

09 PH
K 1928



**The Population Ecology of an Invasive
Social Insect, *Vespula germanica*
(Hymenoptera: Vespidae) in South
Australia.**

MARTA L. KASPER

A thesis submitted in fulfilment of the requirements for the degree of Doctor of
Philosophy.

Environmental Biology
School of Earth and Environmental Sciences
The University of Adelaide, Adelaide, Australia

April 2004

TABLE OF CONTENTS

FIGURE INDEX.....	V
TABLE INDEX.....	X
ABSTRACT.....	XII
DECLARATION.....	XIII
ACKNOWLEDGEMENTS.....	XIV
CHAPTER 1: INTRODUCTION.....	1
1.1 POPULATION DYNAMICS.....	1
1.2 BIOLOGY OF INVASIONS.....	4
1.2.1 Stages of a biological invasion.....	4
1.2.2 Characteristics of successful invaders.....	5
1.3 SOCIAL INSECTS.....	6
1.4 INTRODUCTION TO <i>VESPULA</i> SPP.....	8
1.4.1 Classification.....	8
1.4.2 Morphology and social organisation of <i>V. germanica</i>	9
1.4.3 Determination of sex and caste.....	11
1.4.4 World distribution of <i>V. germanica</i> and <i>V. vulgaris</i>	11
1.4.5 Introduction and spread of <i>V. germanica</i> and <i>V. vulgaris</i>	12
1.5 BASIC BIOLOGY AND ECOLOGY OF <i>VESPULA</i> SPP.....	15
1.5.1 Nest site selection and preferences.....	15
1.5.2 Life cycle.....	15
1.5.3 Colony development.....	17
1.5.4 Overwintering and polygyny.....	18
1.5.5 Foraging.....	19
1.6 ANNUAL FLUCTUATIONS IN <i>VESPULA</i> POPULATIONS.....	21
1.7 IMPACT AND CONTROL OF <i>VESPULA</i> SPP.....	23
1.7.1 Impact on native communities.....	23
1.7.2 Impact on humans.....	23
1.7.3 Chemical and biological control.....	24
1.8 RESEARCH OBJECTIVES AND THESIS OUTLINE.....	25
1.8.1 Overall objectives.....	25
1.8.2 Specific aims.....	25
CHAPTER 2: NEST SITE PREFERENCES AND SEASONAL COLONY GROWTH OF <i>V. GERMANICA</i> IN SOUTH AUSTRALIA.....	28
2.0 CHAPTER SUMMARY.....	28
2.1 INTRODUCTION.....	29

2.2 MATERIALS AND METHODS.....	31
2.2.1 Nest destruction scheme	31
2.2.2 Local councils supporting research	31
2.2.3 Recording of wasp nest sites	33
2.2.4 Nest collection.....	34
2.2.4 Nest analysis.....	34
2.2.5 Traffic as an indicator of nest size	35
2.3 RESULTS.....	35
2.3.1 Nest sites	35
2.3.2 Seasonal abundance	38
2.3.3 Nest size	39
2.3.4 Proportions of small and large cells.....	43
2.3.5 Colony development	43
2.3.6 Sex ratios of brood.....	44
2.3.7 Eggs per cell	46
2.3.8 Traffic as an indicator of nest size	47
2.4 DISCUSSION.....	49
2.4.1 Nest sites	49
2.4.2 Seasonal abundance	49
2.4.3 Nest size	51
2.4.4 Large and small cell proportions.....	52
2.4.5 Colony development	52
2.4.6 Sex ratios	53
2.4.7 Eggs per cell	54
2.4.8 Traffic as indicator of colony size.....	55
CHAPTER 3: CHANGES IN DAILY AND SEASONAL FORAGING CHARACTERISTICS	57
3.0 CHAPTER SUMMARY.....	57
3.1 INTRODUCTION	58
3.2 MATERIALS AND METHODS.....	60
3.2.1 Study area.....	60
3.2.2 Forager sampling.....	60
3.2.3 Experimental design	61
3.2.4 Changes in resource proportions.....	62
3.2.5 Changes in relative proportions of prey orders.....	62
3.2.6 Changes in sucrose concentration	63
3.3 RESULTS.....	63
3.3.1 Changes in resource proportions.....	64
3.3.2 Changes in prey orders	71
3.3.3 Changes in sucrose concentration	72

3.4 DISCUSSION	73
3.4.1 Overall resource proportions	73
3.4.2 Daily changes in resource proportions	74
3.4.3 Seasonal changes in relative resource proportions.....	75
3.4.4 Seasonal changes in prey	77
3.4.5 Changes in sucrose concentration	78
CHAPTER 4: FACTORS INFLUENCING DAILY FORAGING ACTIVITY	79
4.0 CHAPTER SUMMARY.....	79
4.1 INTRODUCTION	79
4.2 MATERIALS AND METHODS.....	82
4.2.1 Data collection	82
4.2.2 Modelling factors influencing foraging	83
4.2.3 Summary of daily activity pattern.....	84
4.3 RESULTS.....	85
4.3.1 Effect of rain.....	86
4.3.2 Effect of light	87
4.3.3 Effect of temperature	88
4.3.4 Effect of humidity	89
4.3.5 Modelling factors influencing wasp activity.....	89
4.3.6 Daily foraging activity pattern.....	90
4.3.6 Changes in incoming vs. outgoing traffic.....	91
4.4 DISCUSSION.....	92
4.4.1 Daily activity pattern.....	92
4.4.2 Environmental influences on wasp activity	93
4.4.3 Effect of rain.....	94
4.4.4 Effect of light	95
4.4.5 Effect of temperature	96
CHAPTER 5: DIET OF <i>V. GERMANICA</i> AND PREY OVERLAP WITH A NATIVE PAPER WASP <i>POLISTES</i>	
<i>HUMILIS</i>.....	99
5.0 CHAPTER SUMMARY.....	99
5.1 INTRODUCTION	99
5.2 MATERIALS AND METHODS.....	103
5.2.1 Prey collection and visual identification	103
5.2.2 Prey identification by nucleotide sequencing.....	103
5.2.3 Phylogenetic analysis	105
5.2.4 Complete prey inventories	106
5.2.5 Prey overlap values	106
5.3 RESULTS.....	107
5.3.1 Morphologically identified prey	107

5.3.2	Nucleotide identified prey inventories	108
5.3.3	Complete prey inventories of <i>Vespula</i> and <i>Polistes</i>	114
5.3.4	Prey overlap	114
5.4	DISCUSSION	114
5.4.1	Diets of <i>Vespula germanica</i> and <i>Polistes humilis</i>	114
5.4.2	The use of nucleotide sequencing for prey identification	115
5.4.3	Extent of overlap between <i>V. germanica</i> and <i>P. humilis</i>	118
CHAPTER 6: POPULATION DYNAMICS		119
6.0	CHAPTER SUMMARY	119
6.1	INTRODUCTION	119
6.2	MATERIALS AND METHODS	122
6.2.1	Study area and wasp density data	122
6.2.2	Weather data	124
6.2.3	Time series analysis	124
6.2.4	Population model	125
6.2.5	Forecasts	126
6.3	RESULTS	126
6.3.1	Time series analysis	127
6.3.2	Factors affecting density	128
6.3.3	Model testing	131
6.4	DISCUSSION	132
6.4.1	Nest densities and fluctuations	132
6.4.2	Modelling annual fluctuations	133
CHAPTER 7: GENERAL DISCUSSION		138
7.1	OUTCOMES	138
7.2	PROBLEMS ENCOUNTERED	142
7.3	FUTURE RESEARCH	143
APPENDIX 1: NESTS USED FOR SEASONAL COLONY GROWTH PATTERNS		144
APPENDIX 2: HIBERNATION IN <i>V. GERMANICA</i> QUEENS		147
A2.1	BACKGROUND	147
A2.2	MATERIALS AND METHODS	147
A2.3	RESULTS	148
A2.4	DISCUSSION	149
APPENDIX 3: DETAILED LIST OF <i>V. GERMANICA</i> PREY		151
REFERENCES		152

ABSTRACT

Since its introduction in the late 1970s, *Vespula germanica* has become one of the major urban pests in Australia. Absence of natural competitors and enemies, the ability for long-term sperm storage, plus human transportation have enabled the wasp to spread quickly. Despite costly eradication efforts, little is known of the species' biology under Australian conditions. In this study, the ecology of *V. germanica* was examined in South Australia. Results indicate that in comparison with its native range in England, milder seasons enable the wasp to be active for seven as opposed to four months. Additionally, three times as many workers and queens are produced per colony. However, at temperatures $\geq 35^{\circ}\text{C}$, foraging activity diminishes by 50%, while colony requirements for water increase. Hot summers also have a negative effect on nest densities in the following year.

The possible impact of *V. germanica* on the environment was assessed by determining its prey diet, and comparing it to the diet of a native paper wasp, *Polistes humilis*. Prey were identified using a combination of visual and molecular techniques. Results indicate that *V. germanica* feeds on at least nine arthropod orders, as well as vertebrate prey, while *P. humilis* is restricted to feeding on Lepidoptera. Phylogenetic analyses reveal that only a small overlap in prey exists. However, future studies need to determine if the numerical dominance of *V. germanica* gives it an advantage as a competitor.

Apart from hot temperatures, the rainfall in April and number of nests destroyed during the previous year were also significant predictors of future wasp densities in a population model. Thus, the spread and development of *V. germanica* may be inhibited by weather, and its distribution may be limited by water availability. The population model also indicates that current control measures are effective in suppressing wasp densities, and broad-area poison baiting should occur.

Although this study has provided a basic outline of the ecology of *V. germanica* in South Australia, future studies on the population genetics of the species and the importance of inter- and intra-specific competition are needed to determine the pathways responsible for its invasion success.