Background briefings on emerging issues for fire managers from AFAC and Bushfire CRC.

bushfire CRC afac

FIRE NOTE

ISSUE 37 SEPTEMBER 2009

PROJECT: EUCALYPT DECLINE IN THE ABSENCE OF FIRE

PREMATURE DECLINE OF COASTAL *E. GOMPHOCEPHALA* IN WESTERN AUSTRALIA AND HIGH-ALTITUDE *E. DELEGATENSIS* IN TASMANIA

Eucalypt decline has been observed since the late 1970s across extensive areas of the temperate eucalypt forest of Southern Australia. While differences exist between forests and locations, there is a high degree of commonality in the characteristsics and process of tree decline, with progressive canopy loss and tree death the final result of the process. This research looks at the link between fire regime and tree decline in eucalypt forests.

BACKGROUND

Fire drives the distribution of ecosystems at a global scale (Bond *et al.* 2005). Bond predicted that, in the absence of fire, the extent of the world's closed forests would double from 27% to 56%. For example, Jackson (1968) explained the patchy distribution of rainforest, eucalypt forest and grassland vegetation types in western Tasmania – a climate that could theoretically support widespread rainforest – in terms of fire frequency. Increasing fire frequency shifts vegetation from rainforest to eucalypt to grassland. This is referred to as 'ecological drift'.

In the absence of fire, Jackson's model describes the shift from eucalypt to rainforest in terms of old age mortality of overstorey eucalypts (at 350-450 years of age), not premature decline (at 150 to 200 years) of trees in their prime reported in this project.

The premature decline of fire tolerant and shade intolerant eucalypts is commonly associated with a change in forest community composition, where increased competition for resources is applied by a fire intolerant and shade tolerant midstorey shrub layer.

For example, fire exclusion since European settlement has led to large-scale shifts in forest structure and species composition in high

▲ Decline in high-altitude *E. degatensis* forest.

SUMMARY

Premature overstorey eucalypt decline is severe in some temperate Australian forests and may be associated with altered fire management since European settlement.

This project hypothesised that an absence of fire leads to the increased development of woody midstorey that out-competes eucalypts for soil water and/or alters tree nutrient availability.

The project took a 'space-for-time' approach of paired sites with a history of either being long unburnt or relatively frequently burnt. The sites were established in *E. gomphocephala* woodland in Western Australia (WA) and in *E. delegatensis* forest in Tasmania (Tas).

It was found found that in the long unburnt sites in both WA and Tasmania there was a greater percentage cover of midstorey (tall shrub layer) and that eucalypts were exposed to greater water stress (measured as higher water-use efficiency). Also, in WA eucalypts of long unburnt sites were deficient in foliar copper (Cu), and in Tasmania eucalypts of long unburnt sites had lower levels of foliar phosphorus (P).

Using an index of tree health with crown cover as the measure, the project showed that tree decline was correlated with increased midstorey shrub cover, and water stress and nutrient deficiency in eucalypt trees.

We conclude that the midstorey that develops in the long absence of fire alters ecological processes, leading to premature eucalypt decline.

altitude *E. delegatensis* forests of Tasmania (Ellis 1985) and coastal *E. viminalis* woodland of Victoria (Lunt 1998). These studies indicate that in the long absence of fire:

- a limited range of woody midstorey species thrive
- dominant overstorey eucalypts prematurely decline, and
- there is a lack of recruitment of the overstorey eucalypts.

The ecological processes that underpin this premature decline are the focus of this study. The study hypothesises that, with a long absence of fire, the increased development of a woody midstorey out-competes overstorey eucalypts for soil water and alters nutrient cycling processes.

BUSHFIRE CRC RESEARCH

Early in 2006 the Bushfire CRC, following a request from a number of park and forest agencies around Australia, started a collaborative research project to investigate links between fire regimes and eucalypt ecosystem health.

This project is the first national study of tree decline caused by reduced frequency or absence of fire.

PROJECT FINDINGS

Tree health and associated vegetation

The tree health index was lower in long unburnt sites in both WA (Figure 1a) and Tasmania (Figure 1b)($p<0.1$). Understorey and midstorey attributes differed between long unburnt sites and relatively frequently burnt sites in *E. gomphocephala* woodland in WA and *E. delegatensis* in Tasmania. The results were consistent with a thickening of the midstorey shrub layer in the absence of fire.

Mesophication and soil P-availability

The project found significantly lower surface soil temperatures and higher surface soil water content in long unburnt sites in WA, similar to that reported for long unburnt *E. delegatensis* sites in Tasmania (Ellis 1971). These results are evidence for 'mesophication' (Nowacki and Abrams 2008). Mesophication is the development of cool, moist understorey conditions associated with a shift to shade tolerant, fire intolerant vegetation.

Mesophication has occurred across vast expanses of Oak forests in the eastern USA due to the suppression of fire and consequent species composition shifts since European settlement (Abrams 1992). Mesophication may have important implications for relationships between eucalypts and fungal symbionts (ectomycorrhizal fungi) that play a key role in acquisition of phosphorous (Tommerup and Bougher 2000) in the highly weathered soils of Australia. Consistent with this, tree foliar phosphorous was significantly lower in long unburnt sites (Figure 2b) and was positively correlated with tree health index in Tasmania. Foliar phosphorous also tended towards lower values in long unburnt sites in WA.

The process of mesophication may be an important ecological change across temperate Australian forests, given the change in fire management, and consequent midstorey development, since European settlement.

Nitrogen – and micronutrient availability

Although surface soils of long unburnt sites had higher total nitrogen (due to N fixation, atmospheric deposition and the absence of volatilisation from fire) we found that tree

ABOUT THIS PROJECT

Eucalypt decline in the absence of fire, Bushfire CRC project B6, is led by Neil Davidson, Dugald Close and Alan Jones of the University of Tasmania.

The project was initiated in June 2006 and is partially funded by the Forest Fire Management Group, with significant additional in-kind support for field trials and operations from Murdoch University, the Department of Environment and Conservation, WA, and Forestry Tasmania.

The ultimate objective of this project is to provide a guide to forest managers to determine when a forest susceptible to decline should be burnt to maintain overstorey eucalypt health.

▲ Decline in Tuart *E. Gomphocephala* forest.

foliar N was not elevated in long unburnt sites relative to frequently burnt sites.

Further we found no differences in soil micronutrients between long unburnt and frequently burnt sites. Despite this, levels of foliar Cu (Figure 2a) were significantly lower in trees of long unburnt sites and foliar Cu and Zn were positively correlated with tree health in WA.

Fire oxidises organic acids and mineralises significant levels of nutrients, and increased concentrations of calcium, magnesium, copper, zinc, sulfur and boron in leaf bases have been related to increased plant availability in ash post fire (eg. Swanborough *et al.* 2003). Eucalypts of the sandy, infertile soils of Western Australia may depend on fire for rendering critical nutrients plant-available.

Water availability

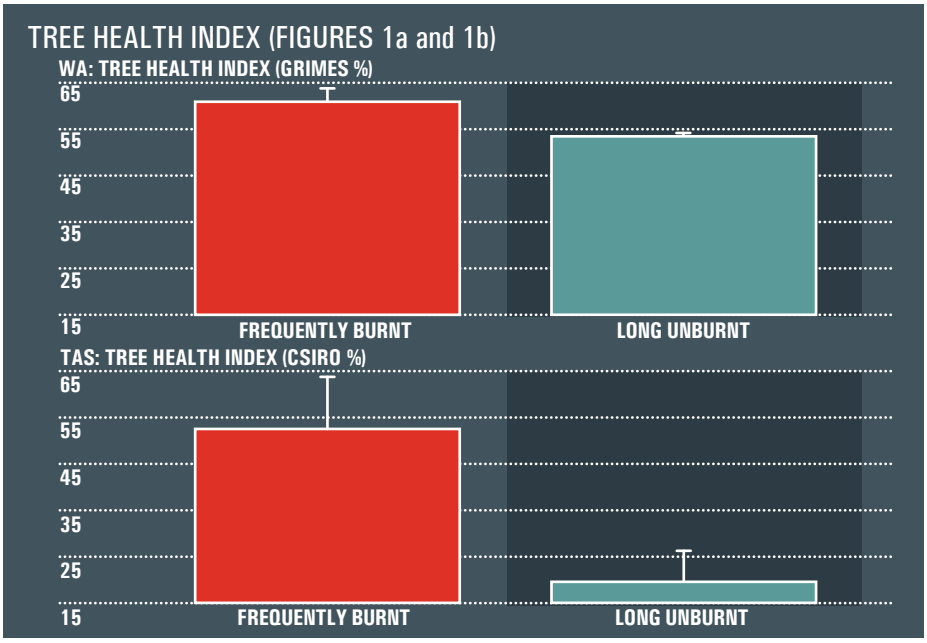
Trees in long unburnt sites had foliar carbon isotope ratios (Figures 3a and 3b) indicative of water stress (Farquhar and Richards 1984). Similarly in the northern Rocky Mountains (USA), where fire exclusion has shifted forest species composition from the fire tolerant *Pinus albicaulis* to mixed stands containing the shade tolerant *Abies lasiocarpa*, transpiration of mixed stands was elevated relative to pure stands of *Pinus albicaulis* (Sala *et al.* 2001). High transpiration rates of Abies is likely to impose water stress on Pinus. Our results show that under the same constraint (thickening understorey) in both western and eastern temperate Australia, water stress increased, which is strong evidence that a critical, and ecologically important, competition for soil water is applied by the midstorey shrub layer that has developed under fire management systems applied since European settlement.

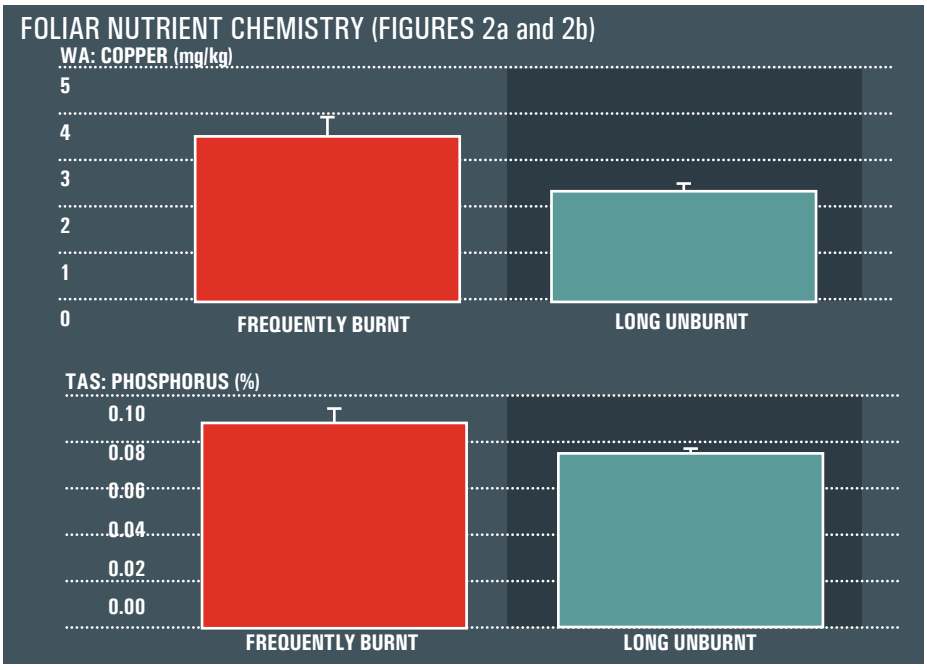
FUTURE DIRECTIONS

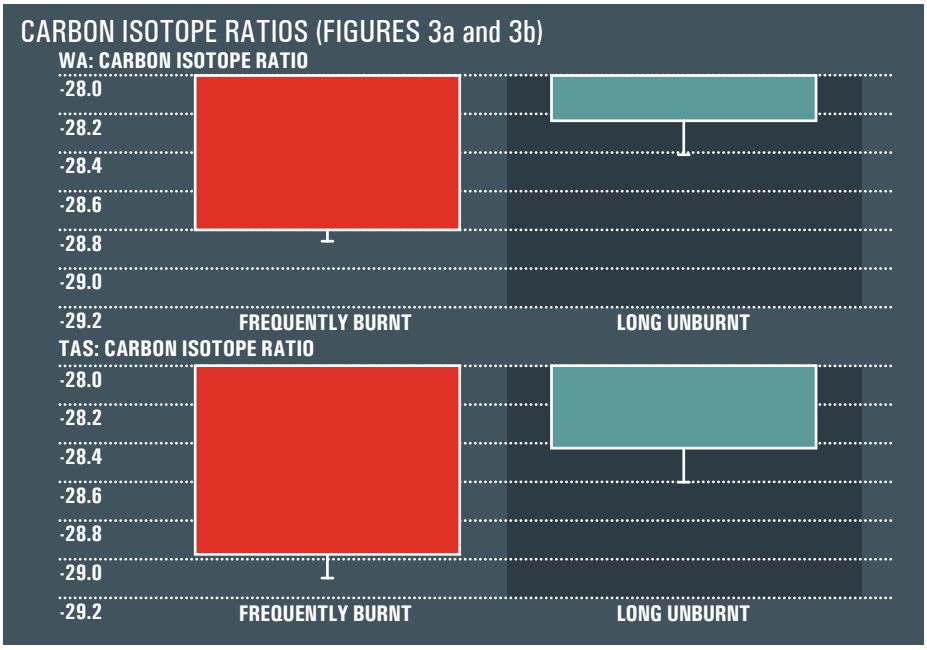
Short-term: The project is well advanced in the production of a decision support tool and technical report.

Although the project was only funded to 30 June 2009, we have gained approval to extend the project to December 2009 with no additional funds. Studies of phosphorus nutrition in the *E. delegatensis* forests exposed to different recent history of fire histories are underway. We hope to establish a link between evidence of reduced amount and diversity of mycorrhizal fungi (fungi symbiotic with tree roots) in long unburnt forests (Bryony Horton's PhD in this project) with changes in acid phosphatase activity (involved in mobilisation of bound phosphorus) in soils of different age since fire.

Long-term: The potential decline and loss of the overstorey eucalypts from even a proportion of the southern Australian forests is a major concern aesthetically and ecologically,







END USER STATEMENT

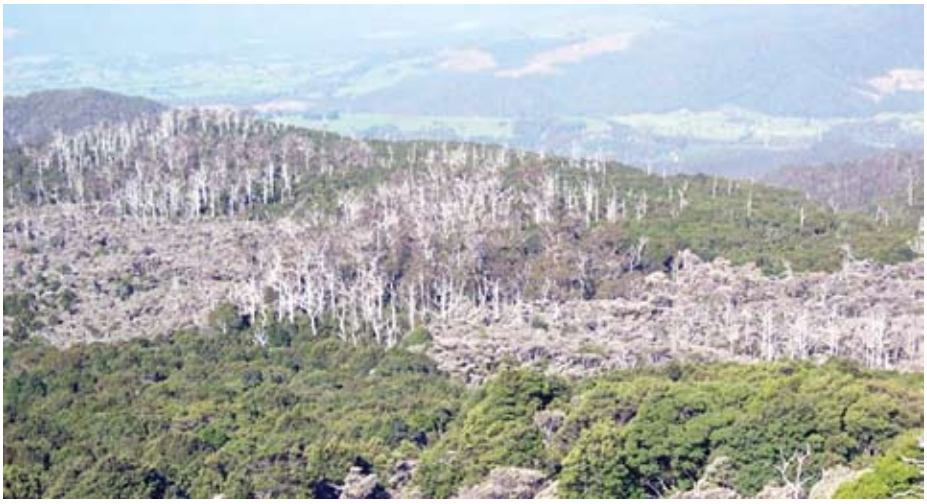
"This project provides another significant piece in the puzzle of eucalypt forest management.

"The possibility of the premature decline and loss of the overstorey eucalypts from even a proportion of the southern Australian forests is of major concern aesthetically and ecologically, but also for the effect this process will have on carbon sequestration. It is within the 200 to 400-year-old eucalypts that most of the forest stored carbon resides.

"It is important that forest managers understand the processes which affect the longevity of eucalypts, as a step in finding ways to protect the massive quantities of carbon stored in the stems of our eucalypt forests.

"This is a project of national significance. The research report will be of value to all managers of natural and long rotation eucalypt forests. The popular account to be produced will form a useful base for a general information pamphlet on forest management issues and processes and the field forest condition assessment guide will facilitate the easy field collection of forest state information to assist forest management."

– Tony Blanks, Manager, Fire Management, Forestry Tasmania



▲ Another example of eucalypt forest decline at Mt Maurice in Tasmania.

but will also have a big impact on carbon storage because the majority of biomass carbon in natural forests resides in the woody biomass of large old trees. In an international climate of concern to account for carbon emission and sequestration, we need to find ways of protecting the massive carbon stocks that reside in the stems of our eucalypt forests. Looking ahead, we propose to study the effect of no fire, wildfire and proscribed fire on the ecosystem services of the forest, particularly: How do we apply fire to protect carbon stores, maximise water storage for domestic use and maintain biodiversity?

CONCLUSION

The low frequency of fire since European settlement has promoted the development of dense, shade tolerant midstorey shrubby vegetation and caused the premature decline of overstorey *E. gomphocephala* in WA and *E. delegatensis* in Tasmania. In these systems, the midstorey out-competes eucalypts for soil water, and tree-nutrient availability is restricted, perhaps due to a lack of mineralisation by fire and/or through compromising the relationships between tree roots and their symbiotic fungi.

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Fire Note is published jointly by the Bushfire Cooperative Research Centre (Bushfire CRC) and the Australasian Fire and Emergency Service Authorities Council (AFAC).

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Bushfire CRC is a national research centre in the Cooperative Research Centre (CRC) program, formed in partnership with fire and land management agencies in 2003 to undertake end-user focused research.
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AFAC is the peak representative body for fire, emergency services and land management agencies in the Australasia region. It was established in 1993 and has 26 full and 10 affiliate members.