

Impacts of invasive exotic plants on reptile and amphibian assemblages

Leigh Martin

School of the Environment



Thesis submitted for the degree of

Doctor of Philosophy

University of Technology, Sydney

June 2013



**UNIVERSITY OF
TECHNOLOGY SYDNEY**

Certificate of Authorship/Originality

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 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.

Signature of Student

Acknowledgements

I wish to express my thanks to all those who assisted me over the course of this project. I owe a profound debt of gratitude to my Principal Supervisor Dr Brad Murray who took a risk on a cold calling, prospective student. Thank you for your invaluable encouragement, advice and support on every aspect of my project. Thanks for your boundless optimism and enthusiasm for my project, for always challenging me and for providing a stimulating environment to work in. Thanks also to my Alternate Supervisor Dr Paul Gribben for valuable advice and assistance with statistical analysis.

This project could not have been completed without the help of people and organisations who facilitated access to fieldwork sites. Thank you to Kaiya Donovan, Michael Hand, Peta Norris and Tiffany Knott of the NSW National Parks and Wildlife Service, Paul Price of Sutherland Shire Council, Hugh Cross, John Hughson and Cr Daniel Wallace of Lake Macquarie City Council, Nethan Kana and Damian Vella of Breen Holdings Pty Ltd, and Barbara Bell of the NSW Rifle Association.

I would have been unable to complete this project without the help of UTS Technical Staff. Thank you to Andrew Malecki, Gemma Armstrong, Sue Fenech, Peter Jones and Hilary McNamara.

I am grateful to my good friend Gavin Ayre for providing invaluable assistance with fieldwork and production of the maps in this thesis. I also express my gratitude to Alex Gale for assistance in the field and the laboratory.

Thank you to Sue Wood, Dr Lachlan Mairs and Prof Graham Nicholson of UTS for advice and assistance with animal ethics applications and to Julie McInnes of NSW NPWS for assistance with Scientific Licences. Thanks also to Professor Michael Mahony of the University of Newcastle for helpful advice at the start of my project and to Kien Nguyen and Matt Hingee for providing an incurable Luddite with advice and assistance on the PRIMER statistical software package.

Thanks also to my fellow postgraduate students and occupants of room 4.5.64, Megan Phillips, Ashley Fowler, Gwenael Cadiou, Paul York, Melanie Lewis, Cybelle Shorter, Renee Dowse, Hayden Beck and Nikki Bramwell for helpful advice, friendship and support throughout my project.

I owe a special thank you to my wife Julia Finn, who encouraged me to pursue my passion and tolerated my long hours, poverty and mood swings. This is your work too.

This work was supported by funding from the University of Technology, Sydney School of the Environment, Climate Change Cluster. I received financial assistance from an Australian Postgraduate Award scholarship. Thank you to all those involved.

Finally, I wish to dedicate this thesis to my late and greatly missed pet blue-tongue lizard (*Tiliqua scincoides scincoides*) (1987-2011) who helped maintain a passion for herpetology for almost a quarter of a century.

Abstract

The invasive spread of exotic plants into native vegetation can pose serious threats to native faunal assemblages. This is of particular concern for reptiles and amphibians because they form a significant component of the world's vertebrate fauna, play a pivotal role in ecosystem functioning and are often neglected in biodiversity research. A framework to predict how exotic plant invasion will affect reptile and amphibian assemblages is imperative for conservation, management and the identification of research priorities.

In this thesis I present and test the first predictive framework to describe the impacts of exotic plant invasions on reptiles and amphibians. Central to the framework is the identification of exotic plant and native reptile and amphibian life-history traits that influence the response of reptiles and amphibians to exotic plant invasion. These traits are integrated into three mechanistic models based on exotic plant invasion altering: (1) habitat structure; (2) herbivory and predator-prey interactions; (3) the reproductive success of reptile and amphibian species and assemblages. With this framework, I identified novel growth forms and structural features of exotic plants and small body size of reptiles and amphibians as life-history traits most likely to be linked to strong and readily detectable impacts of invasion.

A test of framework predictions against available empirical evidence in the literature provided support for predictions from each of the three mechanisms of the framework. I performed field-work to test predictions relating to differential effects of exotic plant growth forms and the susceptibility of small-bodied native reptile and amphibian species to invasion. I compared the impacts of Lantana (*Lantana camara*), which differs strongly in growth form to the dominant native vegetation in the dry sclerophyll forest it invades, and Bitou Bush (*Chrysanthemoides monilifera* ssp. *rotundata*) which provides a similar growth form replacement in the coastal heathland it invades. Lantana significantly altered habitat structure by increasing understorey cover, creating cooler and shadier conditions. Lantana invasion was associated with lower reptile abundance, particularly of the scincid lizard *Lampropholis delicata*, the

smallest reptile species present. In contrast, Bitou Bush did not significantly alter habitat structure, insolation or habitat temperature and was not associated with significant changes in reptile abundance.

The findings of this thesis confirm the importance of plant and animal life-history traits in determining responses of reptiles and amphibians to exotic plant invasions. The trait-based approach employed in this thesis offers considerable benefits to assessing the impacts of exotic plant invasion on native biodiversity. In particular, my framework provides a basis for predicting impacts and determining future research and management priorities.

Table of Contents

Certificate of Authorship/Originality.....	ii
Acknowledgements.....	iii
Abstract.....	v
Table of Contents.....	vii
List of Figures.....	xi
List of Tables.....	xv
Acronyms.....	xviii
Chapter 1: General Introduction.....	1
1.1 Biological invasions.....	1
1.2 Exotic plant invasions.....	2
1.3 Impacts of invasive exotic plants on vertebrates.....	3
1.4 Importance of reptiles and amphibians to biodiversity.....	4
1.5 Research significance and objectives.....	5
1.6 Thesis objectives.....	6
1.7 Thesis structure.....	7
Chapter 2: A predictive framework and review of the ecological impacts of exotic plant invasions on reptiles and amphibians.....	10
2.1 Introduction.....	10
2.2 Conceptual framework and mechanisms of impact.....	12
2.2.1 Model 1: changes to habitat structure quality and heterogeneity.....	14
2.2.2 Model 2: alteration of herbivory and predator-prey interactions.....	26
2.2.3 Model 3: modification of reproductive success.....	31
2.3 Management implications and future research opportunities.....	36
2.4 Conclusions.....	37

Chapter 3: How do native reptile assemblages respond to invasion by exotic plant species of differing growth form.....	39
3.1 Introduction.....	39
3.2 Methods.....	40
3.2.1 Site descriptions and experimental design.....	41
3.2.1.1 Lantana study.....	41
3.2.1.2 Bitou study.....	44
3.2.1.3 Study sites.....	46
3.2.2 Reptile and amphibian sampling.....	47
3.2.3 Statistical analyses.....	50
3.2.4 Amphibian species richness and abundance.....	50
3.3 Results.....	51
3.3.1 Lantana study.....	51
3.3.2 Bitou study.....	55
3.4 Discussion.....	59
Chapter 4: Response of a native reptile assemblage to spot-spraying of Bitou Bush, <i>Chrysanthemoides monilifera</i> ssp. <i>rotundata</i>, with glyphosate herbicide	63
4.1 Introduction.....	63
4.2 Methods.....	64
4.2.1 Site descriptions and experimental design.....	64
4.2.2 Statistical analyses.....	65
4.3 Results.....	65
4.4 Discussion.....	68
Chapter 5: Impacts of Lantana (<i>Lantana camara</i>) and Bitou Bush (<i>Chrysanthemoides monilifera</i> ssp. <i>rotundata</i>) on reptile habitat	71
5.1 Introduction.....	71
5.2 Methods.....	72
5.2.1 Site descriptions and experimental design.....	72
5.2.2 Habitat structure and leaf-litter characteristics	73
5.2.3 Direct solar radiation reaching the ground	75

5.2.4 Leaf-litter temperature.....	76
5.2.5 Statistical analyses.....	77
5.3 Results.....	78
5.3.1 Lantana study.....	78
5.3.1.1 Habitat structure and leaf-litter characteristics.....	78
5.3.1.2 Direct solar radiation reaching the ground.....	82
5.3.1.3 Leaf-litter temperature.....	82
5.3.2 Bitou study.....	82
5.3.2.1 Habitat structure and leaf-litter characteristics.....	82
5.3.2.2 Direct solar radiation reaching the ground.....	87
5.3.2.3 Leaf-litter temperature.....	87
5.4 Discussion.....	87
Chapter 6: Impacts of Lantana (<i>Lantana camara</i>) and Bitou Bush (<i>Chrysanthemoides monilifera ssp. rotundata</i>) on the availability of invertebrate prey for reptiles.....	93
6.1 Introduction.....	93
6.2 Methods.....	94
6.2.1 Site descriptions and experimental design.....	94
6.2.2 Invertebrate sampling and identification.....	94
6.2.3 Statistical analyses.....	97
6.3 Results.....	98
6.3.1 Lantana study.....	98
6.3.2 Bitou study.....	102
6.4 Discussion.....	105
Chapter 7: A comparison of short-term marking methods for small frogs using a model species, the striped marsh frog (<i>Limnodynastes peronii</i>).....	109
7.1 Introduction.....	109
7.2 Methods.....	109
7.2.1 Experimental design and marking procedures.....	110
7.2.2 Statistical analyses.....	112
7.3 Results.....	112

7.4 Discussion.....	112
Chapter 8: General discussion.....	115
8.1 Were the objectives of this thesis met?.....	115
8.2 Research significance and management implications.....	119
8.3 Future research directions.....	121
8.4 Conclusion.....	123
Appendix 1. GLM results for modified analysis of reptile abundance and species richness in relation to invasion of dry sclerophyll forest by <i>Lantana camara</i>.....	125
References.....	126

List of Figures

Figure 2.1 Three mechanisms determining the impacts of exotic plants on reptiles and amphibians and the role of plant reptile/amphibian traits. Intensity of response to invasion increases from right to left in relation to plant reptile/amphibian traits (top arrow). The timeframe for detectable impacts increases from left to right (bottom arrow).....	13
Figure 3.1 Dry sclerophyll forest and invasion of <i>Lantana camara</i> . Uninvaded vegetation (a), invaded vegetation (b).....	42
Figure 3.2 Coastal heathland and invasion of <i>Chrysanthemoides monilifera</i> ssp. <i>rotundata</i> . Uninvaded vegetation (a), invaded vegetation (b).....	42
Figure 3.3 Location of Lantana study sites in the Newcastle/Lake Macquarie area of NSW.....	43
Figure 3.4 Location of Bitou study sites in the Botany Bay and Kurnell Peninsula area of NSW.....	45
Figure 3.5 Schematic representation of large (50 m x 50 m) study plots.....	48
Figure 3.6 Schematic representation of small (50 m x 20 m) study plots.....	48
Figure 3.7 Mean abundance/100 m ² (\pm SE) of (a) all reptiles, (b) <i>Lampropholis delicata</i> , (c) all reptile species excluding <i>Lampropholis delicata</i> compared between sites of dry sclerophyll forest invaded by <i>Lantana camara</i> and uninvaded sites.....	52
Figure 3.8 Mean reptile species richness/100 m ² (\pm SE) compared between sites of dry sclerophyll forest invaded by <i>Lantana camara</i> and uninvaded sites.....	53
Figure 3.9 Mean abundance/100 m ² (\pm SE) of (a) all reptiles, (b) <i>Lampropholis</i> spp., (c) all reptile species excluding <i>Lampropholis</i> spp. compared between sites of coastal heathland invaded by <i>Chrysanthemoides monilifera</i> ssp. <i>rotundata</i> and uninvaded sites.....	56

Figure 3.10 Mean reptile species richness/100 m ² (± SE) compared between sites of coastal heathland invaded by <i>Chrysanthemoides monilifera</i> ssp. <i>rotundata</i> and uninvaded sites.....	57
Figure 4.1 Mean reptile abundance/100 m ² (± SE) at uninvaded, invaded and sprayed sites, before (autumn 2010) and after (spring 2010 and summer 2011) application of glyphosate herbicide to Bitou Bush (<i>Chrysanthemoides monilifera</i> ssp. <i>rotundata</i>) at sprayed sites.....	66
Figure 4.2 Mean reptile species richness/100 m ² (± SE) at uninvaded, invaded and sprayed sites, before (autumn 2010) and after (spring 2010 and summer 2011) application of glyphosate herbicide to Bitou Bush (<i>Chrysanthemoides monilifera</i> ssp. <i>rotundata</i>) at sprayed sites.....	66
Figure 5.1 Arrangement of habitat sampling areas in large (50 m x 50 m) study plots.....	74
Figure 5.2 Arrangement of habitat sampling areas in small (50 m x 20 m) study plots.....	75
Figure 5.3 Mean understorey projected foliage cover (± SE) compared between sites of dry sclerophyll forest invaded by <i>Lantana camara</i> and uninvaded sites.....	70
Figure 5.4 Mean percentage cover of <i>Lantana camara</i> (± SE) compared between invaded and uninvaded dry sclerophyll forest sites.....	70
Figure 5.5 Mean percentage of exotic leaf-litter (± SE) compared between sites of dry sclerophyll forest invaded by <i>Lantana camara</i> and uninvaded sites.....	81
Figure 5.6 Daily mean (± SE) direct photosynthetically active radiation (PAR) (measured as Mols m ⁻² d ⁻¹) reaching the ground compared between sites of dry sclerophyll forest invaded by <i>Lantana camara</i> and uninvaded sites.....	81

Figure 5.7 Mean leaf-litter temperatures (\pm 95% CI) compared between sites of dry sclerophyll forest sites invaded by <i>Lantana camara</i> and uninvaded sites in (a) autumn 2010, (b) spring 2010, (c) summer 2011.....	83
Figure 5.8 Mean leaf-litter temperatures (\pm SE) during reptile sampling hours (0900-1100 and 1500-1700) compared between dry sclerophyll forest invaded by <i>Lantana camara</i> and uninvaded sites.....	84
Figure 5.9 Mean percentage cover of <i>Chrysanthemoides monilifera</i> ssp. <i>Rotundata</i> (\pm SE) compared between invaded and uninvaded coastal heathland sites.....	85
Figure 5.10 Mean percentage of exotic leaf-litter (\pm SE) compared between sites of coastal heathland invaded by <i>Chrysanthemoides monilifera</i> ssp. <i>rotundata</i> and uninvaded sites.....	86
Figure 5.11 Daily mean (\pm SE) direct photosynthetically active radiation (PAR) (measured as Mols m ⁻² d ⁻¹) reaching the ground compared between sites of coastal heathland invaded by <i>Chrysanthemoides monilifera</i> ssp. <i>rotundata</i> and uninvaded sites.....	86
Figure 5.12 Mean leaf-litter temperatures (\pm 95% CI) compared between coastal heathland sites invaded by <i>Chrysanthemoides monilifera</i> ssp. <i>rotundata</i> and uninvaded sites in (a) autumn 2010, (b) spring 2010, (c) summer 2011.....	88
Figure 5.13 Mean leaf-litter temperatures (\pm SE) during reptile sampling hours (0900-1100 and 1500-1700) compared between coastal heathland sites invaded by <i>Chrysanthemoides monilifera</i> ssp. <i>rotundata</i> and uninvaded sites.....	89
Figure 6.1 Arrangement of invertebrate pitfall traps in large (50 m x 50 m) study plots.....	96
Figure 6.2 Arrangement of invertebrate pitfall traps in small (50 m x 20 m) study plots.....	96
Figure 6.3 Invertebrate pitfall trap (a) and wooden cover to exclude vertebrates (b).....	97

Figure 6.4 Mean abundance (\pm SE) of invertebrates compared between sites of dry sclerophyll forest invaded by <i>Lantana camara</i> and uninvaded sites.....	99
Figure 6.5 Mean invertebrate morphospecies richness (\pm SE) compared between sites of dry sclerophyll forest invaded by <i>Lantana camara</i> and uninvaded sites.....	99
Figure 6.6 Non-metric multidimensional scaling (nMDS) plots comparing the composition of leaf litter invertebrate assemblages between dry sclerophyll forest sites invaded by <i>Lantana camara</i> (L1-L5) and uninvaded forest sites (C1-C5) in (a) autumn 2010, (b) spring 2010 and (c) summer 2011.....	101
Figure 6.7 Mean abundance (\pm SE) of invertebrates compared between sites of coastal heathland invaded by <i>Chrysanthemoides monilifera</i> ssp. <i>rotundata</i> and uninvaded sites.....	102
Figure 6.8 Mean invertebrate morphospecies richness (\pm SE) compared between sites of coastal heathland invaded by <i>Chrysanthemoides monilifera</i> ssp. <i>rotundata</i> and uninvaded sites.....	103
Figure 6.9 Non-metric multidimensional scaling (nMDS) plots comparing the composition of leaf litter invertebrate assemblages between coastal heathland sites invaded by <i>Chrysanthemoides monilifera</i> ssp. <i>rotundata</i> (B1-B5) and uninvaded sites (C1-C5) in (a) autumn 2010, (b) spring 2010 and (c) summer 2011.....	104
Figure 7.1 Retention times (days) for marks applied to feet of <i>Limnodynastes peronii</i> using gentian violet, mercurochrome and powdered fluorescent pigment.....	113
Figure 7.2 Weight change (day 1 to day 5) of <i>Limnodynastes peronii</i> marked with either gentian violet, mercurochrome or powdered fluorescent pigment.....	113

List of Tables

Table 2.1 Studies examining the ecological impacts of exotic plants on reptiles and amphibians. Ecological measures include species richness or abundance. Effect indicates the change in species richness or abundance (+ = increase in abundance or richness, - = decrease, 0 = no change).....	14
Table 2.2 Australian reptile species identified as threatened by exotic plants. Selected reptile traits (native habitat, size, reproductive strategy and diet)and the threatening plant species are listed. SL = shell length; SVL = snout-vent length; TL = total length; Generic = general threat from exotic plants with no particular exotic plant species identified. Sources include Cogger (2000), Coutts-Smith & Downey (2006), Department of Environment and Climate Change (2009), Department of Environment, Water, Heritage and the Arts (2009) and Wilson & Swan (2010).....	15
Table 2.3 Australian amphibian species identified as threatened by exotic plants. Selected amphibian traits (native habitat, size, parental transport and diet) and the threatening plant species are listed. Generic = general threat from exotic plants with no particular exotic plant species identified. Sources include Cogger (2000), Coutts-Smith & Downey (2006), Department of Environment and Climate Change (2009) and Department of Environment, Water, Heritage and the Arts (2009).....	19
Table 3.1 Geographic location and elevation data for Lantana study sites. NP = National Park, SP = State Park, NR = Nature Reserve, SCA = State Conservation Area. All plot sizes = 50 m x 50 m.....	44
Table 3.2 Geographic location and elevation data for Bitou study sites. NP = National Park. ¹ = large plot (50 m x 50 m), ² = small plot (50 m x 20 m), see ‘Study sites’ in the Methods for details about plot sizes.....	46
Table 3.3 GLM results for reptile abundance and species richness in relation to invasion of dry sclerophyll forest by <i>Lantana camara</i> . Significant <i>P</i> values are in bold. ‘Condition’ = invaded or uninvaded, ‘Time’ = autumn, spring or summer.....	51

Table 3.4 Total abundance of reptile species compared between sites of dry sclerophyll forest invaded by *Lantana camara* and uninvaded sites in Autumn 2010, Spring 2010 and Summer 2011. ¹ = five sites sampled, ² = four sites sampled.....54

Table 3.5 GLM results for reptile abundance and species richness in relation to invasion of coastal heathland by *Chrysanthemoides monilifera* ssp. *rotundata*. ‘Condition’ = invaded or uninvaded, ‘Time’ = autumn, spring or summer.....55

Table 3.6 Total abundance of reptile species compared between sites of coastal heathland invaded by *Chrysanthemoides monilifera* ssp. *rotundata* and uninvaded sites. ¹ = five sites sampled, ² = three sites sampled.....58

Table 4.1 Reptile species found in Bitou Bush (*Chrysanthemoides monilifera* ssp. *rotundata*) before and after herbicide spraying (‘Sprayed’) in autumn 2010 compared with ‘Unsprayed’ Bitou Bush and ‘Uninvaded’ vegetation. + = present; - = absent.....67

Table 5.1 GLM results for habitat structure characteristics in relation to invasion of dry sclerophyll forest by *Lantana camara*. Significant *P* values are in bold. ‘Condition’ = invaded or uninvaded, ‘DBH’ = diameter at breast height.....79

Table 5.2 Results of GLMMs for average leaf-litter temperature during reptile sampling hours (0900-1100 and 1500-1700) in relation to invasion of dry sclerophyll forest by *Lantana camara*. Significant *P* values are in bold. Condition = invaded or uninvaded, ‘Site’ is nested within ‘Condition’; ¹ = $F_{1,26}$, ² = $F_{1,24}$, “-“ = non-significant interaction removed from the model as its inclusion led to over-parameterisation of the model..84

Table 5.3 GLM results for habitat structure characteristics in relation to invasion of coastal heathland by *Chrysanthemoides monilifera* ssp. *rotundata*. ‘Condition’ = invaded or uninvaded, ‘DBH’ = diameter at breast height.....85

Table 5.4 Results of GLMMs for average leaf-litter temperature during reptile sampling hours (0900-1100 and 1500-1700) in relation to invasion of coastal heathland by *Chrysanthemoides monilifera* ssp. *rotundata*. Significant *P* values are in bold. Condition = invaded or uninvaded, 'Site' is nested within 'Condition'; ¹ = $F_{1,30}$, ² = $F_{1,25}$, ³ = $F_{1,24}$ “-“ = non-significant interaction removed from the model as its inclusion led to over-parameterisation of the model.....89

Table 6.1 GLM results for invertebrate abundance and morphospecies richness in relation to invasion of dry sclerophyll forest by *Lantana camara*. Significant *P* values are in bold. 'Condition' = invaded or uninvaded, 'Time' = autumn, spring or summer.....100

Table 6.2 ANOSIM results comparing invertebrate assemblages between dry sclerophyll sites invaded by *Lantana camara* and uninvaded sites in autumn 2010, spring 2010 and summer 2011.....100

Table 6.3 GLM results for invertebrate abundance and morphospecies richness in relation to invasion of coastal heathland by *Chrysanthemoides monilifera* ssp. *rotundata*. Significant *P* values are in bold. 'Condition' = invaded or uninvaded, 'Time' = autumn, spring or summer.....103

Table 6.4. ANOSIM results comparing invertebrate assemblages between coastal heathland sites invaded by *Chrysanthemoides monilifera* ssp. *rotundata* and uninvaded sites in autumn 2010, spring 2010 and summer 2011.....105

Acronyms & Abbreviations

ANOSIM	Analysis of Similarity
ANOVA	Analysis of Variance
C	Carbon
CI	Confidence Interval
DBH	Diameter at Breast Height
ESD	Environmental Sex Determination
EST	Eastern Standard Time
GLM	General Linear Model
GenLMM	Generalised Linear Model
GLMM	Generalised Linear Mixed Model
GSD	Genotypic Sex Determination
HSD	Honestly Significant Difference
LSD	Least Significant Difference
M-BARCI	Multiple Before-After Reference Control-Impact
PAR	Photosynthetically Active Radiation
N	Nitrogen
nMDS	Non-metric Multidimensional Scaling
NSW	New South Wales
P	Phosphorus
SE	Standard Error
SL	Shell Length
SVL	Snout-Vent Length
TL	Total Length
TSD	Temperature-dependent Sex determination
UV	Ultraviolet