AN INVESTIGATION OF THE INVASION DYNAMICS OF *ASPARAGUS ASPARAGOIDES* AT THE HABITAT LEVEL USING SPATIAL ANALYTICAL TECHNIQUES

KRIS SIDEROV

BSc (Optometry) (*University of Melbourne*), GradDipNeuroscience (*Lincoln Institute of Health Sciences*), GradDipErgonomics (*Lincoln Institute of Health Sciences*), BAppSc (Environmental Science) (*CSU*)

SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

SCHOOL OF MATHEMATICAL AND GEOSPATIAL SCIENCES

PORTFOLIO OF SCIENCE, ENGINEERING AND TECHNOLOGY

RMIT UNIVERSITY

MELBOURNE, VICTORIA

AUGUST 2005

DECLARATION

This thesis contains no material that has been accepted for the award of any other higher degree or graduate diploma in any tertiary institution. This thesis contains work of mine alone and to the best of my knowledge and belief contains no material previously published or written by any person, except where due reference is made in the text. Furthermore, the work presented has been carried out since the official starting date of the program.

Kris Siderov

August 2005

ACKNOWLEDGEMENTS

I would like to thank Professor Kim Lowell for taking me on as a PhD student and giving me free reign to develop my research, especially as he only spent four months of the year at RMIT University. I appreciate Kim's time and patience, particularly when I was trying to understand some of the subtleties surrounding Ripley's K function and logistic regression. I would also like to thank him for the seemingly instant return of any writings I had sent to him for critical comment. I must admit that on receiving back my first attempt I found his judicious use of the red pen initially unnerving. Thanks also to Dr Nigel Ainsworth for his help and encouragement during my candidature. Nigel also was quick to return anything I sent to him for comment and provided me with the opportunity to make the best use of the data I collected. I am also in debt to Dr Jann Williams for her input during the early stages of my research, in particular her comments and suggestions that helped me in my review of the literature. Chris Bellman took on the task of supervision in the late stages of my research. While I thought it would be primarily an administrative role, it quickly became apparent that a simple question by Chris could often lead to lengthy discussion about aspects of the study that I initially thought were straightforward. His help in keeping things in perspective, especially when the comments from Kim and Nigel about a particular topic seemed at odds with each other was very welcome.

Many of the staff from the Geospatial Sciences gave freely of their time and expertise in areas for which I had no previous experience in or existed as a faded memory. I also enjoyed the camaraderie of my fellow postgraduate colleagues, in particular to Prem Chhetri, Scott Wiley, Dale Watson and Darren Baldyga who provided an interesting mix of experience and intellectual discussion, Tawee Chaipimonplin for helping out with the collection of data used in chapter five. Thanks also to Cristhiane da Silva Ramos for her addiction to coffee and listening skills and Joanne Kuluveovski for reading through initial drafts of the first three chapters.

This thesis was undertaken with the financial support of the Australian Government through an Australian Postgraduate Award and supplemented by a top up scholarship from the CRC for Australian Weed Management. Thanks also to the people involved with Phillip Island Landcare, in particular Kellie Nichols, for their support and cooperation.

Finally I wish to thank my wife Christine and my son Alexander for their support during the research, sharing the highlights and the low points and putting up with me for the duration.

TABLE OF CONTENTS

DECLARATION....................i

ACKNOWLEDGEMENTS....................ii

LIST OF FIGURES....................xi

LIST OF TABLES....................xvii

ABSTRACT....................xxi

INTRODUCTION AND THESIS OVERVIEW....................1

1.1 Environmental change....................2

1.2 Invasive species in a fragmented landscape....................3

1.3 Invasion success and seed dispersal....................5

1.4 Bird dispersal of *Asparagus asparagoides*....................6

1.5 Research questions....................7

1.6 Thesis layout....................9

1.6.1 Literature review....................9

1.6.2 *Asparagus asparagoides* invasion of remnant vegetation....................10

1.6.3 Application of the findings....................10

1.7 Summary....................10

LITERATURE REVIEW: BIOLOGICAL PLANT INVASIONS....................11

2.0 Introduction....................12

2.1 Historical overview of scientific study of plant invasion....................13

2.1.1 International....................13

2.1.2 The Australian experience....................14

2.1.3 Invasion biology as a sub discipline of ecology 15
2.2 Defining an invasive plant 15
2.3 Key issues in invasion biology 19
2.3.1 Invasiveness - Identifying a potentially invasive plant 20
2.3.2 Invasibility – Disturbance and species diversity 23
2.3.3 Impacts of invasion 25
2.3.4 Invasive species driven change 27
2.4 The Invasion Process 29
2.4.1 Patterns and Rates of invasion 30
2.4.2 Models of invasion – An overview 33
2.5 Seed dispersal 35
2.5.1 Ecology of seed dispersal 35
2.5.2 Dispersal distance 37
2.5.3 Animal behaviour and dispersal patterns 37
2.5.4 Metapopulation dynamics 38
2.5.5 Long distance seed dispersal 39
2.6 Seed dispersal by birds 39
2.6.1 Evolution of avian frugivore dispersed plants 40
2.6.2 Frugivores and heterogeneous habitat 41
2.6.3 Factors controlling seed dispersal by birds 42
2.7 Geographic information systems and modelling 44
2.7.1 GIS and ecological applications 45

2.7.2 GIS in the investigation and management of invasion 46

2.8 Taxonomy of *Asparagus asparagoides* 48

2.8.1 Ecology and life history.. 49

2.8.2 History of invasion 50

2.8.3 Current Victorian distribution 51

2.8.4 Control of *Asparagus asparagoides* invasion 54

2.9 Conclusions 54

FIELD WORK DESIGN AND PRELIMINARY DATA ANALYSIS........................... 56

3.0 Introduction 57

3.1 Factors that influence dispersal of fleshy-fruited species... 58

3.1.1 Frugivore behaviour 60

3.1.2 Landscape elements influencing frugivore behaviour.. 60

3.2 Methods 61

3.2.1 Introduction 61

3.2.2 Site selection.. 62

3.2.3 Oswin Roberts Koala Reserve.. 63

3.3 Field data 64

3.3.1 Quadrat locations.. 64

3.3.2 Software.. 68

3.3.3 Quadrat sampling.. 68

3.3.4 Landscape attributes 69

3.3.5 Vegetative attributes 71

3.3.6 Age of *Asparagus asparagoides* plants ... 74

3.4 Site characteristics ... 76

3.4.1 Landscape attributes ... 77

3.4.2 Vegetation attributes ... 79

3.5 Discussion ... 87

3.6 Summary ... 90

SPATIAL ANALYSIS OF WEED INVASION ... 91

4.0 Introduction ... 92

4.1 Spatial statistics and ecology ... 92

4.2 Spatial point patterns ... 93

4.2.1 Complete spatial randomness ... 95

4.3 Spatial point pattern analysis ... 96

4.3.1 Pattern detectors and CSR ... 96

4.4 Methods ... 97

4.4.1 Data set preparation: Oswin Roberts study site ... 97

4.4.2 Quadrat analysis ... 99

4.4.3 Kernel intensity estimation ... 101

4.4.4 Nearest neighbour analysis ... 102

4.4.5 Ripley's *K*-function ... 102

4.4.6 Spatial autocorrelation methods: Moran's *I* and Geary's *c* ... 104

4.5 Results ... 105

4.5.1 Quadrat analysis ... 105

4.5.2 Kernel estimation 107

4.5.3 Nearest neighbour analysis 108

4.5.4 Moran's *I* and Geary's *c* 109

4.5.5 Ripley's *K*-function 109

4.6 Discussion 114

4.6.1 *Asparagus asparagoides*: A CSR or structured pattern 114

4.6.2 Functional processes that may generate the observed patterns 115

4.7 Summary 118

PATHWAYS & TRACKS: CONDUITS FOR INVASION 120

5.0 Introduction 121

5.1 Methods 122

5.1.1 Site Selection 122

5.1.2 Transects 124

5.1.3 The Sampling Unit (SU) 124

5.1.4 Data Recorded for each Sampling Unit 125

5.1.5 Spatial extent 126

5.1.6 *Asparagus asparagoides* surface 127

5.2 Results 127

5.2.1 Spatial extent 130

5.2.2 *Asparagus asparagoides* surface 132

5.3 Discussion 134

5.4 Summary 137

LOGISTIC REGRESSION MODELLING 139

6.0 Modelling species presence 140

6.1 Multiple logistic regression modelling 143

6.1.1 Logistic regression and the odds ratio 143

6.1.2 Fitting the logistic regression 144

6.1.3 Testing the logistic regression 145

6.1.4 Goodness-of-fit assessment 145

6.2 Methods 146

6.2.1 Data set construction 147

6.2.2 Data set and site characteristics 149

6.2.3 Modelling process 151

6.2.4 Probability mapping 151

6.3 Results 152

6.3.1 ORR.best 152

6.3.2 ORR.simple 155

6.3.3 Is there a significant difference between models? 157

6 3.4 Changing probability threshold values 158

6.3.5 Probability surface 159

6.4 Discussion 160

6.5 Summary 162

MODEL VALIDITY: TESTING AT A SECOND SITE 163

7.0 Introduction 164

7.1 Ventnor Koala Reserve 164

7.2 Methods 167

7.2.1 Introduction 167

7.2.2 Field Data 167

7.2.3 Analysis 169

7.3 Results 172

7.3.1 The Ventnor reserve data set 172

7.3.2 Ventnor reserve site characteristics 173

7.3.3 Mean cover density: tracks and paths 174

7.3.4 Kernel intensity estimation 176

7.3.5 Ripley's *K*-function 178

7.3.6 Spatial extent 180

7.3.7 Logistic modelling 181

7.4 Discussion 189

7.4.1 Initial observations 189

7.4.2 Practical applications of the logistic model 190

7.4.3 Weed management and remnant vegetation 191

7.4.4 Vegetation corridors and weed invasion 192

7.5 Summary 193

CONCLUSIONS 195

8.0 Introduction 196

8.1 Conclusions 196

8.2 Summary of contributions 197

8.3 Summary of limitations of the study 199

8.4 Future directions for research 200

REFERENCES 201

APPENDIX 1 SITE DATA SHEET 221

APPENDIX 2 *ASPARAGUS SCANDENS* 222

APPENDIX 3 LOGISTIC REGRESSION 223

LIST OF FIGURES

Figure 1–1. Number of vegetation remnants in fragmented vegetation in the IBRA subregions. (Source: http://audit.ea.gov.au/anra/vegetation/docs/native_vegetation). 4

Figure 1–2. The seed dispersal cycle. The right side of the cycle (red text) indicates seed dispersal while the left half of the cycle (green text) refers to the consequence of dispersal. Patterns are shown as boxed text while the processes generating the patterns are given by text outside the boxes. Source: (Wang and Smith 2002). 5

Figure 2–1. Long-standing view of the stages of invasion. 31

Figure 2–2. A new stage approach in the study of invasion. Each stage is reached through the combination of up to three interactions that can act in a positive or negative way. Modified from Colautti and MacIsaac (2004). 32

Figure 2–3. Major causes and consequences of patterns among seeds at various stages. Unbroken arrows represent processes, broken arrows show influences upon these processes, broken boxes indicate influencing factors, and rounded boxes indicate that the dispersion patterns of that stage are of interest. Source: (Nathan 2001). 36

Figure 2–4. Types of spatial distribution of metapopulations. Filled circles indicate an occupied habitat patch, empty circles an unoccupied habitat patch and broken circles are the boundaries of the population. Source: (Gillman and Hails 1997 Figure 6.3 p. 148).. 38

Figure 2–5. Processes and factors associated with seed dispersal and recruitment of fleshy-fruited species. Modified from Kollmann (2000)... 40

Figure 2–6. Predicted probability of potential sites around Australia where *A. asparagoides* could become established using climate based data. The uncoloured areas indicate unsuitable sites. Source: (Weiss 2002). 51

Figure 2–7. The grey squares represent sites in Victoria that satisfy climatic criteria where *Asparagus asparagoides* could become established. Source: (Weiss 2002)................... 52

Figure 2–8. Potential establishment sites for *A. asparagoides* based on climate, land use and broad vegetation types. In areas with no colour, climate, soil or land uses are not presently suitable and the plant is unlikely to establish. Source: (Weiss 2002). 53

Figure 2–9. At the habitat scale, predicted potential establishment sites miss out on small areas of potentially suitable habitat where *A. asparagoides* is known to be established. 54

Figure 3–1. Oswin Roberts Koala Reserve on Phillip Island. The red star in the inlaid map shows the vicinity of Phillip Island in Australia. 63

Figure 3–2. Spacing of quadrats a) during the initial fieldwork and b) subsequent fieldwork. 65

Figure 3–3. Location of quadrats within ORR and pasture adjacent the study site. 65

Figure 3–4. The spread of recorded positions for the field control point (yellow dots)........... 67

Figure 3–5. An example of *A. asparagoides* growing at the base of a large tree in ORR. 70

Figure 3–6. An example of two combinations of vegetation structure: 71

Figure 3–7. Overview of the Braun-Blanquet method: a) Vegetation contained within boundary of a quadrat, b) Distribution of individual vegetation components, c) Cover of each component as a percentage of total quadrat is estimated by eye. Areas of the individual rectangles correspond to $^1/_2$, $^1/_4$ and $^1/_{20}$ of the quadrat area........................... 73

Figure 3–8. The appearance of tubers at various plant ages. From left to right, dark shrivelled appearance greater than three years old, brown tuber two years old and white tuber at one year old. Each division on the scale is one centimetre. 75

Figure 3–9. Tuber appearance on a plant two months after germination. Each division on the scale is one centimetre. 75

Figure 3–10. Number of vegetation layers across the study site. 79

Figure 3–11. Distribution of Crown cover (≥35%) and perch numbers across the study site. 81

Figure 3–12. *Asparagus asparagoides* distribution and mean density within the study site. .. 81

Figure 3–13. Mean *Asparagus asparagoides* density: 62.5%. 83

Figure 3–14. Mean *Asparagus asparagoides* density: 37.5% and greater. 83

Figure 3–15. Mean *Asparagus asparagoides* density: 15% and greater. 84

Figure 3–16. Mean *Asparagus asparagoides* density: 3% and greater. 84

Figure 3–17. Mean *Asparagus asparagoides* density: 0.5% and greater. 85

Figure 3–18. Mean *Asparagus asparagoides* density: 0.25% and greater. 85

Figure 3–19. Distribution of remnant vegetation patches across the study area with and without *A. asparagoides* present. 86

Figure 4–1. Point locations in the study site. a) Location of all sampled points, b) Point locations where *A. asparagoides* was present at a density > 0%, c) Point locations where *A. asparagoides* was present at densities of 3.0% or greater. See text for further details. 98

Figure 4–2. An illustration of the two quadrat count methods used in this study: a) and c) complete coverage of the study area with a regular grid and b) and d) randomly distributed cells. Values for n refer to the data sets used in the analysis; for details see the section on data set preparation.. 100

Figure 4–3. Steps in the determination of Ripley's *K* statistic for a hypothetical SPP. Redrawn from: (O'Sullivan and Unwin 2003 p 94). 103

Figure 4–4. Kernel estimates for aa73 (left image) and aa113 (right image) using the binning method (n*x*=50, n*y*=50, span=0.2) for the function intensity in the S+SpatialStats® module. 107

Figure 4–5. Kernel estimates for aa73 (left image) and aa113 (right image) overlaid with the ORR track and path network. 108

Figure 4–6. L(*d*) as a function of *d* for aa113 showing the observed values of L(*d*) and the 99% confidence envelope for complete spatial randomness given by L(*d*) minimum and L(*d*) maximum. 110

Figure 4–7. L(*d*) as a function of *d* for aa73 showing the observed values of L(*d*) and the 99% confidence envelope for complete spatial randomness given by L(*d*) minimum and L(*d*) maximum. 111

Figure 4–8. Derived statistic $L^*(d)$ (solid line) plotted as a function of *d* for aa113. The dotted lines indicate the 99% confidence envelope for complete spatial randomness. 111

Figure 4–9. Derived statistic $L^*(d)$ (solid line) plotted as a function of *d* for aa73. The dotted lines indicate the 99% confidence envelope for complete spatial randomness. 112

Figure 4–10. Weighted *K*-function $L_w(d)$ (solid line) as a function of *d* for aa113. The dotted lines indicate the 99% confidence envelope. $L_w(d)$ values within the confidence envelope indicate a random distribution of mean cover density values among any pattern of points observed in the unweighted *K*-function. 113

Figure 4–11. Weighted *K*-function $L_w*(d)$ (solid line) as a function of *d* for aa113. The dotted lines indicate the 99% confidence envelope. $L_w*(d)$ values within the confidence envelope indicate a random distribution of mean cover density values among any pattern of points observed in the unweighted *K*-function. 113

Figure 4–12. Weighted *K*-function $L_w(d)$ (solid line) as a function of *d* for a typical simulation. The observed $L_w(d)$ lies inside the 99% confidence envelope for all values of *d*. 116

Figure 4–13. Weighted *K*-function $L_w*(d)$ (solid line) as a function of *d* for a typical simulation. The observed $L_w*(d)$ lies inside the 99% confidence envelope for all values of *d*. 117

Figure 5–1. The three Sub-site locations within Oswin Roberts Reserve. 123

Figure 5–2. Layout of a series of 10 transects along a 150m-track section. 124

Figure 5–3. Six possible starting locations for the first SU for each 60m transect. Each SU is a square of 0.5m x 0.5m. Midpoints of the first SU lie at 0.25m, 0.75m, 1.25m, 1.75m, 2.25m and 2.75m from the edge of the track. Once the position of the first SU is chosen, subsequent SU positions are located at 3m multiples from the first SU. 125

Figure 5–4. A histogram of *A. asparagoides* frequency for each distance range away from the track in Sub-site 1. Rooted: plants recorded as growing in the SU. Foliage: plants overhanging the SU. 129

Figure 5–5. Percentage of quadrats with *A. asparagoides* present for each distance range in Sub-site 1. 130

Figure 5–6. The percentage of quadrats with *A. asparagoides* present as a function of distance from tracks for the whole of ORR. 131

Figure 5–7. *Asparagus asparagoides* density map with the ORR track network. The field location of points where *A. asparagoides* was recorded present is also shown. Possible satellite colonies are circled in blue. 132

Figure 5–8. a) The three dimensional TIN surface showing the high and low regions of *A. asparagoides* density. The red squares indicate beginning of two new satellite colonies. b) The same surface with the track network overlaid showing the proximity to the high *A. asparagoides* density areas of ORR. 133

Figure 5–9. Location of Sub-sites in Oswin Roberts Reserve and their relation to the distribution of *A. asparagoides* mean cover density. 134

Figure 6–1. Distribution of the 271 quadrats used in the logistic regression modelling. Dark blue squares *A. asparagoides* present; light blue squares *A. asparagoides* absent. 147

Figure 6–2. Predicted probabilities for *A. asparagoides* using the fitted values for the logistic model ORR.best. 159

Figure 6–3. Interpolated probability of *A. asparagoides* using the fitted values for the logistic model ORR.best. 160

Figure 7–1. Location of Ventnor Koala Reserve on Phillip Island. 165

Figure 7–2. Layout of Ventnor reserve showing roads, track network and water features. 166

Figure 7–3. Inter annual rainfall difference May/Jan04/05 - May/Jan02/03. Modified from: Australian Bureau of Meteorology (2005). 166

Figure 7–4. Location of the 147 quadrats surveyed in Ventnor Koala Reserve. 168

Figure 7–5. Spread of coordinates for a field control point. 168

Figure 7–6. Map series showing mean *Asparagus asparagoides* density from 87.5% to 0.5%. 175

Figure 7–7. Mean *Asparagus asparagoides* density: 0.25% and greater. 176

Figure 7–8. Contour plot of kernel intensity estimates for Ventnor Koala Reserve. 177

Figure 7–9. Contour plot of KIE overlaid with roads (red), tracks (black) and surface water (black bold). Dotted lines indicate expected extent of swamp. 177

Figure 7–10. L(*d*) as a function of *d* for VKR data set showing the observed values of L(*d*) and the 99% confidence envelope for complete spatial randomness. 178

Figure 7–11. $L^*(d)$ plotted as a function of *d*. The dotted lines indicate the 99% confidence envelope for complete spatial randomness. 178

Figure 7–12. $L_w(d)$ plotted as a function of *d*. The dotted lines indicate the 99% confidence envelope for complete spatial randomness. 179

Figure 7–13. $L_w^*(d)$ plotted as a function of *d*. The dotted lines indicate the 99% confidence envelope for complete spatial randomness. 180

Figure 7–14. Percentage of quadrats with *Asparagus asparagoides* present as a function of distance from tracks for Ventnor Koala Reserve.. 181

Figure 7–15. The plot of p_{vr} as a function of p_L is a straight line fit where $p_{vr} = p_L$. 183

Figure A2-16. Distribution of mean *Asparagus scandens* density. 222

LIST OF TABLES

Table 1-1. Definitions of spatial scale and associated dispersal processes Source: (Kollmann 2000). 7

Table 2-1. A selection of terms used to describe invasive plants. 16

Table 2-2. Varying definitions of invasive plants. 17

Table 2-3. A standardised terminology for use in invasion ecology studies. 18

Table 2-4. Synonyms and common names for *Asparagus asparagoides*. 49

Table 3-1. Data types used by various authors in dispersal and invasion studies. 59

Table 3-2. Criteria for selection of a suitable site for this study. 62

Table 3-3. Landscape attributes recorded for each 20m x 20m quadrat. 69

Table 3-4. Braun Blanquet cover scale Modified from (Mueller-Dombois and Ellenberg 1974; Barbour *et al.* 1999). 72

Table 3-5. Vegetation attributes recorded for each 20m x 20m quadrat. 74

Table 3-6. Mean, median and standard deviation for a number of landscape and vegetative variables, n = 410 except where noted. 76

Table 3-7. The number of quadrats with various Slope Forms and associated presence of *A. asparagoides* for each given slope category. 77

Table 3-8. The number of quadrats with various Slope Classes and associated presence of *A. asparagoides* for each given slope category. 77

Table 3-9. Disturbance levels and associated presence of *A. asparagoides*. 78

Table 3-10. Collapsed disturbance levels. 78

Table 3-11. Perch Type and associated presence of *A. asparagoides*. 78

Table 3-12. Perch Number and associated presence of *A. asparagoides*, n = 406. 78

Table 3-13. Vegetation layers and associated presence of *A. asparagoides*. 79

Table 3-14. Plant habit of tallest vegetation layer and associated presence of *A. asparagoides*. 80

Table 3-15. Crown cover percentage and associated presence of *A. asparagoides*. 80

Table 3-16. Mean Percent Cover of *A. asparagoides* and associated quadrats. 82

Table 4-1. Values and the associated pattern types for the Moran and Geary statistics. 105

Table 4-2. Quadrat analysis output for random and regular grid of quadrats for aa113. 106

Table 4-3. Quadrat analysis output for random and regular grid of quadrats for aa73. 106

Table 4-4. Results of nearest neighbour distance analysis for aa113 and aa73. 109

Table 4-5. Moran's *I* and Geary's *c* statistics for aa113 and aa73. 109

Table 5-1. Sample of the data sheet used to record Presence/Absence of vegetation types. Presence was recorded with a tick (√) and absence by leaving the space blank. Any comments were recorded in the section 'Notes' 126

Table 5-2. Field data for all three Sub-sites. The figures indicate the number of Sampling Units in which each of the variables was recorded. 'Range' is the Distance from track (m). 128

Table 5-3. Buffer distance, quadrat counts and percentage of quadrats with *A. asparagoides* present per distance range. 131

Table 6-1. Categorical variables that were collapsed into two or three broad categories for use in the modelling process. 148

Table 6-2. Description of Variables used in the logistic regression models. Bc is the dependent variable. 148

Table 6-3. Descriptive statistics for continuous variables (N=271). 149

Table 6-4. Descriptive statistics for categorical variables (N=271). 149

Table 6-5. Disturbance levels and associated presence of *A. asparagoides* 149

Table 6-6. Vegetation levels and associated presence of *A. asparagoides*. 150

Table 6-7. Habit and associated presence of *A. asparagoides*. 150

Table 6-8. Crown cover percentage and associated presence of *A. asparagoides*. 150

Table 6-9. ORR.best Logistic regression coefficients (Dependent variable = Bc). 153

Table 6-10. ORR.best Logistic regression results: Deviance and significance values........... 153

Table 6-11. ORR.best: Percent correct predictions. The threshold value is 0.5.................... 154

Table 6-12. Odds ratio, percent change in the expected odds and the 95% confidence interval for each odds ratio in ORR.best... 154

Table 6-13. ORR.simple Logistic regression coefficients (Dependent variable = Bc). 156

Table 6-14. ORR.simple Logistic regression results: Deviance and significance values. 156

Table 6-15. ORR.simple: Percent correct predictions. The threshold value is 0.5. 156

Table 6-16. Odds ratio, percent change in the expected odds and the 95% confidence interval for each odds ratio in ORR.simple. 157

Table 6-17. Comparison of the two models using the likelihood ratio test........................... 157

Table 6-18. Percent correct predictions for ORR.best. A comparison of two threshold values (0.5 and 0.4).. 158

Table 6-19. Percent correct predictions for ORR.simple. A comparison of two threshold values (0.5 and 0.4). 158

Table 7-1. Description of the variables collected at Ventnor Koala Reserve......................... 169

Table 7-2. Mean Percent Cover of quadrats containing *A. asparagoides*. 172

Table 7-3. Descriptive statistics for continuous variables (n=147). 172

Table 7-4. Descriptive statistics for categorical variables (n=147). 172

Table 7-5. Disturbance levels and associated presence of *A. asparagoides*.......................... 173

Table 7-6. Vegetation levels and associated presence of *A. asparagoides*. 173

Table 7-7. Habit and associated presence of *A. asparagoides*. 174

Table 7-8. Crown cover percentage and associated presence of *A. asparagoides*. 174

Table 7-9. Buffer range, quadrat counts and percentage of quadrats with *Asparagus asparagoides* present. 180

Table 7-10. ORR.best Percent correct predictions for VKR data (0.5 and 0.4 threshold values).. 182

Table 7-11. Logistic regression coefficients (Dependent variable = $g(\mathrm{L})$). 182

Table 7-12. Logistic regression results: Deviance and significance values. 182

Table 7-13. ORR.simple Percent correct predictions for VKR data (0.5 and 0.4 threshold values).. 183

Table 7-14. VENT.orr Logistic regression coefficients (Dependent variable = bc). 184

Table 7-15. VENT.orr Logistic regression results: Deviance and significance values. 185

Table 7-16. VENT.orr Percent correct predictions (0.5 and 0.4 threshold values). 185

Table 7-17. Odds ratio, percent change in the expected odds and the 95% confidence interval for each odds ratio in VENT.orr. 186

Table 7-18. VENT.simple Logistic regression coefficients (Dependent variable = bc). 187

Table 7-19. VENT.simple Logistic regression results: Deviance and significance values. ... 187

Table 7-20. VENT.simple Percent correct predictions (0.5 and 0.4 threshold values). 187

Table 7-21. Odds ratio, percent change in the expected odds and the 95% confidence interval for each odds ratio in VENT.simple. 188

Table 7-22. Comparison of the two models using the likelihood ratio test. 188

Table 7-23. A comparison of the odds ratio and 95% confidence interval for each variable in Oswin Roberts Reserve and Ventnor Koala Reserve. 189

ABSTRACT

This thesis reports on research that examines the early stage invasion process of *Asparagus asparagoides* (L.) W. Wight (bridal creeper), primarily a bird-dispersed weed, in a remnant vegetation patch. The study site is on Phillip Island, approximately 100 kilometres south east of Melbourne, Victoria. *Asparagus asparagoides* invasion of the remnant vegetation reserve is a relatively recent phenomenon.

Landscape elements that affect bird dispersal and vegetation types that affect seedling establishment may be important factors that limit or enhance the spread of *A. asparagoides*. A systematic sampling strategy was adopted and data collected for a variety of landscape and vegetative variables including cover and abundance of *A. asparagoides* and the data were presented in a Geographic Information System (GIS).

Preliminary results show that the distribution of *A. asparagoides* within a remnant vegetation patch is not random. It appears to have entered the reserve from two boundaries, spreading toward the centre, which to date remains sparsely colonised despite the capacity of this weed to spread rapidly over long distances by birds. A number of other outcomes are noted. *Asparagus asparagoides* establishment is prevented in pasture where sheep and cattle graze, and paddocks subjected to tillage practices. The exclusion of grazing in fenced off vegetation in pastures demonstrates rapid weed establishment and colonisation several hundred metres from main infestation.

Field observation and visual inspection of temporal progress of invasion (using above ground weed density with tuber appearance to infer age) appear to suggest that invasion into remnant is associated with the track network. This age/density assumption is strengthened when spatial distribution is examined using a data set where low-density values for *A. asparagoides* are removed and compared with a data set using all *A. asparagoides* density values. The mapping of *A. asparagoides* in fenced off farm remnants suggests that velocity of spread at 191m/yr is a considerable underestimate. Subsequent analysis shows that the spatial distribution of *A. asparagoides* is not completely spatially random while intensity surface analysis highlights regions of low and high intensity located near track network. Mapping a density surface within GIS provided confirmatory evidence for the establishment of satellite clusters along the track network. The change in the intensity surface observed using the two data sets (low-density values and all density values) is also consistent with an expanding invasion occurring between two time periods. Spatial point pattern analysis using *K*-function statistics shows that

the clustering observed using GIS appears to be occurring at two scales or distances (130m-160m and 195m-205m).

The association between tracks and the invasion process observed in the initial stages of the study is examined. There is a change in density as a function of distance from a track where the density of *A. asparagoides* appears to reduce the further away from the track a site is and this relationship holds regardless of track width.

The final stages of the study look at the development of a predictive model. Visual exploration of the data through mapping in a GIS and field observation made during data collection provide the starting point for the development of logistic models to estimate the probability of *A. asparagoides* presence. Finally the best overall logistic model is applied to a second independent site to determine the general applicability of the model. A number of variables that impact on the presence of *A. asparagoides*, particularly during the initial stages of the invasion process, are identified. While all the identified variables and the overall model are statistically significant, the model is found to correctly predict presence/absence in only 67% of cases overall. The model however could be expected to correctly predict the presence of *A. asparagoides* in 74% of cases and has a false positive rate of 40%. The model is applied at a second independent site and found to have an overall percent correct rate of 80% and correctly predicted *A. asparagoides* presence in 94% of cases. The variables identified as influential in the early stage of invasion are relatively easy to acquire by simple field survey that does not require specialist skills. When considering the model as a tool for the management of remnant vegetation communities, high false positive rates may lead to limited resources being spent on searching sites where there is no weed. However, a high false negative rate would have a larger impact on the management of the weed since the undetected infestations would form sources for new propagules. The model performs well from this point of view in that it provided low false negative rates at both sites.

The value of the predictive model is its ability to provide managers with information regarding specific areas to target for weed eradication and management can use the model to assess the effectiveness of any control measures by going back to obtain new cover density data, then using the model to examine the changes over time. The model also provides a starting point for the development of a generic model of *A. asparagoides* invasion at sites outside of Phillip Island and could also provide the starting point for developing models that could be used for other bird-dispersed fleshy-fruited weed species.