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# FIRE NOTE

ISSUE 78 MAY 2011

# EUCALYPT DECLINE IN THE ABSENCE OF FIRE: RELATIONSHIP TO THE ECTOMYCORRHIZAL FUNGAL COMMUNITY


## SUMMARY

Ectomycorrhizal fungi are fungi which form symbiotic relationships (a relationship of mutual benefit) with trees and perform critical ecosystem processes, especially in nutrient cycling, which affect tree health.

Eucalypt dieback is widespread throughout Australia, and its cause has been attributed to a variety of factors, including forest management. In Tasmania, dieback in *Eucalyptus delegatensis* has been linked to altered fire regimes and associated changes in mycorrhizal communities. This study explored ectomycorrhizal diversity and community composition in relation to eucalypt health, understorey vegetation and soil chemistry.

▲ Fruiting body of a fungus species that forms beneficial mycorrhizal relationships with eucalypt forest trees.

Ectomycorrhizal community composition and structure was correlated to eucalypt health. Moderately declining plots had a higher diversity of Cortinariaceae (gilled mushrooms) and severely declining plots had a higher diversity of Russulaceae and Thelephoraceae mushrooms. The ectomycorrhizal community was found to be responding to altered soil chemistry, especially increased mineral nitrogen that is associated with severe eucalypt dieback that occurs in the absence of fire.

The results further our understanding of ectomycorrhizal ecology and indicate that fire could be an important tool for managing and maintaining healthy eucalypt forest ecosystems.


## ABOUT THIS PROJECT

This research is part of *Managing fire in the landscape – Eucalypt decline in the absence of fire* project

This *Fire Note* summarises the final research outcomes of Bryony Horton's PhD research, Eucalypt decline in the absence of fire: mycorrhizal indicators of declining forest health.

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## CONTEXT

**Eucalypt dieback is widespread throughout Australia affecting many forests that are utilised for wood resources or are protected for conservation. The causes of eucalypt dieback are currently unknown but may be related to altered fire regimes and associated changes in the ecosystem, such as altered relationships with beneficial mycorrhizal fungi, which were investigated in this study.**

## BACKGROUND

The term dieback refers to a deterioration of health in tree canopy condition resulting in premature death. Symptoms include crown thinning and death of branches beginning at the growing tips and spreading to the primary branches. Dieback has been observed in several species but is widespread amongst the genus *Eucalyptus* throughout Australia.

In most cases eucalypt dieback does not have one single cause but appears to be the result of complex interactions and alterations within an ecosystem. Changes in the pattern of nitrogen cycling has been identified as a possible causal agent of eucalypt decline (Granger *et al.* 1994; Jurskis and Turner 2002). Long-term accumulation of nitrogen, which can occur in the absence of fire, leads to biochemical imbalances in the soil and foliage, root morphological changes (Jurskis and Turner 2002; Jurskis 2005b), altered vegetation dynamics and changes in the ectomycorrhizal fungal community.

Ectomycorrhizal fungi are critical for nutrient cycling, releasing and transferring nutrients through the ecosystem (Tommerup and Bougher 1999; Tommerup and Bougher 2000; Lilleskov and Bruns 2001). Most forest trees, including eucalypts, form ectomycorrhizal associations that enhance plant nutrient uptake of nitrogen and phosphorus, and other inaccessible nutrients, especially in soils of low fertility. Ectomycorrhizal fungi may also influence plant community structure,

Bryony Horton's PhD research has studied mycorrhizal indicators of declining forest health.

### END USER STATEMENT

"Dieback in high altitude Tasmanian *E. delegatensis* forests was first identified as a future problem in the late 1960s and subsequently investigated by Dr Bob Ellis of CSIRO and colleagues. The influence of fire and of the absence of fire in the general health of these forests was soon identified, but the mechanism(s) through which this influence was manifested remained the subject of speculation. Bryony's research on the inter-relationships between fire, fungi and forests has contributed another piece to the jigsaw and as such is a valuable contribution to our knowledge in the often contentious field of the use of fire in the sustainable management of eucalypt forests."

**– Tony Blanks, Manager, Fire Management, Forestry Tasmania**

composition and productivity (Allen *et al.* 1995; van der Heijden *et al.* 1998; van der Heijden *et al.* 2008).

High altitude dieback affects *Eucalyptus delegatensis* forest above 800 metres and has been consistently correlated to the development of a rainforest understorey where fire has been excluded for long periods. Fire has been shown to ameliorate dieback symptoms although the specific reasons for this are unknown (Ellis *et al.* 1980). Dieback has also been linked to changed mycorrhizal associations. Eucalypt seedlings grown in soil from declining forest had sparse root systems and formed few mycorrhizal associations, where as seedlings grown in healthy forest soil formed frequent ectomycorrhizal associations on vigorous root systems (Ellis and Pennington 1992).

## BUSHFIRE CRC RESEARCH

This project aimed to explore the relationship of eucalypt dieback to the ectomycorrhizal community to better understand the causes of dieback. To achieve this aim study sites were established in *E. delegatensis* forest with either sclerophyll (hard leaf) understorey (six plots) or rainforest understorey (six plots). Eight of the plots, located in north-east Tasmania, had been used for a previous dieback study and had known fire histories ranging from 42 years since the last fire to long unburnt (greater than120 years). Four of the plots were located in north-western Tasmania and were long unburnt but had been disturbed by logging 22-25 years ago. Ectomycorrhizal fungal sporocarps, root tips and soil samples were collected during a three-year period from all 12 plots. Fungal operational taxonomic units were identified through DNA sequencing and phylogenetic trees. At each site understorey vegetation was characterised, soil and foliage chemistry was analysed, and eucalypt crown condition was assessed by scoring the extent of primary crown dieback. Multivariate statistical analyses were used to explore the relationships between the ectomycorrhizal communities, eucalypt health, vegetation and abiotic variables.

An example of decline in a high-altitude *E. delegatensis* forest.

The results were then used to identify forest types that were most susceptible to dieback; to understand the soil chemistry of forests affected by dieback; and to identify differences in ectomycorrhizal fungal community composition and structure between healthy and dieback forests that could potentially be influencing dieback, through nutrient cycling, or other pathways.

## RESEARCH OUTCOMES

Long undisturbed (either by fire or forestry operations) *E. delegatensis* forest with rainforest understorey was more likely to be affected by severe eucalypt dieback than forest with a sclerophyll understorey or recently disturbed forest, and had higher

## DEFINITIONS

**Eucalypt dieback:** thinning and death of foliage and branches in the tree canopy beginning at the growing tips and spreading to the primary branches resulting in premature death.

**Ectomycorrhizal fungi:** fungi that form mutually beneficial relationships with plants. The fungi are provided with energy from their host tree in exchange for hard-to-acquire nutrients and other benefits such as pathogen and herbivore protection. This relationship generally leads to improved plant growth and productivity.

concentrations of soil mineral nitrogen (nitrate and ammonium) and foliar nitrogen and lower concentrations of soil and foliar phosphorus. This is consistent with other studies of eucalypt decline across Australia.

Mycorrhizal communities significantly differed between moderate and severe dieback forest and were correlated with altered soil chemistry associated with these levels of dieback. The Cortinariaceae fungi had higher diversity in healthier sites, while there was a higher diversity of the Russulaceae and Thelephoraceae in forest affected by severe dieback. In north-western and north-eastern Tasmania unique and distinctly different ectomycorrhizal fungal communities were found to occur in *E. delegatensis* forest with the rainforest understorey as compared to forest with the sclerophyll understorey. Despite the marked differences in community composition related to understorey type and health, the ectomycorrhizal community of *E. delegatensis* forest is dominated by Cortinariaceae and thus similar to other Australian eucalypt forests. Mineral soil nitrogen, soil pH and crown health were significant in predicting ectomycorrhizal community composition and structure, whereas available soil phosphorus and nitrate significantly predicted ectomycorrhizal species richness, with higher richness associated with both lower available phosphorus and soil nitrate.

This study corroborates northern hemisphere studies which show that changes in soil chemistry, especially mineral nitrogen, can strongly influence mycorrhizal species' richness, community structure and composition. It is the first study to find a strong correlation between ectomycorrhizal fungal communities and the status of eucalypt forest health. The results support the currently proposed model that, in the absence of fire, premature decline of temperate Australian eucalypt forests is closely linked to changes in soil chemistry, understorey vegetation and mycorrhizal communities.

▲ Three species of ectomycorrhizal fungi from the Cortinariaceae family. The Cortinariaceae family dominated the ectomycorrhizal communities of high altitude Tasmanian eucalypt forest (or *E. delegatensis* forest), and were associated with healthier eucalypt forest.

The changes in soil chemistry and vegetation dynamics that are associated with eucalypt dieback possibly occur as a result of the exclusion of fire from forests that have adapted to a particular fire regime. It has been proposed that the application of fire to these ecosystems may alter the soil chemistry, and start a successional process that would result in improved health of the forest. Fire changes vegetation communities, by the removal of vegetation through burning, succession of species following fire from seed, or by regeneration. Fire also acts to create spatially heterogeneous habitats that aid in conserving biodiversity. Fire history is also known to be important affecting Australian fungal communities and fire may act to reinstate assemblages of ectomycorrhizal fungi that are important for the maintenance of healthy forests.

Eucalypt health is probably not maintained by an isolated single fire event but a series of fire and or disturbance events, with specific intensities and intervals. Fire regimes are also likely to be specific to different forest types and would need to be determined individually

for each forest type. Although fire may act to reinstate conditions within the forest that allow healthy functioning, there are many unknowns surrounding the application of fire for the management of eucalypt dieback. Many eucalypt forests have an unknown management history with no record of fire regimes, and thus historic data is not available to inform an appropriate fire regime.

## HOW IS THE RESEARCH BEING USED?

Part of this research resulted in the identification of an efficient method to assess eucalypt health in the field. This method is published (Horton *et al.* 2010) and available for use by all managers and scientists involved with eucalypt dieback. This research has been incorporated into a forest management tool box which will be made available to forest managers and to farmers.

Throughout the project there has been close interaction with partner agencies, Forestry Tasmania (Tasmania), Department of Environment and Conservation (Western Australia), Forests New South Wales and the Department of Primary Industries, Parks, Water and Environment (Tasmania).

This research reinforces the strong interaction between the use of fire and fundamental processes underpinning forest health. Fire applied at the right intensity and frequency can be used to improve the health of eucalypt forests (for susceptible forests) but the appropriate fire regime is specific to each forest type. There is a public perception that fire is destructive and undesirable. This research shows that there is an optimal regime for fire within which eucalypt forests remain healthy and outside which we start to lose the forest values (such as biodiversity, carbon storage, aesthetic). Future work is needed to further refine these regimes.

## FUTURE DIRECTIONS

This study provides a thorough baseline of ecosystem properties associated with dieback which can be used to monitor long-term changes in eucalypt health following fire, and the corresponding changes in soil chemistry and the ectomycorrhizal community. Monitoring following fire will help determine the extent of changes in the ectomycorrhizal community and soil chemistry that can take place without eucalypt dieback occurring.

A better understanding of the specific roles of ectomycorrhizal fungi in dieback affected forest, such as nutrient preferences, would clarify functional differences between healthy and dieback affected forest.

Further research on forests with different fire histories is required to determine the appropriate fire regime for *E. delegatensis* forest that could be applied to maintain healthy eucalypt forest.

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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). This Fire Note is prepared from available research at the time of publication to encourage discussion and debate. The contents of the Fire Note do not necessarily represent the views, policies, practices or positions of any of the individual agencies or organisations who are stakeholders of the Bushfire CRC.**

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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. Bushfire CRC Limited ABN: 71 103 943 755

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