

# **Eucalypt regeneration and ecological restoration of remnant woodlands in Tasmania, Australia**



**Tanya Georgina Bailey**

Bachelor Horticultural Science UWS, Hawkesbury

Bachelor Science (Honours) UTAS

Submitted in fulfilment of the requirements for the  
Degree of Doctor of Philosophy

School of Plant Science, University of Tasmania

July 2012

## **Declaration of originality**

This thesis contains no material which has been accepted for a degree or diploma by the University or any other institution, except by way of background information and duly acknowledged in the thesis, and to the best of the my knowledge and belief no material previously published or written by another person except where due acknowledgement is made in the text of the thesis, nor does the thesis contain any material that infringes copyright.

Tanya Bailey                      Date

## **Authority of access**

This thesis may be made available for loan and limited copying and communication in accordance with the Copyright Act 1968.

Tanya Bailey                      Date

## **Statement of Ethical Conduct**

The research associated with this thesis abides by the international and Australian codes on human and animal experimentation, the guidelines by the Australian Government's Office of the Gene Technology Regulator and the rulings of the Safety, Ethics and Institutional Biosafety Committees of the University.

Tanya Bailey                      Date

## **Statement regarding published work contained in thesis**

The publishers of the paper comprising Chapter 3 hold the copyright for that content, and access to the material should be sought from that journal.

Tanya Bailey                      Date

## Statement of Co-Authorship

Much of the material in Chapter 3 is published as:

Bailey, T. G., N. J. Davidson and D. C. Close (2012). "Understanding the regeneration niche: Microsite attributes and recruitment of eucalypts in dry forests." Forest Ecology and Management **269**(0): 229-238.

The following people contributed to the publication of the paper comprising Chapter 3 undertaken as part of this thesis:

Tanya G. Bailey (70%), Neil J. Davidson (20%), Dugald C. Close (10%).

The ideas for this study were those of the candidate with Neil J. Davidson providing some advice on experimental design. All experimental work was carried out by the candidate. The manuscript was written entirely by the candidate with editorial advice from Neil J. Davidson and Dugald C. Close.

We the undersigned agree with the above stated "proportion of work undertaken" for the above published peer-reviewed manuscript contributing to this thesis:

Signed: \_\_\_\_\_

\_\_\_\_\_

Dr Neil Davidson  
Supervisor  
School Of Plant Science  
University of Tasmania

Associate Professor René Vaillancourt  
Head of School  
School of Plant Science  
University of Tasmania

Date: \_\_\_\_\_

## Abstract

Lack of eucalypt regeneration is a key factor in the decline of forest and woodland remnants in low rainfall agricultural regions in Australia. This thesis provides a new insight into dry forest and woodland regeneration by demonstrating how important and tightly circumscribed the eucalypt seedling regeneration niche is in these forests in Tasmania. The potential of soil water repellency to be a barrier to eucalypt recruitment and the difficulty of mimicking the regeneration niche to improve natural regeneration processes in degraded forests are highlighted. A section on management implications is included.

Key to effective management of dry forests and woodlands is an understanding of the requirements and conditions that promote seed germination and seedling establishment (recruitment niche) and the persistence of lignotuberous sprouts (juvenile persistence niche). The processes of eucalypt recruitment and persistence were investigated in dry forest and woodland remnants in the Midlands of Tasmania at the scales of the stand and microsite. The work was conducted with a view to applying the results to the discipline of restoration ecology.

Measurements of structural complexity at thirty remnant forest stands that were in a range of stages of decline revealed that healthy remnants contained four times the amount of eucalypt regeneration (seedlings, lignotuberous sprouts and saplings) than stands in a degraded condition and that regeneration was absent in stands of paddock trees (except for one stand in which there had been a fire). An additional lack of trees in smaller diameter size classes in both intermediate and paddock tree sites relative to the amounts shown in healthy sites implies a long-term recruitment scarcity and an unavoidable future bottleneck in the development of mature trees. The quantity of eucalypt regeneration was positively associated with other structural attributes: perennial species and life form richness; cover of vegetation 0.5-6m high; litter; dead trees; large trees; and total length of fallen logs >10cm diameter; and negatively associated with quadratic mean tree diameter at breast height. Across the thirty stands, the majority of eucalypt regeneration was in the form of lignotuberous sprouts and saplings. Only in stands burnt 2-6 years prior to the survey did newly recruited seedlings form part of the regeneration.

Within these burnt sites the seedling recruitment niche differed significantly to the juvenile persistence niche (occupied by lignotuberous sprouts), while the juvenile persistence niche had characteristics similar to the general forest floor. Seedling microsites were characterised by the following: canopy gaps and ashbeds; a predominantly northerly aspect; over 220° shelter in profile; an average distance to a sheltering object of < 30cm; shelter provided by coarse woody debris (80% of seedlings sheltered by logs and branches); soil that was significantly softer and less water repellent than the forest floor; and low cover of grass. All these characteristics of seedling microsites affect moisture availability.

The role of ashbeds, coarse woody debris and soil water repellency in eucalypt recruitment was further investigated. Soil water repellency (hydrophobicity) can be severe in dry eucalypt forests as hydrophobic organic compounds coat the surfaces of soil particles and this has implications for the movement and storage of water in the system. Other studies have shown that soil hydrophobicity is differentially affected by fire depending on the temperatures reached, with repellency increasing as temperature increases until a threshold is reached at which repellency is removed (approximately 260°C). Logs lying on the forest floor provide heavy fuel for intense fire which creates ashbeds. The current study showed that in ashbeds hydrophobicity was removed in surface layers but the hydrophobic layer moved lower (1-3cm) down the soil profile. The wettable surface soil zones enabled the germination of eucalypt seed and subsequent establishment of seedlings. Remaining adjacent and partially burnt coarse woody debris provided a soil moisture store (with threefold the amount of moisture in soil under logs compared to 5m away) and probably protection from microclimatic fluctuations and browsing animals. Surface soil outside of the ashbed areas was severely water repellent suggesting that soil water repellency may be a barrier to eucalypt recruitment in lightly burnt and unburnt soils.

These findings were applied to restoration ecology. Patch scale restoration trials were conducted in six dry forest remnants in the Midlands of Tasmania in an attempt to mimic the eucalypt recruitment and persistence niches through the use of intense spot burns or cultivation with and without the addition of large logs. Survival of seedlings established from introduced seed and natural seed rain was variable within and among sites resulting in no treatment effects. Thus the 'Burn with the addition of logs' treatment did not successfully mimic the recruitment niche, probably because

the experiment did not mimic the natural heterogeneity of hydrophobicity following wildfire. However, the survival of planted seedling was greatest in ‘Cultivated with no log’ treatments, which most closely resembled the juvenile persistence niche. Burning treatments did provide a relatively weed-free seed bed for over a year and surviving seedlings grew significantly better than those in cultivated treatments which quickly became infested with grassy weeds despite granular herbicide application.

Survival of planted seedlings and the amount of observed germination of sown seed were each significantly correlated with the structural complexity score of the planting site with seedling survival significantly higher in sites of healthy condition. This suggests that the more degraded sites had crossed an abiotic threshold (using state and transition model terminology) that was not completely removed by the experimental restoration treatments. The early establishment of planted eucalypt seedlings was also shown to be significantly affected by species; the underlying soil water repellency of the planting plot; the proximity to an adult tree and the type of soil amelioration used in the restoration treatment but not by the presence or absence of logs.

Suggestions for further work include trialling treatments that more closely mimic the recruitment niche by partially burning and retaining logs *in situ* rather than post burn addition; investigating the timing and intensity of weed control in cultivated treatments; testing the effects of soil water repellency amelioration through the use of wetting agents; and investigating spatial aspects of treatment patch placement.

## Acknowledgements

First and foremost I wish to thank my supervisors: Dr Neil Davidson, Dr Dugald Close and Dr Greg Unwin, for their support and advice over the years.

I would like to acknowledge the financial support I received from the Forestry CRC for project implementation and through a top up scholarship. I am also grateful for the opportunities provided by the Forestry CRC to attend a number of conferences and student training sessions. I appreciate the award of a Cuthbertson Scholarship through the UTAS foundation.

I would like to thank Steve Summers and Adrian Pyrke from Tasmanian Parks and Wildlife Service and Kerri Spicer from DPIWE for their assistance in identifying and providing access to survey sites. Many thanks to John and Maria Weeding, Peter Meaburn, David Downie, Antony Gunn and Gunns Pty Ltd for allowing me to undertake experimental work on their properties and for their support of it. Thanks also to the other land holders in the Midlands for allowing me access to their properties.

I am very grateful to the many people that provided field assistance including Sam Morgan, Rohan Willis, Scott Livingston, David Page, Keith Churchill, Neil Davidson, Gareth John, Andy Collins, and my dad Alan Bailey. I would particularly like to thank Patrick Sutczak for sharing great conversations and bad food with me during the many hours we spent driving all over the Midlands and for the fantastic help and support he has provided during my field campaign and beyond.

I also really appreciate the moral support, conversations and companionship of my fellow students and researchers at UTAS in Launceston: Brigid Morrison, Russel McGifford, Matt Kuipers, Alisha Dahlstrom, Digs Hulse, Lee Bowket, Jai Larkman and in Hobart: Lisa Watson, Sophie Fern, Helen Stephens and Archana Gaudi.

Most of all I would like to thank my family: Gareth for looking after me and supporting me so well and for so long; Rohan for the endless cups of tea and chats; Freya for her “go mum”s and graphics skills; Megs for her great listening and motivational skills freely shared; and all my other near and dear relatives for their long distance support. I couldn't have done it without you all.

# Table of Contents

<b>Declarations .....</b>	<b>ii</b>
<b>Abstract .....</b>	<b>iv</b>
<b>Acknowledgements .....</b>	<b>vii</b>
<b>Table of Contents.....</b>	<b>viii</b>
<b>List of Figures and Tables .....</b>	<b>xii</b>
<b>Chapter 1 Introduction .....</b>	<b>1</b>
1.1 Vegetation fragmentation and tree decline.....	1
1.2 Regeneration niche .....	8
1.3 Restoration ecology .....	13
1.4 Thesis structure and objectives.....	15
1.5 Terminology .....	18
<b>Chapter 2 Stand structural complexity and eucalypt regeneration.....</b>	<b>20</b>
2.1 Introduction .....	20
2.2 Methods .....	24
2.2.1 Sites .....	24
2.2.2 Sampling design .....	27
2.2.3 Attributes sampled.....	29
2.2.4 Calibration of structural complexity index.....	31
2.2.5 Statistical analysis of attribute data .....	32
2.3 Results .....	34
2.3.1 Attributes .....	34
2.3.2 Calibration of the structural complexity index for Tasmania.....	35
2.3.3 Ordination and evaluation of scored attributes.....	42
2.3.4 Location and community type .....	44
2.3.5 Correlations between regeneration and other structural attributes .....	44
2.3.6 Effect of remnant vegetation condition, fire and disturbance history .	45
2.3.7 Remnant condition and structural attributes.....	48

2.4	Discussion .....	49
2.4.1	Regeneration and structural attributes .....	49
2.4.2	Effect of remnant vegetation condition, fire and disturbance history on regeneration .....	55
2.4.3	How much is enough eucalypt regeneration?.....	58
2.4.4	Index calibration.....	60
<b>Chapter 3</b>	<b>Microsite attributes and eucalypt regeneration .....</b>	<b>64</b>
3.1	Introduction .....	64
3.2	Methods .....	67
3.2.1	Sites .....	67
3.2.2	Sampling design .....	69
3.2.3	Attributes assessed .....	70
3.2.4	Soil sampling and analysis .....	71
3.2.5	Statistical analysis .....	73
3.3	Results .....	75
3.3.1	Shelter.....	80
3.3.2	Ground and vegetation cover .....	82
3.3.3	Soil attributes.....	83
3.4	Discussion .....	85
3.4.1	The recruitment niche: features of seedling microsites.....	85
3.4.2	The persistence niche: features of lignotuberous sprout microsites....	92
3.5	Conclusion.....	94
<b>Chapter 4</b>	<b>Soil water repellency and eucalypt regeneration.....</b>	<b>96</b>
4.1	Introduction .....	96
4.2	Methods .....	101
4.2.1	Water repellency tests .....	101
4.2.2	Sites .....	102
4.2.3	Experiment 1: Liliesleaf Farm Oatlands .....	104
4.2.4	Experiment 2: Forton Farm Epping Forest.....	104

4.2.5	Experiment 3: Forton Farm Epping Forest.....	106
4.2.6	Data analysis.....	108
4.3	Results .....	109
4.3.1	Experiment 1 .....	109
4.3.2	Experiment 2 .....	110
4.3.3	Experiment 3 .....	112
4.4	Discussion .....	116
4.5	Conclusion.....	123
<b>Chapter 5</b>	<b>Restoring the eucalypt recruitment niche .....</b>	<b>125</b>
5.1	Introduction .....	125
5.1.1	Potential barriers to recruitment in degraded remnants.....	126
5.1.2	Potential methods of addressing constraints on regeneration .....	131
5.2	Methods.....	136
5.2.1	Experimental sites .....	136
5.2.2	Establishment treatments.....	139
5.2.3	Seed collection and viability testing.....	142
5.2.4	Seed sowing rates .....	142
5.2.5	Herbicide application .....	143
5.2.6	Assessment .....	144
5.2.7	Soil water repellency .....	145
5.2.8	Data Analysis .....	146
5.3	Results .....	149
5.3.1	Seed viability.....	149
5.3.2	Year 1 germination and survival .....	149
5.3.3	Structural complexity .....	152
5.3.4	Establishment treatment effects.....	152
5.3.5	Year 2 survival (3 sites).....	154
5.3.6	Vegetation and ground cover after 2 years.....	156
5.3.7	Soil water repellency .....	158
5.3.8	Probability of a plot containing seedlings .....	159

5.4	Discussion .....	159
5.4.1	Recreating the recruitment niche.....	159
5.4.2	Overcoming barriers to recruitment .....	161
5.4.3	Site effects .....	172
5.4.4	Assessing recruitment success.....	173
5.4.5	Conclusions .....	176
<b>Chapter 6</b>	<b>Restoring the eucalypt persistence niche.....</b>	<b>177</b>
6.1	Introduction .....	177
6.2	Methods .....	181
6.2.1	Experimental design .....	181
6.2.2	Data Analysis .....	184
6.3	Results .....	187
6.3.1	Weather .....	187
6.3.2	Structural complexity and seedling survival .....	190
6.3.3	Soil water repellency and seedling survival .....	190
6.3.4	Survival analysis of planted seedlings.....	191
6.3.5	Relative growth of planted seedlings .....	198
6.3.6	Seedling health .....	200
6.4	Discussion .....	202
6.4.1	Site.....	202
6.4.2	Species.....	205
6.4.3	Treatments .....	207
6.4.4	Soil water repellency .....	210
6.4.5	Remnant structural attributes.....	212
6.5	Conclusions .....	214
<b>Chapter 7</b>	<b>General discussion.....</b>	<b>217</b>
7.1	Principal research results of the thesis .....	218
7.2	Conceptual model.....	224
7.3	Appraisal of restoration techniques and suggestions for further research.....	227

7.4	Implications of soil water repellency .....	231
7.5	Management of remnants for improved regeneration .....	233
	<b>References .....</b>	<b>236</b>