The dynamics of litterfall in eucalypt woodland surrounding pine plantations

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Thesis submitted for the degree of Doctor of Philosophy at the University of Technology Sydney

June 2009

UNIVERSITY OF TECHNOLOGY SYDNEY

Declaration

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Acknowledgements

I wish to acknowledge the organisations who have supported my PhD financially. During my PhD I was supported by the Postgraduate Doctoral Helix Scholarship, provided by the Faculty of Science at UTS. Thankyou to the Department of Environmental Sciences at UTS, who provided funding, vehicles and equipment needed to undertake the large amount of fieldwork associated with this project. Thankyou to the Jenolan Caves Trust who supported my research both financially and logistically. Thanks especially to Dan Cove, Grant Commins, Stephen Meehan and Steve Reilly for their help and support at Jenolan.

Thankyou to the Linnean Society of New South Wales for their financial support of my project. Seed Energy (South Australia) kindly supported my research through the provision of radiata pine seeds needed to undertake the germination experiments.

A massive round of thanks goes to my primary supervisor Brad Murray, for all his help, ongoing support and guidance throughout the duration of my PhD. Thankyou for advising me on numerous questions, challenging my thinking, and for your encouragement during the tough times. Thankyou to my external supervisor, Grant Hose, for your advice and support, especially during conceptual and set up stages of my research.

Thankyou to Alan Wright, Stuart Young and Tessa Robson for your assistance with fieldwork. Thankyou to Alison and Anthony Passe-Desilva, Alan Wright, Nicole Hills, Stuart Young, and Tessa Robson for your assistance in the lab sorting litter, filling litterbags and/or measuring seedlings. Thankyou to the technical staff at UTS who helped me in particular: Gemma Armstrong, Jordan Illes, Rod Hungerford and Sue Fenech. Thankyou to Bob Covney (Royal Botanic Gardens, Sydney) for assistance with plant identification.

Thankyou to Sue Wright, for proof reading my thesis. Thanks to Greg and Sue Wright, who kindly loaned me the use of their holiday home, so that I could spend numerous weeks in isolation writing.

Thankyou to my fellow postgraduate students for their help and support, especially members of the lab: Carla Harris, Damian Licari and Megan Phillips for many helpful discussions.

Finally thankyou to all my friends who have supported and encouraged me. Thankyou to my parents for providing a loving home and constant help and support,

whether that involved the tedious task of making litterbags and litter traps, use of their car for fieldwork, encouraging me or just chatting. Lastly, thankyou to Tessa Robson, not only for the countless ways that you have supported my research, but more importantly for your invaluable friendship and support through these trying times.

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Abstract

Biological invasions pose one of the greatest threats to global biodiversity and frequently result in the widespread loss of flora and fauna. Biological invasions have become a major focus of ecology in recent decades, and in particular, the invasive species radiata pine (*Pinus radiata* D. Don) is of considerable concern. Radiata pine has a very limited distribution in the northern hemisphere in its natural range. Its utility in the timber and manufacturing industries, however, has lead to widespread planting, especially in the southern hemisphere, where over 4 million hectares of plantations have been established. In fact, radiata pine is now the most commonly cultivated conifer in the world. A growing body of evidence from studies in the southern hemisphere has shown that pines are spreading invasively beyond the confines of plantations, displacing native species and becoming the dominant species in a number of vegetation types. The negative ecological impacts associated with pine plantations now extend well beyond plantation boundaries.

While a number of studies have examined the invasion of individual pines (wildings) from plantations into surrounding vegetation, very few studies have considered the impacts of pine plantations and pine litter on surrounding native plant communities. Pine litter is defined here as structures shed from pines; primarily needles and pollen cones, but also seeds and twigs. In New South Wales (Australia), pine plantations are frequently bordered by native vegetation, providing ideal conditions for pine-litter intrusion to occur. Nevertheless, rates of pine-litter intrusion have never been quantified. Furthermore, the responses of an ecosystem to an influx of pine litter are largely unknown. The aims of this thesis are first to quantify the intrusion of pine litter into native vegetation adjacent to pine plantations and second to determine the impacts of pine litter intrusion on the structure and function of native woodland communities. Fieldwork was conducted at two geographically disparate locations in the Central Tablelands of New South Wales (Australia): Jenolan Caves Karst Conservation Reserve and Gurnang State Forest. At both sites, pine plantations and native woodland are separated by a narrow fire trail that is only a few metres wide. A comparative framework is used, whereby sites in eucalypt woodland that were adjacent to pine plantations (adjacent sites) were compared with sites in eucalypt woodland that were not adjacent to plantations but rather adjacent to eucalypt woodland (reference sites). As the effect of plantations is expected to decrease with increasing distance into native

vegetation, sampling plots located at distances of 0, 5, 15, 25 and 50 m from the edge of the native vegetation were established at reference and adjacent sites. This enabled testing of both the impact of plantations on native vegetation, and also the spatial extent of this impact on native vegetation.

The first and crucial step in examining the intrusive effects of pine plantations was to quantify the amount of native and exotic litterfall at reference and adjacent sites. At each sampling plot, I measured the amount of native and exotic litterfall (i.e. pine litter intrusion) every 4 weeks for 1 year at Gurnang State Forest and for 2 years at Jenolan Caves Karst Conservation Reserve. Pine needles and pollen cones were found to be a significant component of litterfall in woodlands adjacent to pine plantations. Exotic and native litterfall varied both seasonally and annually. Interestingly, peak needlefall from pines occurred in autumn and winter, which coincided with the minimum native leaffall. Conversely, pine needlefall was at a minimum during summer, during which native leaffall was high. The comparison of two separate woodlands adjacent to plantations revealed similar patterns of pine-litter intrusion although the absolute quantity of pine-litter intrusion was greater at Jenolan compared to Gurnang. Comparison of the carbon (C) and nitrogen (N) content of litterfall revealed subtle yet significant differences between pine and native litterfall. Pine litter generally had a lower N content than native leaffall at Jenolan, but a higher N content than native litter at Gurnang. At both locations, the pine litterfall is additional to native litterfall and as such, pine-litter intrusion is adding additional resources to woodlands adjacent to the plantation.

Having determined the rates of pine-litter intrusion, the next step was to determine the fate of pine litter once it had intruded into woodland vegetation. In the absence of fire, plant litter is ultimately broken down through the decomposition process. A three-by-three experimental design was employed, where 3 litter types (pine, native and a 50:50 mix of pine and native litter) were placed under 3 different conditions (‘reference sites’, ‘adjacent sites’, and sites within pine plantations). Litterbags were constructed and filled with a known mass of litter before being placed in the field. Every 8 weeks, for 18 months, litterbags were collected and destructively sampled. Decomposition was measured as a function of weight loss through time, while the corresponding nitrogen and carbon contents were determined. While decomposition was quite slow overall, rates of decomposition were generally faster for native litter than

for pine litter. Throughout the experiment, the N concentration of litter increased in all litter types although it was higher in native litter than in pine litter.

An important consequence of the slower rate of decomposition of pine litter is likely to be the accumulation of pine litter in woodlands adjacent to plantations. This may have severe implications for the structure and composition of plant communities adjacent to plantations. To test this, I examined the seasonal and spatial patterns of plant community structure of eucalypt woodlands surrounding pine plantations at Jenolan and Gurnang. Eucalypt woodland at Gurnang showed only a minor change in the structure and composition of understorey vegetation at sites nearest the plantation. In contrast, eucalypt woodland at Jenolan showed a much stronger response to plantations, with significantly lower total species richness at adjacent sites compared with reference sites. This resulted in a pronounced 'edge effect' up to 15 m into eucalypt woodland adjacent to pine plantations.

Canonical correspondence analysis was used to examine the relationship between environmental variables and plant community structure. Pine litterfall explained a significant portion of the variation in plant community structure at reference and adjacent sites at Jenolan, where large quantities of pine litter intrude into native vegetation. At Gurnang, where smaller quantities of pine litter intrude into eucalypt woodland, pine litter intrusion explained a lower portion of the variance between reference and adjacent sites. The plantation at Jenolan consists of large, mature pines that have formed a dense closed canopy, while at Gurnang, the plantation has been established more recently and the pines are not as large, and have not formed a closed canopy. The plantations at Jenolan are therefore a greater source of litter and are also likely to have more pronounced influence on the microclimate compared with the plantations at Gurnang. Lower diversity of flora at Gurnang also may limit the ability to detect differences in plant communities between reference and adjacent sites.

Finally, I investigated the impact of pine litter on plant community structure by testing the hypothesis that pine litter facilitates the germination and growth of radiata pine seeds. Using a manipulative glasshouse experiment, radiata pine seeds were sown in pots and exposed to varying quantities of different litter treatments (pine litter, native litter and a 50-50 mix of pine and native litter). The germination and subsequent growth and survival of pines were measured over a period of 2 months. Litter depth but not litter type was found to be an important determinant of pine seedling establishment. With the exception of treatments that were covered by a small layer of litter (i.e. 1 cm)

increases in litter depth resulted in delayed and lower rates of seedling emergence. Although pine and native leaves are different shapes (i.e. needle vs. broadleaf) and form very differently structured litter layers (dense mat vs. loosely structured), both litters appear to cause similar physical resistance to seedling establishment. These results indicate that litter accumulation resulting from pine intrusion can alter the establishment of pine seedlings. Given the invasive nature of radiata pine, it is highly likely that increased litter depth resulting from pine-litter intrusion will influence the establishment of many native species.

In summary, significant quantities of pine litter were found to intrude into native woodland adjacent to pine plantations, which in turn, appears to be responsible for observed shifts in ecosystem structure and function. This is of particular concern in instances where pine plantations are situated adjacent to native vegetation that has been set aside specifically for conservation purposes. I therefore suggest the provision of a buffer zone around plantations in order to minimise intrusive impacts of plantations on native biodiversity. Whilst this can be achieved using a number of techniques, careful consideration of the structure of native vegetation is needed when selecting the appropriate technique. Having an inappropriate buffer may have an undesirable influence on native vegetation.