6B).

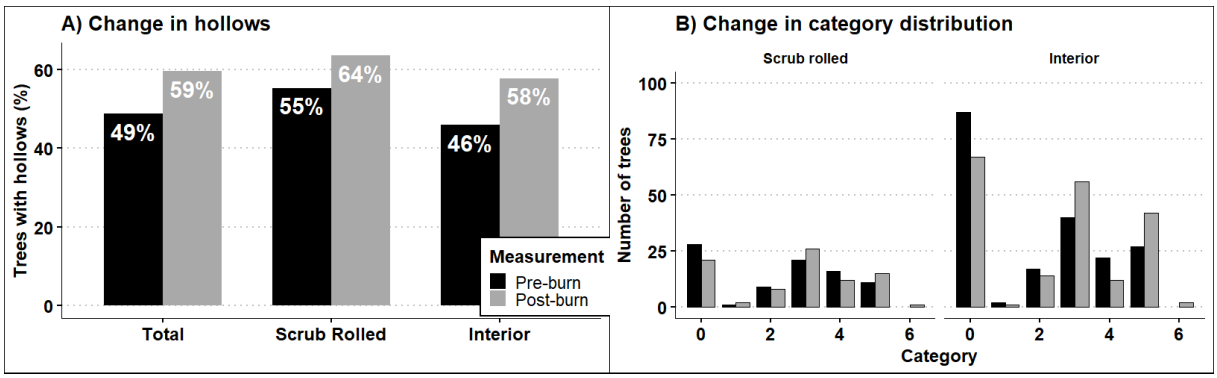

Figure 6. A) Change in the percentage of trees with hollows before (black) and after (grey) the prescribed burn; B) Distribution of tree category assessment before (black) and after (grey) the prescribed burn for interior and scrub rolled trees

Implications

This study highlights underappreciated impacts of individual prescribed burns on the structural integrity of red tingle. While scrub rolling appears to moderate some impacts of basal hollow development, these results should be cautiously interpreted as these same trees are along the edge of the fire boundary and can receive increased attention during the burn, e.g. retardant and water at the base of trees Thus the reduced rates of observed basal hollow expansion for the scrub rolled trees could be caused by multiple individual factors, or the combined impacts of being more accessible to fire fighters.

3. Canopy Physiology

Tree mortality and canopy contraction are a growing concern worldwide. Giant trees are expected to be particularly vulnerable to warming and drying climates due to the hydraulic demands of transporting water to their canopy. This study investigated plant-water status and physiological performance in mature red tingle, a species confined to the wettest part of a rapidly drying region (See Figure 7A). To do so we monitored seasonal changes in plant water status and physiological performance (chlorophyll fluorescence,

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stomatal conductance, apparent transpiration) of red tingle trees at the Department of Biodiversity, Conservation and Attractions Tree Top Walk (Figure 7D and E). The Tree Top Walk allowed us to access canopy leaves safely and efficiently while conducting physiological measurements. During our monitoring period there was also a local heatwave a week after our normal monitoring period, and we purposively sampled during the heatwave to assess changes in performance during this period of higher environmental stress.

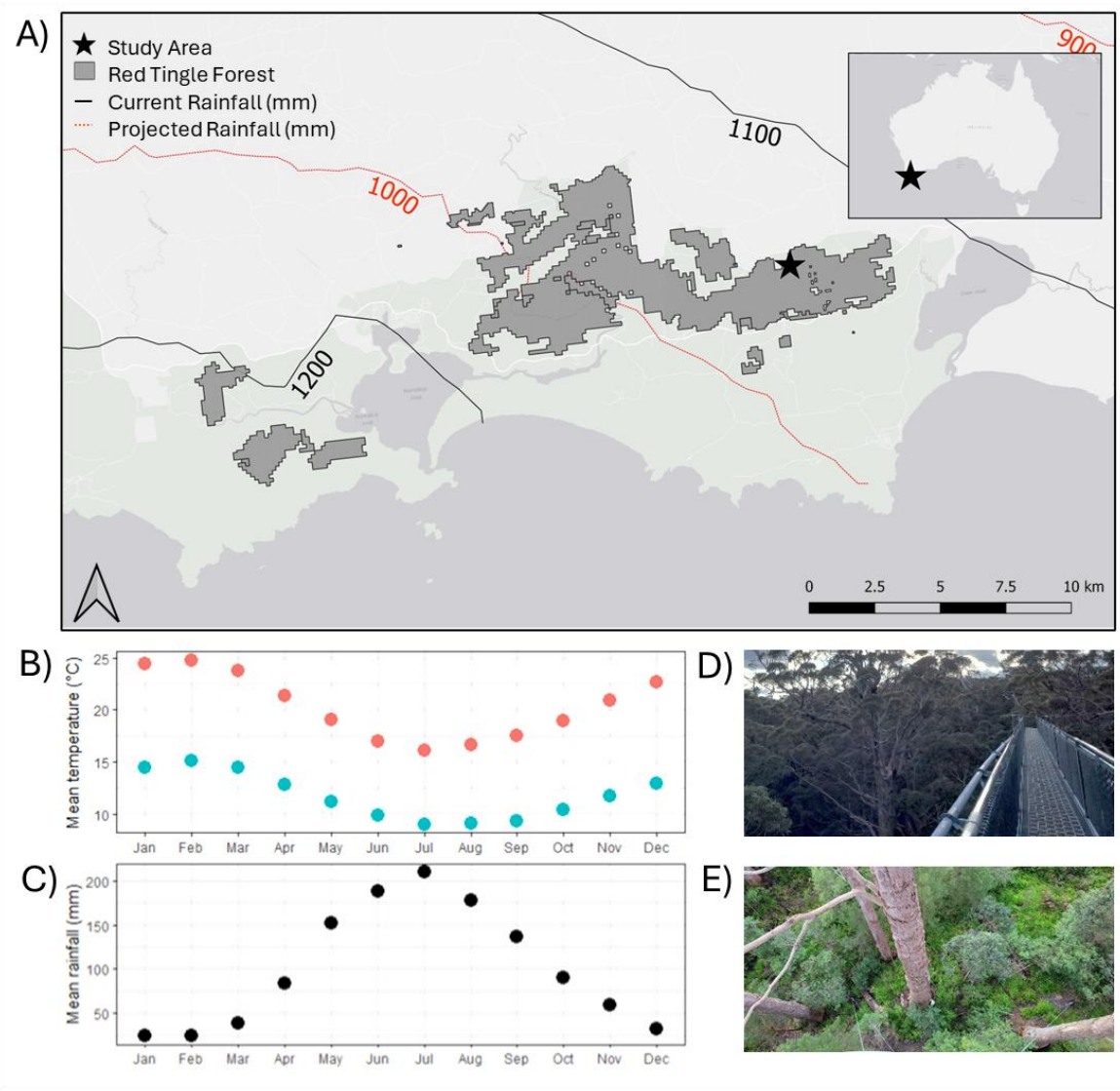

Figure 7. A) Map of the study area and red tingle distribution with current and 50-year projected rainfall using cmip and bioclim data (data sourced from Worldclim 2; Fick and Hijmans 2017); B) Walpole mean maximum (red) and mean minimum (blue) temperatures; C) Walpole mean monthly rainfall; D) Tree Top Walk access structure for the canopy; and E) view down from the Tree Top Walk. Walpole climate data is from North Walpole Bureau of Meteorology weather station (Station ID 9998; 2004-2022) (photos N Anderson)

Results

We found relatively high levels of pre-dawn leaf water potential throughout the study indicating red tingle had readily available moisture throughout the year (Anderson et al. in prep). However, during a heatwave,

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stomatal conductance declined significantly (Figure 8A). The heatwave also reduced photosynthetic efficiency, as measured by effective quantum yield, which took two years to recover to pre-heatwave conditions (Figure 8B).

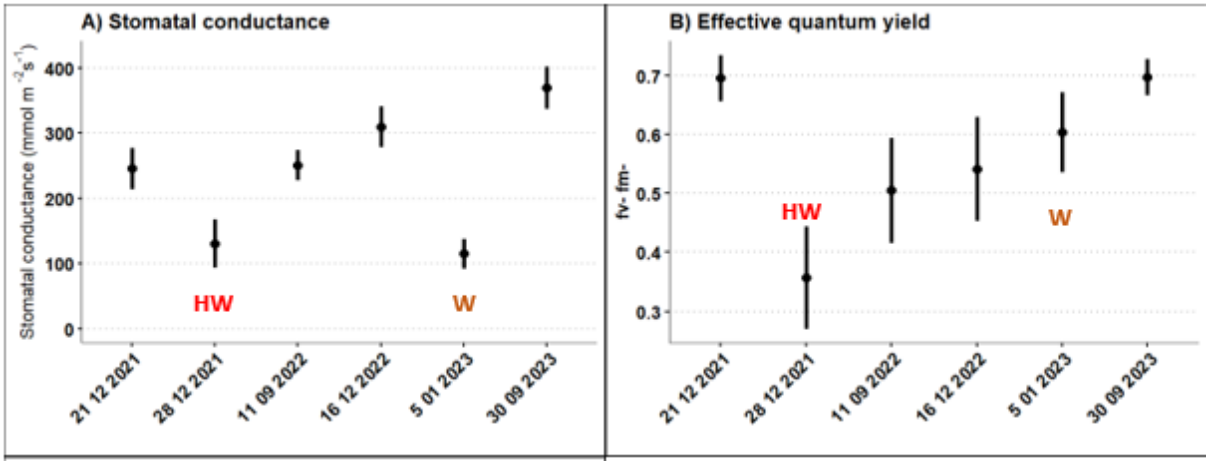

Figure 8. Plant performance in red tingle trees (Eucalyptus jacksonii) across seasons and during a heatwave for A) stomatal conductance, and B) Plant stress as measured by effective quantum yield (Fv/Fm). Heatwave is indicated with red HW, and the warm day with an orange W.

Implications

This study of red tingle trees found that seasonal changes in water availability had less effect on tree health than expected. In contrast, heatwaves proved to be a major stressor: a 2021 heatwave caused a sharp drop in plant stress indicators that took two years to recover, and taller parts of the canopy along the Tree Top Walk appeared more impacted, suggesting tall trees may become increasingly vulnerable if heatwaves become more frequent. At this same site, there is historical evidence of long-term canopy height reduction after a 1937 fire suggests these trees may struggle to fully recover from compounding disturbances (Wardell-Johnson et al. 2017). Together, the findings indicate that red tingle forests may face growing risks to their structure and function as climate change influences the frequency and severity of extreme heat events.

Project summary

Together, these studies highlight the environmental pressures and challenges that populations of red tingle will need to withstand in a warming and drying climate. The influence of fire on basal hollow formation and expansion will likely challenge land managers in the coming decades. Increased fire frequency is associated with greater basal hollow development and lower large-tree density, and even a single low-intensity prescribed burn can measurably advance hollow formation in previously intact and already-hollow trees. At

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the same time, heatwave-driven declines in stomatal conductance and photosynthetic efficiency point to a slow-recovering physiological vulnerability that could compound structural risks over time.

For land managers, these findings suggest that fire frequency and prescribed burning practices around mature red tingle stands warrant careful, transparent consideration alongside fire risk objectives, and that interventions such as scrub rolling may offer a partial but incomplete mitigation of fire impacts on tree structural integrity. More broadly, this project contributes a detailed case study relevant to the conservation of other giant tree species facing similar climate- and fire-related pressures internationally.

Outputs

Publications

Anderson, Nathaniel S., Nik Callow, Alison Lullfitz, and Joseph B. Fontaine. “Does high fire frequency compromise structural integrity of a large eucalypt?” Forest Ecology and Management 595 (2025): 123095.

Conference Presentations

Anderson, Nathaniel S., Alison Lullfitz, Nik Callow, Joseph Fontaine. “Burning giants: Basal hollow development during prescribed burning of a giant tree species.” Ecological Society of Australia. 9–13 December 2024, Melbourne, VIC.

Anderson, Nathaniel S., Ryan Tangney, Nik Callow, Alison Lullfitz, and Joseph Fontaine. “The influence of fire history on a giant eucalypt.” Ecological Society of Australia and Society for Conservation Biology. 28 November – 2 December 2022, Wollongong, NSW.

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We would like to acknowledge the Noongar people who remain the spiritual and cultural custodians of their land, and continue to practice their values, languages, beliefs, and knowledge. We pay our respects to the traditional owners of the lands on which we live and work across Western Australia and Australia.

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References

Anderson, Nathaniel S., Nik Callow, Alison Lullfitz, and Joseph B. Fontaine. “Does high fire frequency compromise structural integrity of a large eucalypt?” Forest Ecology and Management 595 (2025): 123095.

Anderson, N.S, Lullfitz, A., Fontaine, J.B., Webb, W., Knapp, L., Callow, J.N, Life on the edge: assessing the vulnerability of range-restricted forest giant red tingle (*Eucalyptus jacksonii*). *Conservation Science and Practice*, (in review)

Anderson, N.S, Callow, J.N, Lullfitz, A., Fontaine, J.B., Burning Giants: basal hollow development during a prescribed burn in red tingle forest, (in prep).

Anderson, N.S, Lewandrowski, W., Tudor, E.T., Callow, J.N, Lullfitz, A., Fontaine, J.B., Heatwaves negatively impact plant function for a giant eucalypt, (in prep).

Hawke, Kerryn A., Jatin Kala, and Ian J. Foster. "A Review of Drivers of Cool Season Rainfall in Southwest Western Australia." *Wiley Interdisciplinary Reviews: Climate Change* 16, no. 6 (2025): e70028.

Mattheck, C., K. Bethge, and P. W. West. "Breakage of hollow tree stems." *Trees* 9, no. 1 (1994): 47-50.

Wardell-Johnson, Grant, Liam Crellin, Casey Napier, Garrett Meigs, Alyssa Stevenson, and Su Ing Wong. "Has canopy height and biomass recovered 78 years after an intense fire in south-western Australia’s red tingle (Eucalyptus jacksonii) forests?." *International Journal of Wildland Fire* 26, no. 2 (2017): 148-155.

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