

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

**Developing biosecurity strategies for an invasive reptile,
the plague skink (*Lampropholis delicata*) on Great Barrier Island**

**A thesis presented in partial fulfilment of the requirements for the
degree of**

**Master of Science in Conservation Biology
at Massey University, Albany
New Zealand**

Jacqueline Wairepo

2015

***“May your trails be crooked, winding, lonesome, dangerous,
leading to the most amazing view.***

May your mountains rise into and above the clouds”

Edward Abbey



Abstract

Human exploration has a long history of removing geographical barriers and facilitating species dispersal. In the last 100 years alone, human activities and international trade have further circumvented these biogeographic boundaries, allowing species to access, establish and impact novel locations at an unprecedented rate.

The biological invasion process is composed of three distinct phases: arrival, establishment and spread. Once established, pest species across plant, invertebrate and vertebrate taxa can cause substantial harm to ecosystems and have severe socioeconomic impacts. Management of pest invasion has historically been reactionary, however, as the consequences have become increasingly apparent, conservation managers and invasion biologists have redirected their focus towards arrival prevention where possible. While efforts have been largely focussed on terrestrial vertebrates, there has been a distinct lack of progression in the development of effective control and eradication techniques for invasive herpetofauna.

The Australian plague skink (*Lampropholis delicata*) arrived in New Zealand in the late 1960s and has rapidly dispersed throughout much of the North Island. Additionally, it has established thriving populations on several off-shore islands in Auckland's Hauraki Gulf. It is now considered as New Zealand's only established pest reptile species since it's classification as an Unwanted Organism under the Biosecurity Act (1993) in 2010. The discovery of *L. delicata* on Great Barrier Island (Aotea) in April 2013 and subsequent biosecurity incursion response have provided the opportunity to test and develop effective control and eradication techniques in the absence of any existing management strategy for this species.

To test and evaluate techniques of detection for low density populations of *L. delicata*, we designed a surveillance system to locate the dispersal pathways and range limits of the plague skink population at Tryphena Wharf, Great Barrier Island. Approximately 750 traps were installed and serviced according to a mixture of standard and removal sampling designs. No skinks were found beyond the estimated boundary line which was supported statistically with 95% confidence.

To test and evaluate eradication techniques we designed a trapping grid system to parameterize the requirements of reducing the plague skink population to extinction using a highly adaptive and experimental operational framework. Two grids were set up using three standard herpetological monitoring trap types at varying spatial intensities according to the practicalities of the heterogeneous and often inaccessible landscape. Intensive trapping was implemented for several months before the effort and tools were statistically evaluated for their efficiency. Logistic ANCOVA indicates the effort was not sufficient, suggesting that greater intensity, greater efficiency or alternative methodologies are required.

To support a multi-faceted management approach a controlled laboratory trial was implemented to test the oral toxicity of acetaminophen to plague skinks. An 'Up-down procedure' was used to calculate the lethal dose required to kill 50% of the population (LD50). Acetaminophen was found to be lethal at a 550 mg/kg dosage, indicating its potential as a commercially viable toxicant.

An urgent focus on the development of effective techniques is required to manage invasive herpetofauna, which are becoming globally problematic at an increasing rate. Our operational field effort and research will make a practical and meaningful contribution towards the development of this field of invasion biology.

Acknowledgements

Wow what a ride! The journey this research has taken me on has been filled with adventure, excitement, frustration, elation and quite literally a bit of blood, a lot of sweat and, dare I say it, a few tears as well.

I'd like to extend a sincere and heartfelt thanks to my supervisors Professor Dianne Brunton of Massey University and Dr Nick Waipara of the Auckland Council, for letting me be so independent, run free, make mistakes, learn a lot and pull it all together in a last minute sprint to the finish line. Your time, assistance and guidance has been greatly appreciated.

A huge thanks to the Auckland Council Biosecurity team, without your financial and emotional support none of this research would have been possible. To the silver foxes Jeff Cook and Brian Shields (a.k.a 'Uncle'), your wise words, encouragement and terrible 'dad jokes' have been excellent. Thank you for not yelling at me for 'blowing the budget' with my crazy ideas. I feel extremely privileged to have worked with you both and look forward many more Treasure Island adventures in the future. To the Unitec staff Dr Diane Fraser, Mel Galbraith and Dr Nigel Adams who supported this research through the provision of fantastic student helpers Sarah Killick, Shanti Morgan and Molly Wilson, a sincere thank you all. And of course to the Auckland Council team on Great Barrier, especially Jeremy Warden, thank you so very much for a warm welcome, listening to frustrated ramblings and supporting my work. And to my island family (the Langfords) and friends, my time over there would not have been the completely wonderful experience it was without each of you.

To my super dooper awesome 'Skinkinators' you guys are awesome! And to my Co-chief Skinkinator Halema Jamieson, you are amazing, talented and a true inspiration. Your guidance, advice and shoulder were so very appreciated. Thank you also to Envirokiwi for providing me with such a great bunch of people to work alongside. Huge thanks must also be extended to Andy Warneford for your help, hard work and mutual respect for great coffee.

A further thank you must be extended to the Department of Conservation and the Lizard Technical Advisory Group for your assistance with permits, funding and letting me have use of the outstanding Dr James Reardon. James, your involvement with this project has been fantastic, I'm so very grateful.

A huge thanks to Massey University for supporting this project via the Massey Masterate Scholarship fund, which meant I wasn't reduced to eating out of the noodle pot like so many other poor students. To staff and fellow students at Massey University, a collective 'thank you' for creating such a warm and encouraging environment for this very green ecologist. A special thanks to my late night study buddy Tom Dixon for motivating me to keep going even when the food coma kicked in and all I wanted to do was crawl on the couch and nap. Thank you to Dr Aaron Harmer and Dr David Aguirre for the much needed and last minute stats help when I developed a terrible reaction to 'R', my thesis is so much better for it. To my Building 5 buddies Moeo Finauga, Jessica Perez, Wesley Webb, Luca Butikofer, Marleen Baling, Manu Barry and Luis Ortiz-Catedral, it is always inspirational to be around clever, talented and passionate people such as yourselves. Huge thanks to my dear friend Lydia Tyrrell for the last minute proof reading and a million thanks to my super talented friend Victoria Jollands for motivation, support and work opportunities during these final stages when things have been so stressful.

To all of the awesome fellow 'lizard geeks' I've met along the way. It is an absolute pleasure to geek out with you over lizards when I have the rare opportunity to do so. A special thanks to those of you in the 'Plague skink TAG' for your brainstorming and input to the project.

To my friends who have put up with my extended period of time on the 'downlow'. I have missed birthday parties, baby birthday parties, baby showers, dinners, lunches and so many get togethers I have lost count. I am so thankful my 'Peter Pan' years have finally come to an end and I will once again have time to spend with you all.

And finally to my family. To my parents who have supported me and watched me get progressively crankier over these past four weeks, to my sister and brother in law who I have all but ignored since their return from the UK two months ago and my cousin Tracey (and family), for squeezing in some formatting time when you had better things to do. You guys are awesome, let the good times roll! And to my amazing and tireless husband Daniel for working around the clock to save up for our holiday while I sat chained to the computer these past several months. I am so grateful for your patience and your MasterChef cooking.

And a final shout out to the big guy upstairs for your ever present reassurance and guidance through this journey, without which I may not have made it to the top of this epic mountain.

Table of Contents

Abstract.....	v
Acknowledgements.....	vii
List of Tables	xiii
List of Figures.....	xiii
List of Plates.....	xiv
Chapter 1	1
1.1 Introduction to invasion biology	2
1.2 Introductions and pathways	3
1.2.1 Unintentional vectors and pathways	5
1.2.2 Intentional vectors and pathways	6
1.3 Invasability – the major hypotheses	6
1.3.1 The enemy release hypothesis	7
1.3.2 Empty niche hypothesis	7
1.3.3 Environmental resistance hypothesis	7
1.3.4 Island invasibility hypothesis	8
1.3.5 Disturbance hypothesis.....	9
1.3.6 Propagule pressure hypothesis.....	10
1.3.7 Invasion meltdown hypothesis	11
1.4 The invasion process.....	11
1.4.1 Population growth & lag phase.....	13
1.4.2 Dispersal & range expansion.....	14
1.5 Management.....	15
1.5.1 Adaptive management.....	16
1.6 Invasive reptiles	17
1.6.1 General.....	17
1.6.2 Ecological Impacts.....	18
1.6.3 Economic & Social impacts	20
1.6.4 Management of invasive herpetofauna.....	21
1.6.5 Plague skinks	22
1.6.6 Management gaps	28
1.7 Research objectives	30
1.8 Thesis structure	30

Chapter 2.....	32
2.1 Abstract	33
2.2 Introduction	34
2.2.1 Biosecurity surveillance	34
2.2.2 Survey design.....	35
2.2.3 Detectability	36
2.2.4 Detecting invasive reptiles	38
2.3 Study rationale.....	40
2.4 Aims.....	41
2.5 Methodology.....	42
2.5.1 Background.....	42
2.5.2 General	43
2.5.3 Sticky trap shelter construction & deployment	44
2.5.4 Predation mitigation.....	44
2.5.5 Weather conditions	45
2.5.6 Capture and dispatch.....	46
2.5.7 Dispersal pathway identification	47
2.5.8 Delimitation	48
2.5.9 The Model.....	49
2.6 Results	52
2.6.1 General	52
2.6.2 Dispersal pathways.....	54
2.6.3 Delimitation	55
2.6.4 Data Analysis	56
2.7 Discussion	58
2.7.1 Survey design.....	58
2.7.2 Dispersal pathway	61
2.7.3 The model.....	63
2.8 Conclusions	66
Chapter 3.....	67
3.1 Abstract	68
3.2 Introduction	69
3.2.1 History of eradication	70
3.2.2 Requirements of a successful eradication.....	71
3.2.3 Eradication, control or containment?	73
3.2.4 Development of techniques	74

3.2.5 Methods for lizard and amphibian eradications.....	76
3.2.6 Traditional reptile capture techniques	77
3.2.7 Measuring success	81
3.2.8 Advantages and disadvantages of eradication	82
3.3 Study rationale	86
3.4 Aims.....	86
3.5 Methodology.....	87
3.5.1 General.....	87
3.5.2 Grid 1.....	88
3.5.3 Grid 2.....	88
3.5.4 Trap clusters.....	88
3.5.5 Lizard gondolas	88
3.5.6 Trap types	90
3.5.7 Identification	93
3.5.8 Release	94
3.5.9 Morphometric data collection	95
3.5.10 Euthanasia.....	95
3.5.11 Data analysis and statistics	96
3.6 Results	97
3.6.1 Capture results.....	97
3.6.2 Spatial distribution.....	100
3.6.3 Capture trend.....	102
3.6.4 Statistical analysis	103
3.7 Discussion	104
3.7.1 System evaluation	104
3.7.2 Tool evaluation	106
3.7.2.1 Pitfall traps	106
3.7.2.2 G-minnow traps	106
3.7.2.3 Invertebrate sticky traps	107
3.7.3 Study limitations - balancing operational and research goals	109
3.7.4 Learning and innovation	111
3.8 Conclusion.....	112
Chapter 4.....	113
4.1 Abstract	114
4.2 Introduction	115
4.2.1 Toxicant use in invasion biology and conservation	115

4.2.2 Ecotoxicology of reptiles	116
4.2.3 Invasive reptiles.....	117
4.2.4 Classes of toxicants.....	118
4.2.5 Metabolism of toxicants.....	118
4.2.6 Toxicity Testing	120
4.2.7 Acetaminophen	123
4.3 Study Rationale	125
4.4 Aims.....	126
4.5 Methods	126
4.5.1 Pre treatment	126
4.5.2 UDP dosage methodology	127
4.5.3 Toxicant preparation	127
4.5.4 Administration.....	129
4.5.5 Post treatment.....	129
4.5.6 Analysis	131
4.5.6.1 Stopping point	132
4.6 Results	132
4.6.1 LD50.....	132
4.6.2 Signs of toxicity.....	134
4.6.3 Post mortem	134
4.6.4 Histopathology	134
4.7 Discussion	136
4.7.1 Case study: Brown tree snake (<i>B. irregularis</i>).....	136
4.7.2 Treatment on other reptiles.....	137
4.7.3 LD50 results	138
4.7.4 Histopathology results.....	139
4.7.5 Signs of toxicity.....	140
4.8 Conclusions	141
Chapter 5.....	142
5.1 Synopsis	143
5.2 Management options	144
5.2.1 Management	144
5.2.2 Research	146
5.3 Final remarks.....	147
References.....	149

Appendix 1: Optimal number of traps required over 14 nights	170
Appendix 2: High impact, research and collection permit (# 36317-FAU)	171
Appendix 3: Acetaminophen trial data for each skink dosed	172
Appendix 4: Toxicology report from Dr Cathy Harvey of the NZVP	173

List of Tables

Table 2.1	Weather scale for data collection	48
Table 2.2	Transect and grid data	55
Table 3.1	Essential requirements and desirable attributes of an eradication	75
Table 3.3	Plague skink capture results by month and by trap type	101
Table 4.1	Chemical properties of acetaminophen	129
Table 4.2	Dosage calculations according to the UDP scale	134
Table 4.3	Acetaminophen dose-related mortality	138
Table 4.4	Histology results	140

List of Figures

Figure 1.1	Number of citations between 1975 – 2005 including terms ‘invas’ and ‘ecol’	3
Figure 1.2	Herpetofaunal introduction pathways	5
Figure 1.3	Ship traffic evolution between 1992 – 2002 and 2003 – 2012	6
Figure 1.4	The invasion process	13
Figure 1.5	Population growth through the lag phase process	15
Figure 1.6	Native distribution range of <i>Lampropholis delicata</i>	24
Figure 1.7	<i>L. delicata</i> identification diagram	29
Figure 2.1	Location map of original and relocated delimitation boundary lines	45
Figure 2.2	Location map of delimitation transects and grids	51
Figure 2.3	Location map of <i>L. delicata</i> detections	56
Figure 2.4	Location map of <i>L. delicata</i> distribution	58

Figure 2.5	Detectability curve	59
Figure 2.6	Location map of dispersal pathways	65
Figure 3.1	Graph of the successful eradications since 1950	74
Figure 3.2	Biological invasion strategic management process	76
Figure 3.3	Location map showing trapping grid boundaries	90
Figure 3.4	Location map of trapping Grid layout by trap type	95
Figure 3.5	Proportional graph of plague skink captures by age class	102
Figure 3.6	Proportional graph of plague skink captures by sex	102
Figure 3.7	Spatial distribution diagram of plague skink captures at trap level	104
Figure 3.8	Graphs of cumulative number of plague skink captures over time	106
Figure 3.9	Regression of plague skink captures per trap type	124
Figure 4.1	Diagram of fate and effect of toxicants in the body	126
Figure 4.2	Typical dose response curve	126
Figure 4.3	Molecular formula for acetaminophen	128
Figure 4.4	Dose response curve for trial	138

List of Plates

Plate 1.1	Sealink barge transporting cars, trailers and freight	28
Plate 2.1	Custom made corflute trap shelter	46
Plate 2.2	Six plague skinks captured on a sticky trap	63
Plate 2.3	Two native skinks captured on a sticky trap	63
Plate 2.4	Drift fence installed at the delimitation line	64
Plate 3.1	Lizard traps	83
Plate 3.2	Installation of the Lizard Gondola system in Grid 1	92
Plate 3.3	Lizard Gondolas set up in Grid 2	93
Plate 3.4	<i>L. delicata</i> identification via head scale	96
Plate 3.5	Removal of skink from sticky trap	97
Plate 3.6	Euthanized female plague skink with exposed egg clutch	98
Plate 3.7	Sticky traps fouled with leaf litter	112
Plate 4.1	Acetaminophen tablet prepared for dosage	133
Plate 4.2	Plague skink returned to cage post-treatment	135
Plate 4.3	Plague skink and locust	135