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FORUM

Reply to: Mechanisms by which growth and succession limit the impact of fire in a south-western Australian forested ecosystem—A comment on Zylstra et al.'s model

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Abstract

1. Empirical evidence in scientific literature shows that forest flammability in south-western Australia declines as forests recover from disturbance, indicating that current policies mandating disturbance may be counterproductive. Zylstra et al. (2023) used mechanistic modelling to explain this trend in Red Tingle (*Eucalyptus jacksonii*) forest in south-western Australia. McCaw. (2024) have questioned the validity of the modelling, advancing hypothetical arguments as to why one of the inputs ('suspended litter') is incorrect and re-asserting the need for the current policy.
2. The primary argument by McCaw. (2024) depends upon the redefinition of a component of surface litter into suspended litter. The published definition of near-surface fuel defines necromass as 'suspended' fuel only if it is suspended in living plants or collapsed shrubs. McCaw. (2024) removed this requirement, so that a component of surface fuel was incorrectly measured as 'suspended' fuel long after the plants that might suspend it had self-thinned from the landscape.
3. This physically impossible assertion was supported by an empirical study led by an architect of the policy and utilising the same redefinition of suspended litter, also reporting physically impossible findings as a result.
4. Given the well-documented decline in wildfire likelihood in long-unburnt forest, the claim by McCaw. (2024) that suspended litter does not decline suggests at best that such litter plays a lesser role than previously believed. The approaches used by McCaw. (2024) to defend Government policy should be understood in context of growing international concerns around scientific suppression used in defence of Government policy.

KEYWORDS
disturbance stimulated flammability, ecological control theory, fire ecology, fire management, fuels, prescribed burning

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1 | INTRODUCTION

Red Tingle (*Eucalyptus jacksonii*) trees dominate tall, wet forests in a geographically restricted, high rainfall area of south-western Australia (Wardell-Johnson & Coates, 1997). All indicators are that fire was highly infrequent in these forests prior to British invasion (Wardell-Johnson, 2000; Wardell-Johnson et al., 2018), with only very rare traces of charcoal in lake sediments (Hassell & Dodson, 2003), and almost no fire scars in the *E. diversicolor* trees that can co-occur with Red Tingle (Rayner, 1992). Long exclusion of fire from these forests does not lead to replacement of these dominant overstorey trees by other species (Wardell-Johnson, 2000). Traditional owners deliberately excluded fire from Red Tingle forests (Pers. Comms. Dr. Wayne Webb, Pibulmun-Wadandi-Yunungjarlu elder, 24 September 2021), burning small patches in surrounding vegetation for specific reasons (Rodrigues et al., 2022). Fire scars in the drier surrounding forests dominated by *E. marginata* averaged 81 years between scarring events prior to invasion, but frequency increased to every 17 years after invasion (Burrows et al., 1995).

McCaw. (2024) note that the trends in suspended litter used by Zylstra et al. (2023) were taken from previously published data that were collected in Karri (*E. diversicolor*) dominated forests, rather than in Red Tingle (*E. jacksonii*) dominated forests. Their central concern is that Zylstra et al. (2023) fit a quadratic function to those data, rejecting the negative exponential function used by the original authors. The effect of using a quadratic function was that suspended litter initially increased as in the negative exponential function, but then later decreased. McCaw. (2024) argue that this trend was contrary to the widely accepted usage of a negative exponential trend and that the declining trend in long-unburnt forests likely caused an artificial decline in the modelled flammability of the forest being studied. In support of this, they referenced a recent study in Karri Forest (Burrows et al., 2023), which reported that although understorey cover did decline in long-unburnt forest following this quadratic trend, suspended litter weights did not decline. This argument is problematic because it is dependent upon equivocation that enables the reassignment of surface litter into the near-surface pool of litter and the removal of objective definitions. We explain this below and briefly discuss implications of the broader debate around this subject.

2 | EQUIVOCATION

In their analysis of near-surface fuel dynamics, Burrows et al. (2023) stated that they used the published definition of near-surface fuel developed in the guidelines developed for 'Project Vesta', a major Australian fire behaviour research project conducted in these forests (Gould, McCaw, Cheney, Ellis, Knight, et al., 2007; Gould, McCaw, Cheney, Ellis, & Matthews, 2007). This defines near-surface fuel as 'grasses, low shrubs, creepers, and collapsed understorey usually containing suspended leaf, twig and bark from the overstorey vegetation.' Whereas surface litter can be either packed tightly on the forest floor or loosely amongst fallen twigs and bark, near-surface fuel is explicitly differentiated from this by the fact that it is either *composed of* low plants or else *suspended in* low plants. In either case, it is the presence of living or collapsed understorey vegetation that is the defining feature of this fuel layer. Near-surface cover is therefore inextricably linked to understorey cover dynamics.

The definition of near-surface fuels used by Zylstra et al. (2023) was consistent with this definition. In their study, the authors divided near-surface fuels between (a) the plant species present and (b) the litter component that was suspended within those plants. This second component of suspended litter was taken from published data for neighbouring Karri Forests (McCaw et al., 2002), which have a similar understorey composition to that of Red Tingle Forest and were therefore the best available data. McCaw et al. (2002) found that dominant understorey shrubs in the Karri Forest had self-thinned to form a very open understorey by ~30 years, and Zylstra et al. (2023) found that after low woody shrubs had self-thinned in the Tingle Forest, the near-surface layer of plants was dominated by the Sword-sedge *Lepidosperma effusum*, which is non-woody and ineffective at suspending litter (Figure 1). It is likely that collapsed shrubs remain for a period after they have died, but these decay with a half-life ranging from 0.6 years for shrub leaves and up to 5.8 years for Karri twigs (O'Connell, 1987).

Given this context, McCaw. (2024) mischaracterise the actions of Zylstra et al. (2023) when they refer to their '*assumption* of a decline in suspended litter'. This was not an assumption; it was a consequence of applying the correct definition to near-surface fuels. McCaw. (2024) argue that the negative exponential function commonly used to describe surface litter dynamics (Olson, 1963) should have been applied to near-surface dynamics, but this assertion conflicts with the correct definition of near-surface fuel. Olson (1963) used a negative exponential curve because he argued that the rates of litter deposition and decomposition reached a point of equilibrium on the surface, but this is not the case in near-surface dynamics as they are inextricably tied to plant cover. Once the cover of woody understorey has self-thinned and the collapsed shrubs have decayed, the near-surface layer cannot exceed the cover of remaining later-successional species. The fact that the McCaw et al. (2002) data were better approximated by a function that captured this decline ($R^2 = 0.71$ cf. 0.59) was consistent with the mechanistic expectation.

McCaw. (2024) equivocate when they argue that 'The elongated shape of twigs predisposes them to forming a layer of near-surface fuel separated from the surface litter where they can intercept bark and other necromass shed from overstorey and mid-storey trees.' This is an incorrect redefinition of near-surface fuels that decouples them from plant cover dynamics, and it removes all objective distinction between surface and near-surface fuels.

Consider the implications of this in a field survey. If a quadrat falls on the pile of bark ribbons and twigs that typically forms at the base of a Karri tree (Figure 2), it is classified as surface fuel under the Project Vesta definition because no plants are present to suspend the litter. Under the modified definition used by McCaw. (2024), however, the upper, more aerated component may be classified



FIGURE 1 Sword-sedge forms a dominant low cover in long-unburnt Red Tingle Forest. This lack of woody structure is ineffective at supporting coarser litter. Photo: P. Zylstra.



FIGURE 2 Bark ribbons from Karri trees are long and easily suspended in low woody plants. This image shows the typical arrangement of bark at the tree base, where it occurs as surface rather than near-surface fuel. Photo: Melissa Howe & Nathan McQuoid.

as suspended litter, even though it is not suspended in any plants Although Burrows et al. (2023) at first stated that they used the definition published by (Gould, McCaw, Cheney, Ellis, Knight, et al., 2007; Gould, McCaw, Cheney, Ellis, & Matthews, 2007), they later defined surface fuels as 'up to 120 mm above the surface' without offering any justification for the value. Using near-surface fuels as they had been specifically defined, Project Vesta correlated them with fire behaviour in a series of experimental burns. In contrast, the division at 120 mm is entirely arbitrary. In addition, Burrows et al. (2023) did not describe any procedure for separating fuels above and below this point, stating only that they were 'harvested'. By redefining this component of surface fuel into the near-surface component then, this definition allows for suspended fuels to persist indefinitely after the matrix that should suspend them has disappeared, and in so doing removes all objectivity in measurement. We note that this lack of objective technique was further compounded by a lack of any methodology to control the placement of transects by Burrows et al. (2023), contrasting with the detailed controls described by Zylstra et al. (2023) to ensure randomised placement of transects.

3 | THE WIDER CONTEXT

This discussion can be better understood when placed into the context of the recent history of debate over fire management in Australia—particularly in the south-west. Fire management in the region rests heavily on the claim that there is a negative correlation between the areas of planned and unplanned fire (Boer et al., 2009; Burrows & McCaw, 2013; Sneeuwjagt, 2011). That is, examination of a subset of the West Australian fire history dataset suggested that wildfire area has increased as the rate of prescribed burning decreased. Subsequent replication of the analysis using the records of the same dataset over the entire area and time period, however, showed that

a. this correlation did not occur in the surrounding bioregions where it had also been applied;
b. it disappeared entirely when climate change was accounted for;
c. wildfire area continued to increase after the area of prescribed burning was increased in more recent years; and
d. the correlation depended upon attributing reductions in wildfire area to prescribed burns which occurred *after* the wildfires, so that causality was impossible (Campbell et al., 2022; Zylstra et al., 2022).

In addition to these findings, examination of long-term trends in the same dataset showed that wildfires in the region were most likely in areas that had been subject to prescribed burning in recent decades and least likely in long-unburnt forests. According to these records, prescribed burning produced a short period of reduced risk, but then drove a pulse of increased risk that lasted for decades as vegetation regrew (Zylstra et al., 2022, 2024). This trend is consistent with globally observed trends in 'disturbance-stimulated flammability' (Lindenmayer & Zylstra, 2024).

As the situation currently stands then, all available empirical evidence of what has historically occurred underpins the argument that long-unburnt forests become less flammable. This trend is entirely consistent with the expectations that arise from existing knowledge of fire behaviour and understorey dynamics in these forests:

1. Burning forests produces a pulse in understorey cover and height (Burrows, 1994; McCaw et al., 2002; Zylstra et al., 2023), and
2. understorey cover and height are the primary drivers of fire spread and flame height (Cheney et al., 2012; Cruz et al., 2022).

As was made clear by the authors, the modelling analysis of Zylstra et al. (2023) was not presented as evidence for the decline in flammability. Rather, it was an attempt to more fully explain the mechanisms that drive the observed decline. The conclusion by McCaw. (2024) that a different trend in near-surface fuels calls the findings of Zylstra et al. (2023) into question misses this point. If altering the dynamics of near-surface fuels causes the model to contradict the empirically measured trend, then the modelling of fire behaviour in near-surface fuels is incorrect.

4 | MODELLING SUSPENDED LITTER FLAMMABILITY DYNAMICS IN RED TINGLE FOREST

We acknowledge that the McCaw et al. (2002) dataset has limited value for modelling suspended litter dynamics in Red Tingle Forest, but contrary to the claims by McCaw. (2024), these have the effect of exaggerating the influence of suspended litter rather than reducing it. Specifically,

1. Karri trees shed bark ribbons (Figure 2) that account for nearly 25% of the weight of litter in those forests (O'Connell, 1987). These are readily suspended in vegetation, whereas Red Tingle trees have fine fibrous bark (Figure 3) which cannot form a component of the suspended fuel.
2. The McCaw et al. (2002) dataset measured suspended litter up to a diameter of 25 mm rather than the usual 6 mm diameter used to describe fine fuels that ignite in the fire front (McCaw, 2013). Reported weights of suspended litter are therefore greater than the subset of fine fuels.
3. O'Connell (1987) found that as time since fire increases, litter fuels in Karri Forest were dominated by the coarser fuel components of bark, twigs and fruit. Zylstra et al. (2022) calculated the packing of suspended litter from mass and volume by using an assumed mean particle diameter. However, if mean fuel particle diameter increases over time, then the litter becomes more sparsely packed and slower to ignite because of the increased particle diameter. Consequently, it is more likely to burn in the wake of the fire front. As a result, in older forests it would contribute more to flame depth (the distance between the front and rear edges of the flame front) than it does to flame height.



FIGURE 3 Bark fibres from Red Tingle trees are too fine to be suspended in low plants, instead forming a mat of 'duff'. Here, the layer is overlaid with leaves from *Allocasuarina decussata* and other species. Photo: Melissa Howe & Nathan McQuoid.

The data collected by Burrows et al. (2023) do not provide any solution to this. They also were representative of Karri rather than Red Tingle Forest, with only two of the 72 sites containing Red Tingle. As a result, they are dominated by the same bark ribbons. Fuels were collected up to 6 mm diameter, but as we have shown, these data are fundamentally unreliable due to the altered definitions used for near-surface litter, and the survey design which allowed for biased placement of transects. As a result, the reported cover of suspended litter in their oldest sites was more than twice the reported cover of the plants that should be suspending it. A large proportion of the litter reported by these authors as 'near-surface' in long-unburnt forests must, therefore be litter resting on the surface.

Correctly accounting for suspended litter in Red Tingle Forests will require collection in Red Tingle Forests, with proper accounting for changes in litter composition. Until that occurs, the points listed here suggest that suspended litter likely plays a lesser role in promoting flames than that modelled by Zylstra et al. (2023), and potentially may exert a greater effect on flame depth than it does on flame height in longer-unburnt forests.

5 | OTHER ARGUMENTS

McCaw. (2024) conclude by stating that fire exclusion in tall open forests of the south-west has not been achievable. Therefore, regular planned burning is a more effective strategy for risk reduction. This argument is not scientifically relevant, as it has no bearing on the underlying trends being discussed. However, we also note that fire exclusion has not been the intention of management for the area. Approximately 80% of fire in the south-west is prescribed rather

than wildfire (Boer et al., 2009). Further, suppression of wildfires has been made more difficult due to the area over which this policy has rendered the vegetation as more flammable regrowth (Lindenmayer & Zylstra, 2024; Zylstra et al., 2022, 2024). Over reliance on prescribed burning has also limited efforts towards improvement in firefighting (Lindenmayer et al., 2022; Lindenmayer & Zylstra, 2024) and in building early detection and rapid response capability.

6 | POLITICAL INTERFERENCE AND CONFLICTS OF INTEREST

Political interference in research is a growing concern internationally (Hess, 2024). In Australia, Government employees and recipients of Government funds have been shown to be under greater pressure than in any other work environment to defend policy through intellectual suppression (Driscoll et al., 2021). Those subject to political interference may be 'rewarded or penalized on the basis of complying with opinions of senior staff regardless of evidence' (Driscoll et al., 2021). These rewards and punishments are highly consequential, defining the success or failure of individual careers subject to Government funding (Driscoll et al., 2021; Martin, 1999). This is particularly relevant in Australian fire research, as all fire management agencies are signatories to a position statement that the scientific question of prescribed burning efficacy has been answered (Australasian Fire Authorities Council, 2021). Prescribed burning doctrine is therefore treated not just as policy, but as orthodox 'truth'.

It is in this context that Campbell et al. (2022) demonstrated the fundamental flaws in the primary study underpinning Government prescribed burning policies in south-western Australia. At the same time, Zylstra et al. (2022) showed that these policies were not simply ineffective mitigation measures, but actual drivers of increased fire risk. The Government response to Zylstra et al. (2022) argued that all evidence for a declining trend in long-unburnt forest should be excluded from analysis due to hypothetical and untested issues of data quality (Miller et al., 2024). When the analysis was replicated with these issues accounted for, however, the declining trend in flammability for long-unburnt forest was strengthened rather than weakened (Zylstra et al., 2024). This reanalysis showed that the only way for prescribed burning to minimise fire frequency to the same level as it naturally occurs in long-unburnt forests would be to burn annually. The study by Burrows et al. (2023) underpinning McCaw. (2024) built on these Government defences of policy, drawing upon theoretical arguments around fuel load. As we have shown, the findings of Burrows et al. (2023) were dependent upon survey techniques, which (a) removed the objective definition of the subject and (b) allowed the biased placement of transects through patches that would provide desired results.

Until this well-documented culture of political interference can be addressed, Government funding and other forms of influence on research into the efficacy of Government policies may constitute a conflict of interest.

7 | CONCLUSION

The decrease in flammability of long-unburnt forests in south-western Australia is now well established empirically and all hypothetical objections have been thoroughly addressed (Campbell et al., 2022; Zylstra et al., 2022, 2024). In the absence of any empirical evidence to the contrary, theoretical arguments regarding the role of different fuel components should be validated against these trends to determine whether they replicate the decline in flammability in forests that have recovered from disturbance. The finding that flame height and rate of spread are driven primarily by the height and cover of the understorey (Cheney et al., 2012; Cruz et al., 2022) is consistent with this trend, as the decline in flammability closely matches the well-documented self-thinning trend of an undisturbed understorey (Zylstra et al., 2022, 2024). Zylstra et al. (2023) demonstrated mechanistically why this occurs and showed that the trend is enhanced by other aspects of growth and succession such as the self-pruning of lower, shaded branches. The Project Vesta definition of suspended litter is also consistent with this, as suspended litter disappears under this definition when the matrix of vegetation that suspends it disappears. The argument by McCaw. (2024) rests entirely upon equivocation around this definition. However, even if their claims were possible, they would simply demonstrate that suspended litter is less important to fire behaviour than the authors believe it to be.

This debate and the well-documented culture of political interference in the field illustrate the need for independent research into Government policies.

AUTHOR CONTRIBUTIONS

Both authors contributed directly to the wording of the manuscript throughout each version.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

No additional data were used in this manuscript.

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