Utilisation of *Phytophthora cinnamomi* affected habitats by honey possums (*Tarsipes rostratus*) in the Cape Riche area, Western Australia.

This thesis is presented for the degree of Bachelor of Science Conservation and Wildlife Biology Honours Murdoch University, 2008.

Submitted by
Shannon Jean Dundas BSc.
Declaration

I declare that this thesis is my own account of my research and contains as its main content work which has not been previously submitted for a degree at any tertiary educational institution.

Shannon Jean Dundas

Date:
ABSTRACT

This study investigated how the presence of the plant pathogen *Phytophthora cinnamomi* in vegetation assemblages impacts on habitat utilisation by the honey possum (*Tarsipes rostratus*). The study took place in coastal heathlands at Cape Riche, Western Australia, between January 2007 and November 2007. Honey possums were radio tracked through an area affected with *P. cinnamomi* as well as healthy areas to determine the extent to which habitat utilisation is impacted on. This will then allow for a more robust prediction of how further spread of *P. cinnamomi* is likely to impact on honey possums in the future. The presence of *P. cinnamomi* was confirmed by plating samples of dying plants. The areas of *P. cinnamomi* at the study site are extensive but patchy with ‘islands’ of healthy vegetation assemblages still remaining. A comparison of microclimate at the study site showed that unaffected areas had a larger range of temperatures than affected areas which may be due to differences in wind which is restricted (having a buffering effect) due to dense vegetation in unaffected sites. In affected areas, a greater proportion of the time was recorded where temperature was below 5°C compared with unaffected areas. This could potentially impact on honey possums, which go into torpor during cool weather, and at temperatures below 5°C, have a higher metabolic rate to maintain their body temperature. This means they need to forage for more nectar and pollen during cooler weather in affected areas where foodplants are less abundant. The number of honey possums captured was correlated to season ($\chi^2=13.1$, $p<0.0005$) with the largest number of honey possums captured during the summer field trip when more plants were flowering.

Honey possum preferred foodplants were identified from pollen collected from captured honey possums. A total of 20 different pollen species were identified from samples, nine of which were identified as important honey possum preferred foodplants as they were found in more significant amounts. Based on pollen, *Banksia plumosa* subsp. *plumosa* was identified as the preferred foodplant at the Cape Riche study site followed by *Adenanthes cuneatus*. Both are common throughout the study area and flower all year.
Banksia plumosa subsp. plumosa is susceptible to *P. cinnamomi* and was only found in unaffected areas whereas *Adenanthes cuneatus* was found to less susceptible and was prevalent throughout *P. cinnamomi* affected areas. Honey possums fed on a diverse range of plant species (determined by pollen) during all seasons, except autumn when *B. plumosa* subsp. *plumosa* was the most prevalent pollen species collected from honey possums.

A total of 18 honey possums (body mass 5.9 – 16g) were radio tracked for up to 9 days using radio transmitters weighing 0.36g and 0.9g (Holohil Systems Ltd, Canada). Radio tracked honey possums demonstrated a particular preference for *Banksia plumosa* subsp. *plumosa* which they utilised for food, shelter and as a daytime refuge. Comparison of vegetation structure indicated that sites selected by radio tracked honey possums had significantly denser vegetation between 40-140 cm in height compared with randomly selected sites. Significant differences were identified between *Phytophthora cinnamomi* affected and unaffected locations with vegetation at affected locations being sparser and shorter than that at unaffected sites.

This study clearly showed that honey possums are influenced by the presence of *P. cinnamomi* affected vegetation at Cape Riche. The presence of *P. cinnamomi* at the study area results in large areas which are generally lacking in susceptible Proteaceous species such as *Banksia* and food resources tend to be sparse through these areas. Honey possums are capable of moving relatively large distances with estimated distances ranging from 4m to 1400m over a period of 30 minutes to 9 days. In areas affected with *P. cinnamomi* some honey possums fed on less susceptible plant species. Other honey possums moved long distances to healthy unaffected areas with higher densities of preferred foodplants. Further spread of *P. cinnamomi* is likely to have a serious impact on honey possums as healthy areas become affected and food resources become too limited to sustain honey possum populations.
Acknowledgements

Firstly I would like to thank my supervisors Dr Trish Fleming, Associate Professor Giles Hardy and Dr Bill Dunstan for their help and advice over the last two years. Trish thank you for the huge amount of support and advice you have given me - you made seemingly impossible things possible and I would not have been able to do this project without you. Giles, thank you for all of your advice and for reading through lots of editions of this thesis and providing lots of helpful suggestions in a very timely fashion. Thank you also for carrying out the $P. cinnamomi$ testing at Cape Riche and for advising on $P. cinnamomi$ coverage at the study site. Thank you Bill for you advice about the study site at Cape Riche and for the photos.

To my parents Pat and Craig Dundas – thank you for the huge amount of help you gave me in the field and for all of your support (and a special thanks to mum for the honey possum painting (frontispiece)) – I will get a job soon I promise! Thank you to my other helpful field assistants, Daina Tucker and Lyn Barber and also to Pattie Leighton, Penny and Mike Moir and the community at Cape Riche and Wellstead for their help and interest in this project. Thank you to Nicole Moore (Dieback conservation officer at DEC) who came out and helped me with dieback mapping and gave me lots of helpful suggestions and advice. Thank you to Colin Crane for providing details of plant susceptibility to $P. cinnamomi$. Thank you to the following people at Murdoch University who helped with me with a range of other bits and pieces associated with this project – I really appreciated your help! Janet Box, Gillian Bryant, Damien Cansilla, Sarah Comer (DEC Albany), Mike Craig, Amanda Hewison and Gordon Thomson.

This study was approved by the Murdoch University ethics committee (W2007/06). Relevant licences to take flora and fauna were obtained from the Department of Conservation and Land Management Licence to take fauna for scientific purposes (License SF5574 & SF006014) and Department of Conservation and Land Management Flora Licence for scientific or other prescribed purposes (Licence SW011486 & CE001689) Field work was approved by Murdoch University ref 07/30
# TABLE OF CONTENTS

Declaration (ii)  
Frontispeice (iii)  
Abstract (iv)  
Acknowledgements (vi)  
Table of contents 7

## 1 GENERAL INTRODUCTION AND LITERATURE REVIEW

### 1.1 The pathogen - *Phytophthora cinnamomi*
- History 14  
- *Phytophthora cinnamomi* biology 15  
- Lifecycle 16  
- Distribution and spread of the pathogen 16  
- Modes of dispersion 16  
- Distribution 17  
- Management and Control 18  
- Hygiene and Management 18  
- Phosphte application 19  
- Direct impact of *Phytophthora cinnamomi* on native flora and vegetation structure 20  
- Floral diversity of South West WA 20  
- Native flora susceptibility to *Phytophthora cinnamomi* 20  
- Impact of *Phytophthora cinnamomi* on flora in native bushland 21  
- Symptoms of *Phytophthora cinnamomi* infestation in plants 22

### 1.2 Secondary impacts of *Phytophthora cinnamomi* on flora
- Loss of canopy species 23  
- Potential loss of pollinators 24  
- Secondary impacts of *Phytophthora cinnamomi* infestation on fauna 24  
- Current research focussing on fauna and *Phytophthora cinnamomi* infestation 26

### 1.3 Overall aim of this research project 34
- Research Objectives 34

## 2 CHAPTER 2: STUDY SITE LOCATION AND SITE DESCRIPTIONS

### 2.1 Introduction 36

### 2.2 Methods and Materials 36
- Study site location 36  
- Climate 37  
- Soil and Geology 40  
- Fire history 40  
- Vegetation assemblages at the study site 40  
- Site selection and descriptions 41  
- Site 1 description 42  
- Site 2 description 45
CHAPTER 4: RADIO TRACKING OF HONEY POSSUMS IN PHYTOPHTHORA CINNAMOMI AFFECTED AREAS

4.1 Introduction ........................................................................................................... 102
4.2 Materials and Methods ......................................................................................... 103
  4.2.1 Experimental Design .................................................................................. 103
  4.2.2 Transmitter attachment ............................................................................ 104
  4.2.3 Radio tracking honey possums and transmitter ranges ......................... 105
  4.2.4 Vegetation analysis of honey possum selected and random locations .......... 106
  4.2.5 Statistical analysis ................................................................................... 107
4.3 Results .................................................................................................................. 110
  4.3.1 Vegetation analysis of Phytophthora cinnamomii affected and unaffected areas .............................................................. 110
  4.3.2 Movements of radio tracked honey possums ........................................... 119
  4.3.3 Honey possum preference for Banksia plumosa subsp. plumosa .......... 124
  4.3.4 Resting/Nesting locations ........................................................................ 126
4.4 Discussion ............................................................................................................. 127
  4.4.1 Change in vegetation as a result of Phytophthora cinnamomii infestation and honey possum habitat selection ... 127
  4.4.2 Importance of Banksia plumosa subsp. plumosa used for refuge by honey possums at Cape Riche ................. 128
  4.4.3 Distances travelled by radio tracked honey possums ............................. 129
  4.4.4 Distribution of Phytophthora cinnamomii at Cape Riche in relation to areas utilised by honey possums .......... 131

CHAPTER 3: POLLEN SAMPLING TO DETERMINE PREFERRED FOOD PLANTS

3.1 Introduction ........................................................................................................... 73
3.2 Methods and Materials ......................................................................................... 74
  3.2.1 Pollen sampling from captured honey possums .................................... 74
  3.2.2 Statistical analyses ................................................................................... 74
3.3 Results .................................................................................................................. 78
3.4 Discussion ............................................................................................................. 84
  3.4.1 Observed food plant preferences at Cape Riche study site .................... 84
  3.4.2 Seasonal pollen diversity ......................................................................... 99
  3.4.3 Relative pollen counts carried by honey possums ................................ 99
  3.4.4 Mammal type (theriophily) plants versus bird type (ornithophily) plants .......................................................... 100

CHAPTER 4: RADIO TRACKING OF HONEY POSSUMS IN PHYTOPHTHORA CINNAMOMI AFFECTED AREAS TO DETERMINE HABITAT PREFERENCES

4.1 Introduction ........................................................................................................... 102
4.2 Materials and Methods ......................................................................................... 103
  4.2.1 Experimental Design ................................................................................ 103
  4.2.2 Transmitter attachment ............................................................................ 104
  4.2.3 Radio tracking honey possums and transmitter ranges .......................... 105
  4.2.4 Vegetation analysis of honey possum selected and random locations .......... 106
  4.2.5 Statistical analysis ................................................................................... 107
4.3 Results .................................................................................................................. 110
  4.3.1 Vegetation analysis of Phytophthora cinnamomii affected and unaffected areas .............................................................. 110
  4.3.2 Movements of radio tracked honey possums ........................................... 119
  4.3.3 Honey possum preference for Banksia plumosa subsp. plumosa .......... 124
  4.3.4 Resting/Nesting locations ........................................................................ 126
4.4 Discussion ............................................................................................................. 127
  4.4.1 Change in vegetation as a result of Phytophthora cinnamomii infestation and honey possum habitat selection ... 127
  4.4.2 Importance of Banksia plumosa subsp. plumosa used for refuge by honey possums at Cape Riche ................. 128
  4.4.3 Distances travelled by radio tracked honey possums ............................. 129
  4.4.4 Distribution of Phytophthora cinnamomii at Cape Riche in relation to areas utilised by honey possums .......... 131
4.4.5 Usefulness of radio tracking to determine habitat utilisation by honey possums ................................................................. 132

5 Chapter 5: General Discussion, Conclusions and Suggestions for further research ......134
  5.1 Overall aim of this research project ........................................ 134
  5.2 The indirect impact of *Phytophthora cinnamomi* on honey possums........... 135
  5.3 Conservation priorities at Cape Riche ........................................ 139
  5.4 Suggestions for further research ............................................. 139
  5.5 Conclusion ............................................................................. 140

6 References .................................................................................... 142

7 Appendices .................................................................................. 147
  7.1 Appendix 1 Species list with authorities .................................... 147
  7.2 Appendix 2: Article which appeared in 1st May 2007 edition of "The Whisper" the local Wellstead community newsletter ............................. 149
  7.3 Appendix 3 Glue trials in cool room (5°C) ................................. 150
  7.4 Appendix 4 Bycatch ................................................................ 151
LIST OF FIGURES

Figure 1.1: Lifecycle of Phytophthora cinnamomi.................................................................15
Figure 1.2: Map of confirmed Phytophthora cinnamomi infestations in South West Western Australia..............................................................18
Figure 1.3: Phytophthora cinnamomi affected area at Cape Riche (Site 2). .......................23
Figure 1.4: Honey possum in torpor..........................................................31
Figure 1.5: Flowchart of thesis structure.................................................................35
Figure 2.1: Location of study site at Cape Riche...............................................................37
Figure 2.2: Minimum and maximum mean temperatures for a) Mettler and b) Ongerup........38
Figure 2.3: Mean rainfall and rainfall in 2007 for a) Mettler and b) Ongerup.......................39
Figure 2.4: Seasonal photos at the Cape Riche study site in the Phytophthora cinnamomi unaffected area at Site 1. Blue arrows indicate dominant Banksia baxteri. ..........................43
Figure 2.5: Seasonal photos at the Cape Riche study site in the Phytophthora cinnamomi affected area at Site 1.................................................................44
Figure 2.6: Seasonal photos at the Cape Riche study site in the Phytophthora cinnamomi unaffected area at Site 2.................................................................46
Figure 2.7: Seasonal photos at the Cape Riche study site in the Phytophthora cinnamomi affected area at Site 2.................................................................47
Figure 2.8: Seasonal photos at the Cape Riche study site in the Phytophthora cinnamomi unaffected area at Site 3.................................................................49
Figure 2.9: Seasonal photos at the Cape Riche study site in the Phytophthora cinnamomi affected area at Site 3.................................................................50
Figure 2.10: Aerial photo (obtained from Landgate, Midland) of study area at Cape Riche Western Australia with 100m trap lines at sites 1, 2 and 3 indicated.................................52
Figure 2.11: HOBOn/H8 Pro series field data loggers in the field with cardboard cover........54
Figure 2.12: Setup of trap lines (not to scale).................................................................55
Figure 2.13: Trap line with 10m flywire drift fencing at site 2 in the Phytophthora cinnamomi affected area.................................................................55
Figure 2.14: Honey possum in pit trap.................................................................................56
Figure 2.15: Honey possum with identifying notch in right ear........................................57
Figure 2.16: Honey possum drinking saturated sugar water solution from spoon................57
Figure 2.17 (a-d): Average temperature data and standard deviations in Phytophthora cinnamomi affected and unaffected areas at the Cape Riche study site......................60
Figure 2.18 (e & f): Proportion of records <5°C (e) and >28°C (f) in Phytophthora cinnamomi affected and unaffected areas at the Cape Riche study site........................................61
Figure 2.19 (g-j): Average relative humidity data and standard deviations in Phytophthora cinnamomi affected and unaffected areas over one year at the Cape Riche study site......................................................62
Figure 2.20: Percentage trapping success of honey possums in each of the four trapping sessions for adults (>7g bodyweight) and juveniles (<7g bodyweight). .................................................................66
Figure 3.1: Reference photomicrographs used for pollen identification for the 18 observed foodplants used by honey possums during this study........................................78
Figure 3.2: Percentage of pollen species collected from captured honey possums........81
Figure 3.3: Mean (±1SD) Shannon’s Diversity Index for foodplant species identified from pollen grains collected from honey possums captured during each season.................................................................83
Figure 3.4: Banksia plumosa subsp. plumosa shrub (left) and flower (right).......................85
Figure 3.5: Adenanthos cuneatus shrub. Arrow indicates tiny pink flowers approximately 1cm in length.................................................................86
Figure 3.6: Eucalyptus angustifolia tree and flowers (approx. 2.5 - 3cm in length) ..............87
Figure 3.7: Beaufortia anisandra flowers (approx. 2cm long)........................................88
Figure 3.8: Calothamnus gracilis. (Photos courtesy of FloraBase 2008 online database). Flowers (left) are approx. 3cm long.................................................................89
Figure 3.9: Banksia nutans. Flowers (left) are 4 - 7cm in length (George, 1996) and forms dense shrubs (right). Photos courtesy of Bill Dunstan.........................90
Figure 3.10: Banksia tenuis (flower 4cm across) (Cavanagh & Pieroni, 2006)................91
Figure 3.11: Banksia brunnea plant (left) and flower (right) 3.5 – 4cm across (Cavanagh & Pieroni, 2006). .................................................................................................................. 91
Figure 3.12: Banksia baxteri in flower.................................................................................................................. 92
Figure 3.13: Banksia coccinea.......................................................................................................................... 93
Figure 3.14: Banksia attenuata. (Flowers are 5-26cm long, 3.5-5cm wide (George, 1996)). ........................................................................................................... 93
Figure 3.15: Lambertia inermis. Red arrow indicates flowers approx. 5cm long................................. 94
Figure 4.1: A 6.5g honey possum with 0.36g LB-2N Holohil Systems Ltd (Canada) transmitter attached............................................................... 105
Figure 4.2: Average (± 1 SD) number of vegetation touches at height classes 0 – 230cm................................. 113
Figure 4.3: Non-metric Multi-Dimensional Scaling (MDS) graph representing a 2D visual representation of the rank order of P. cinnamomi affected and unaffected locations............................................................. 116
Figure 4.4: Non-metric Multi-Dimensional Scaling (MDS) graph representing a 2D visual representation of the rank order of honey possum selected locations and random locations.................................................. 116
Figure 4.5: Locations of individual honey possums as determined by radio tracking in relation to the study site. Red lines represent the trap lines at sites 1, 2 and 3................................................................. 118
Figure 4.6: Healthy vegetation assemblage on spongelite ridge characterised by taller, thicker vegetation including Banksia species........................................................... 120
Figure 4.7: Healthy vegetation on the side of the spongelite ridge at site 1.................................................. 121
Figure 4.8: Phytophthora cinnamomi affected area at Cape Riche........................................................................ 123
Figure 4.9: Healthy vegetation ‘island’ utilised by honey possums at site 3.................................................. 123
Figure 4.10: Torpid honey possum TR 76 (indicated by red arrow) with attached radio transmitter in a Banksia plumosa subsp. plumosa, sitting within a dried Hakea cucullata leaf................................................................. 125
Figure 4.11: Ground view of tunnel through Banksia plumosa subsp. plumosa to which a honey possum was radio tracked......................................................................................... 125
Figure 4.12: Torpid honey possum TR 70 in dig out under Calathamnous gracilis shrub.................................................................................................................. 126
Figure 5.1: Flowchart of the potential impacts of the presence of Phytophthora cinnamomi in vegetation assemblages on honey possums................................................. 138
Figure 7.1: (a) Sminthopsis griseoventer (grey bellied dunnart) and (b) Pseudomys albocinereus (ash grey mouse) ...................................................................................... 151
LIST OF TABLES

Table 1.1: Effects of vegetation and subsequent predicted effects on fauna ..........................25
Table 2.1: Significance values determined by a three way ANOVA for temperature
data collected in *Phytophthora cinnamomi* affected and unaffected areas
over one year at the Cape Riche study site. ..........................................................63
Table 2.2: Significance values determined by a three way ANOVA for relative humidity
data collected in *Phytophthora cinnamomi* affected and unaffected areas
over one year at the Cape Riche study site. ..........................................................64
Table 2.3: Capture data for honey possums over 4 trapping sessions between
January 2007 – November 2007 at the Cape Riche study site. ............................65
Table 3.1: Flowering phenology for 44 common plant species found at the Cape Riche
study site. .............................................................................................................82
Table 3.2: Comparison of foodplants identified from pollen collected from captured
honey possums at different study sites. .................................................................95
Table 3.3: Comparison of major honey possum foodplants at Cape Riche ....................97
Table 4.1: Comparison of average vegetation structure parameters for the four
location categories .................................................................................................114
Table 4.2: Individual honey possums radio tracked in during the study. ........................117
Table 7.1: Mammals other than honey possums captured during pit fall trapping
during four field trips between January 2007 – November 2007. ...........................152
1 GENERAL INTRODUCTION AND LITERATURE REVIEW

GENERAL INTRODUCTION

The plant pathogen *Phytophthora cinnamomi* was introduced into Australia and has had a major impact on Australian ecosystems. The habitat destruction as a result of this pathogen has resulted in it being likened to a ‘biological bulldozer’ (WWF Australia, 2004). With limited natural resistance, many native Australian plant species are susceptible or highly susceptible to infection by the pathogen.

The most obvious direct impact of the pathogen is the loss of susceptible plant species in affected ecosystems. The loss of dominant over storey species in an ecosystem results in a significant change in vegetation structure which has the potential to indirectly impact on fauna. *Phytophthora cinnamomi* is known to impact on the structural integrity of plant communities, and many studies have suggested how such changes in plant community structure could have devastating impacts on fauna communities. Despite a recognition of the potential impact of *P. cinnamomi* on fauna, little research work has been done in this area, and particularly so in Western Australia (WA). The endemic mammals found in WA, in particular *Tarsipes rostratus* (honey possum), are of special interest because *P. cinnamomi* has had a significant impact in the forest woodland and heathland plant communities of the southwest of WA which these animals inhabit. The honey possum, which is completely dependent on pollen and nectar for food, is potentially at risk from the presence of *P. cinnamomi* in vegetation assemblages particularly as many of the plant species this mammal feeds on (such as *Banksia* species) which are among the most susceptible to *P. cinnamomi* infection.

This study investigates the movement of honey possums as determined by radio tracking to obtain a greater understanding as to how honey possums are utilising habitats affected with *Phytophthora cinnamomi*. *Tarsipes rostratus* was selected as the species of interest for this research project as
its lifecycle is intricately linked to the flowering phenology (requiring species richness and plant health) of foodplants. The honey possum can therefore be used as a possible indicator species to evaluate the secondary impacts of *P. cinnamomi* on fauna.

This thesis begins with a literature review which examines the previous work carried out on the biology, ecology, and pathology of *Phytophthora cinnamomi* including research on the impact on flora and secondary impacts on fauna in affected habitats. This chapter also introduces the focus mammal species of this study, *Tarsipes rostratus*. The literature review concludes with the aim, hypotheses and research objectives of this research project.

The second chapter details the study site and location, microclimate analysis and animal trapping results and discussion. Chapter three details the analysis of pollen to determine foodplants and radio tracking of honey possums. Chapter four details the results of radio tracking individuals and vegetation and habitat selectivity. The thesis is concluded with a general conclusion and suggestions for future research in this area.

**LITERATURE REVIEW**

**1.1 The pathogen - *Phytophthora cinnamomi***

**1.1.1 History**

*Phytophthora cinnamomi* is a plant pathogen that was possibly introduced from Asia (Zentmyer, 1988). However, it was during the 1960s when the *P. cinnamomi* pathogen was identified and linked with the death of previously healthy jarrah forest (Podger *et al*., 1965). As a result, the disease caused by *P. cinnamomi* was colloquially known as jarrah dieback (Newhook & Podger, 1972). As *P. cinnamomi* is an introduced pathogen, native species have limited natural resistance and are therefore severely threatened by infection (Shearer *et al*., 2004a). Many other Australian native plant species, especially members of the Proteaceae family such as *Banksia* have been
identified as susceptible to *P. cinnamomi* infection. Consequently, many Australian plant communities are at risk (Shearer *et al.*, 2007).

### 1.1.2 *Phytophthora cinnamomi* biology

*Phytophthora cinnamomi* is a soil borne water mould from the Class Oomycota which causes *Phytophthora* dieback disease in susceptible plants (Hardham, 2005).

![Lifecycle of Phytophthora cinnamomi](image)

*Figure 1.1:* Lifecycle of *Phytophthora cinnamomi*

Diagram from (WWF Australia, 2004).
**Lifecycle**

The lifecycle of *Phytophthora cinnamomi* is dictated by moisture and warm temperatures (Shearer *et al.*, 2007) (Figure 1.1). The pathogen reproduces rapidly during the wetter, warmer months of autumn and spring, producing infectious asexual motile zoospores which attach to healthy roots (Shearer, 1994). Zoospores then form a cyst which penetrates the roots via hyphae that spread through the root system (Hardham, 2005). The penetration of the roots by the pathogen results in necrotic lesions on the roots and trunk which hinder the infected plants’ ability to obtain water and nutrients, eventually causing the plant to die (Shearer, 1994). During the drier months, the hyphae of *P. cinnamomi* can produce highly resistant chlamydospores which are specialised for survival in dry periods (Shearer, 1994).

1.1.3 **Distribution and spread of the pathogen**

**Modes of dispersion**

*Phytophthora cinnamomi* is spread within the environment by movement of water and via root to root contact of infected plants (Shearer, 1994). The movement of infected soil primarily carried on vehicles and shoes is a significant means by which the disease is spread (CALM, 2003). Feral animals such as pigs are a potential vector for spread of the pathogen (Brown, 1976; Kliejunas & Ko, 1976). The movement of soil and gravel from infected forests for road development resulted in the preliminary spread of *P. cinnamomi* in earlier days when little was known about the pathogen (Podger, 1972).

Current knowledge about the biology of *Phytophthora cinnamomi* and means of dispersal within the environment has improved immensely since the initial discovery of the pathogen. Risks of disease spread, however, still exists from human and vehicle movements which are the most worrying as they have the potential to spread the pathogen to healthy natural ecosystems currently free from the pathogen. Other high risk activities with the potential to spread the pathogen include road works, firebreak management, logging and contaminated nursery stock (Hardy *et al.*, 2001). It is crucial that companies
and the public are educated as to the potential disease risks and that the threat of disease spread is managed appropriately.

**Distribution**

High rainfall and warm weather as well as the high prevalence of susceptible host plants growing in infertile acid leached sandy soils with poor drainage are the ideal environment for *Phytophthora cinnamomi* and hence many plant communities of the southwest corner of WA are affected (Figure 1.2) (Shearer, 1994; Shearer *et al.*, 2007). *Eucalyptus marginata* forests on laterites and *Banksia* woodlands on leached sands along the Swan Coastal Plain as well as the north and south sand plains in WA, tend to be the most impacted from *P. cinnamomi* infestation (Figure 1.2) (Shearer, 1994). The impact of *P. cinnamomi* infestation is evident throughout Australia but tends to be more prevalent in the more southerly parts of Australia (Weste, 1994). There are a number of areas in southeast of Victoria including the Grampians, Brisbane Ranges, Dandenong Ranges, east Gippsland and Wilson’s Promontory recognised as areas of severe infestation (Weste, 1994). In South Australia, severe infestations are evident in the woodlands in the Adelaide Hills, Fleurieu Peninsula and Kuitopo Forest (Weste, 1994). In Tasmania, *P. cinnamomi* is widely spread through dry sclerophyll communities, however is not present in cold, dry highlands (Weste, 1994). In north east Queensland, *P. cinnamoni* has been identified in patches of subtropical rainforest at Eugella and Garrawalt (Brown, 1976; Weste, 1994).
Figure 1.2: Map of confirmed *Phytophthora cinnamomi* infestations in South West Western Australia.
(CALM, 2003)

1.1.4 Management and Control

Hygiene and Management

*Phytophthora cinnamomi* has been nationally acknowledged as a key threatening process to Australia’s biodiversity in the *Environment Protection and Biodiversity Conservation Act* 1999. Major initiatives are currently being undertaken by the Department of Environment and Conservation (DEC) as part of this Act aimed at managing and preventing further spread of *P. cinnamomi* as well as more accurate mapping of confirmed affected areas (CALM, 2003).

Once *Phytophthora cinnamomi* is present within an ecosystem, it cannot be eradicated so quarantine measures to prevent the movement of the pathogen from diseased to healthy areas are paramount. Areas that have been recognised as affected by *P. cinnamomi* are signposted with disease risk
signs to indicate limits of diseased habitats and to make the public aware when they are moving in and out of diseased areas. Other hygiene measures include vehicle wash-down bays on the border of affected and healthy areas which provide chlorinated water to remove potentially infected mud and soil from the tyres and undercarriage of the vehicle. In some managed National Parks such as the Fitzgerald River National Park (FRNP), the risk of disease spread can be reduced by closing off access roads to the public during the wetter months when the pathogen is more easily spread (CALM, 2003).

Bushwalkers also have the potential to spread the pathogen via mud and infected soil on their boots. Boot brush down areas are becoming more commonplace in popular bushwalking areas, as are signs explaining dieback and the importance of removing soil and mud from boots to limit its spread. High risk activities such as road works, logging and mining which utilise large machinery should be restricted to hot, dry months when the potential for disease spread is lowest (Hardy et al., 2001).

Phosphite application

As well as trying to prevent the spread of *Phytophthora cinnamomi* with improved hygiene and management practices, methods of chemical means of control are being investigated. Current studies are testing the effectiveness of the fungicide phosphite to contain the rate of spread and impact of *P. cinnamomi* (Wilkinson et al., 2001). The fungicide functions by inducing host defence responses to the pathogen (Guest & Bompeix, 1990). The production of zoospores (involved in reproduction and distribution of the pathogen) are reduced following phosphite application (Wilkinson et al., 2001). Phosphite application, however, does not completely eliminate *P. cinnamomi* zoospores from the infected plant and may not be enough to prevent the spread of the pathogen in affected areas as was previously hoped (Wilkinson et al., 2001).

The application method of the fungicide depends on the size and nature of the affected area. Traditional phosphite application methods include spraying for large areas, hand spraying for smaller areas and direct phosphite injection.
for application to specific plants (Hardy et al., 2001). More recent studies have investigated phosphite injections as a means of administering phosphite for more long term protection (Shearer et al., 2006). Phosphite injections were conducted for three common WA species, *Eucalyptus marginata*, *Banksia grandis* and *Banksia coccinea*, all of which are susceptible to *P. cinnamomi* infection (Shearer et al., 2006). Injections lasted for 4-5 years and proved to be an effective means by which a dieback front can be controlled and threatened flora can be protected (Shearer et al., 2006).

1.1.5 Direct impact of *Phytophthora cinnamomi* on native flora and vegetation structure

*Floral diversity of South West WA*

Since its introduction, *Phytophthora cinnamomi* has had devastating effects on Australian flora most especially in the southwest of WA. This area is renowned as being a biodiversity hot spot especially in terms of floristic diversity (Myers et al., 2000). In the southwest Botanical Province of WA, there are 5710 species which have been described and approximately 40% of these are susceptible to *P. cinnamomi* infection and another 14% of these species are noted as being highly susceptible (Shearer et al., 2004a). This region, which is approximately 300,000 km² in size contains 1.4% (4200 species) of total global endemic plants which is the 11th highest percentage of endemic plant species in the world (Myers et al., 2000).

*Native flora susceptibility to Phytophthora cinnamomi*

Since *Phytophthora cinnamomi* is an introduced pathogen, many native species have limited natural resistance and are therefore severely threatened by infection by the pathogen (Shearer et al., 2004a). Plant species within Proteaceae, Papilionaceae, Epacridaceae and to a lesser extent Myrtaceae families tend to be the most susceptible to dieback in the *Banksia* woodlands and jarrah forest of southwest Australia (Shearer et al., 2004a). Proteaceous species were found to be especially prone to *P. cinnamomi* infection with 85% being classed as susceptible (Wills, 1993). Plant family alone however does not dictate susceptibility of a species to *P. cinnamomi* infection, with
resistant species from these families also being observed (Shearer et al., 2004a). In Banksia woodlands, an estimated 32% of plant species classified are classified as susceptible to P. cinnamomi, with 15% of plant species classified as highly susceptible (Shearer et al., 2004a). In the jarrah forest, 44% of all plant species present in these ecosystems are classified as susceptible and 12% are classified as highly susceptible (Shearer et al., 2004a).

*Impact of Phytophthora cinnamomi on flora in native bushland*

The death of dominant plant species within an ecosystem due to *Phytophthora cinnamomi* infestation has the potential to cause major habitat changes in terms of species richness and vegetation structure (Wills, 1993). Many common but key species are susceptible to *P. cinnamomi* dieback as evident in dense Banksia and Eucalypt woodlands; these sites can appear healthy but can be rapidly transformed into open communities lacking dominant over-storey species (Shearer, 1994; Shearer & Dillon, 1996b). In WA, *Phytophthora* disease fronts can move at a rate of up to 2m year\(^{-1}\), the rate being dependant on a number of factors such as soil type, climate and vegetation susceptibility (Hill et al., 1994; Shearer et al., 2007; Shearer et al., 2004b). In WA, a study carried out for on the Banksia woodlands in the Swan Coastal Plain indicated that 10-64% of plants were dying in *P. cinnamomi* affected areas (average of 28% ± 2% s.e) which represents a significant reduction in floristic composition and structure (Shearer & Dillon, 1996). Areas of old infestation tend to be open communities often characterised by visually evident changes in species composition (Figure 1.3) (Shearer et al., 2007)

In the Stirling Range National Park, WA, widespread infestation of *Phytophthora cinnamomi* is having a significant effect on vegetation structure (Wills, 1993). Species from the Proteaceae and Myrtaceae represent a significant percentage of projective foliage within healthy bushland in the Stirling Range National Park, proteaceous species especially provide the fundamental vegetative and floristic structure of this ecosystem and contribute significantly to floral species richness (Wills, 1993). The
abundance of plant species susceptible to *P. cinnamomi* is noticeably decreased in affected areas although the persistence of more resilient plants from susceptible species are often present (Wills, 1993). In older infestations, these more resilient plants, however, often succumb to infection (Wills, 1993). Loss of susceptible species then allows for the few *P. cinnamomi* field resistant and tolerant species most of which are herbaceous species (e.g. Cyperaceae and Restionaceae) to prosper (Wills, 1993).

Furthermore, an estimated 59% of plant species in the Stirling Range National Park that have vertebrate pollinated flowers are susceptible to *P. cinnamomi* infection (Wills, 1993). All species of *Banksia* present in the park are susceptible to *P. cinnamomi* infection (Wills, 1993). As these are primary food plant species on which animals such as honey possums and pygmy possums are reliant, there is a possibility that these animal species may become locally rare or extinct in old *P. cinnamomi* affected areas (Wills, 1993).

Long term studies in the Grampians, western Victoria, indicate that 54% of understorey species are susceptible to dieback including the dominant *Xanthorrhoea australis* (Weste *et al.*, 2002). The death of these plants results in significant changes to species composition and community structure (Weste *et al.*, 2002). Susceptible flora such as *Xanthorrhoea* and *Eucalyptus* are replaced with native sedges, rushes and tea tree (Weste *et al.*, 2002).

**Symptoms of Phytophthora cinnamomi infestation in plants**

*Phytophthora cinnamomi* affected plants are characterised by chlorosis of leaves, dieback of twigs (most notable in dominant canopy trees) followed by the sudden or eventual death of the plant (Podger, 1972). Affected vegetation communities tend to have an active dieback front which contains dead and dying plants (Shearer *et al.*, 2007) (Figure 1.3).
1.1.6 Secondary impacts of *Phytophthora cinnamomi* on flora

The structure of a plant community relies on a delicate balance of essential factors including nutrient availability, rainfall and availability of water and amount of sunlight. The widespread impact of *Phytophthora cinnamomi* on such a large number of species is likely to have secondary effects on plant communities beyond the initial death of susceptible flora species.

*Loss of canopy species*

The first *Phytophthora cinnamomi* zoospores were isolated and identified in WA jarrah (*Eucalyptus marginata*) forest (Podger *et al.*, 1965). Jarrah is highly susceptible to *P. cinnamomi* and the death of previously healthy jarrah trees is a diagnostic impact of *P. cinnamomi* in *Eucalyptus* forests. Canopy trees are especially important in established ecosystems for a number of reasons. Canopy species tend to capture then majority of incoming sunlight, which can subsequently act as a limiting factor to reduce the growth of grasses and sedges in the understorey. In the Stirling Range National Park, most Stylidiaceae species are resistant to *P. cinnamomi* however *Stylium scandens*, which grows under jarrah stands, is generally absent in affected areas.
areas lacking canopy species (Wills, 1993). Canopy trees provide leaf litter which is important for nutrient replenishment of the soil as well as working like mulch, retaining water in the soil. *Phytophthora cinnamomi* affected areas have lower litter fall and litter biomass compared to healthy areas (Carter, 2003; Garkaklis *et al.*, 2004). In addition to influencing litter dependent plant species, this has the potential to impact on fauna, small mammals and birds which rely on leaf litter to provide invertebrates which thrive in the decomposing matter.

*Potential loss of pollinators*

The flowers and nectar of Proteaceous species are an important food source for insects, birds and small mammals such as the honey possum. The loss of susceptible plant species could potentially result in a loss of associated pollinators within an ecosystem as mammal and bird populations are unable to be sustained with a reduction in food resources (Garkaklis *et al.*, 2004; Wills, 1993). The loss of pollinators also has the potential to affect the reproductive success of plants not killed by the *Phytophthora cinnamomi* infestation (Wills, 1993).

**1.1.7 Secondary impacts of *Phytophthora cinnamomi* infestation on fauna**

The loss of habitat for fauna as a secondary impact of *Phytophthora cinnamomi* infestation has not been as well studied or acknowledged. Table 1.1 presents the effects a change in vegetation structure as a result of *P. cinnamomi* could potentially have on fauna. With any environmental change, it can be predicted that as the area of suitable habitat shrinks and essential resources become limiting, the population of animals dependent on these will also decline. Species-specific factors such as size of home range, availability of nesting areas or presence of specific plant species will also impact on how animal populations cope with a reduction in the size of suitable habitat. The level at which disturbances such as *P. cinnamomi* infestation can impact on fauna depends on the species of animal and its ability to adapt to changes.
Table 1.1: Effects of vegetation and subsequent predicted effects on fauna (Table derived from Wilson et al., 1994).

<table>
<thead>
<tr>
<th>Effects on vegetation</th>
<th>Effects on fauna</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of susceptible plant species from the canopy, midstorey and understorey</td>
<td>Direct loss of food sources like pollen, nectar, seeds, fungi for animals and indirect loss of food such as invertebrates</td>
</tr>
<tr>
<td>Decrease in floral richness and diversity in plant communities</td>
<td>Loss of food for species dependent on floral diversity, reduced seasonal availability of food</td>
</tr>
<tr>
<td>Decrease in vegetation coverage resulting in bare ground</td>
<td>Loss of habitats for fauna requiring dense vegetation, predation risk increased due to reduction in areas to shelter, change in microclimate conditions</td>
</tr>
<tr>
<td>Reduced litter on ground</td>
<td>Indirect decrease in food source for animals i.e. invertebrates</td>
</tr>
<tr>
<td>Increase in resistant flora post infection i.e. sedges</td>
<td>Increased food for herbivores as habitat becomes more open.</td>
</tr>
</tbody>
</table>
Current research focusing on fauna and Phytophthora cinnamomi infestation

Currently there is a limited amount of work which focuses on the impact of Phytophthora cinnamomi infestation on fauna communities. Studies have suggested that the loss of floral diversity and a change in vegetation structure due to P. cinnamomi infestation will have a significant impact on native fauna (Garkaklis et al., 2004; Wilson et al., 1994) however few studies have actually shown that the presence of P. cinnamomi in a vegetation assemblage has impacted the population of an animal species. Much of the work carried out in this area has been conducted by Barbara Wilson and colleagues, working in Victoria on small native mammals living in P. cinnamomi affected habitats e.g. (Laidlaw & Wilson, 2006; Newell & Wilson, 1993; Wilson et al., 2000; Wilson et al., 1994; Wilson et al., 1990). Despite this there has been relatively limited research as to how habitats affected with P. cinnamomi in WA have impact on native fauna. Some West Australian mammal species such as the honey possum are unique and different species have different habitat requirements. It is difficult to compare a nectarivorous marsupial such as the honey possum with a carnivorous marsupial such as an Antechinus as they will be impacted in different ways.

Antechinus stuartii, a small carnivorous marsupial present in the Brisbane Ranges, Victoria, were captured less frequently in Phytophthora cinnamomi affected areas in comparison to non affected areas (Newell, 1994; Newell & Wilson, 1993). Antechinus stuartii has a preference for tall dense vegetation which includes Xanthorrhoea australis (Newell & Wilson, 1993). A decrease in capture rates in the presence of P. cinnamomi was concluded as resulting from a loss of dense vegetation due to loss of X. australis plants (Newell & Wilson, 1993; Wilson et al., 1994). Radio tracking studies of Antechinus stuartii observed animals actively selecting uninfected areas (Newell, 1994). Male home ranges were found to be much larger than female home ranges and both overlapped significantly with areas uninfected by P. cinnamomi, especially areas in which X. australis was a dominant species (Newell, 1994; Wilson et al., 1994). A significant relationship was observed from radio
tracking studies between the presence of *A. stuartii* and vegetation density above 1m in height (Newell, 1994). This was especially apparent in *X. australis* dominated areas where *A. stuartii* were found to spend significant amounts of time (Newell, 1994).

Laidlaw and Wilson (2006) examined *Phytophthora cinnamomi* infected areas in the eastern Otway Ranges, Victoria, Australia. Seven common small mammal species including two native rodents *Rattus fuscipes* (bush rat), *Rattus lutreolus* (swamp rat), the introduced house mouse, *Mus domesticus*, two carnivorous marsupials, *Antechinus agilis* (previously *A. stuartii*), *Smithopsis leucopus*, a bandicoot *Isodon obesulus* (southern brown bandicoot) and *Cercartetus nanus* (eastern pygmy possum) were captured in non diseased, active disease and post disease areas, however the last two species were not captured often enough to analyse data (Laidlaw & Wilson, 2006). Capture rates were highest in non diseased areas and lowest in post diseased areas (Laidlaw & Wilson, 2006). High capture rates were associated with dense vegetation and floristic components (Laidlaw & Wilson, 2006).

In Western Australia, Whelen (2003) examined the effects of *Phytophthora cinnamomi* on the abundance of bush rats (*Rattus fuscipes*) during studies carried out in Waychinicup in the southwest heathlands. Bush rats were far less abundant in *P. cinnamomi* affected areas in comparison with captures in unaffected bushland (Whelan, 2003). Bush rats feed on an array of fungi (as well as insects) and fungal collections taken from the study sites were much lower in *P. cinnamomi* affected areas (Whelan, 2003).

Another West Australian study investigated the effects of *Phytophthora cinnamomi* on the abundance and distribution of mardo (*Antechinus flavipes leucogaster*) in jarrah forest (Carter, 2003). Study sites included unaffected sites, sites that were currently affected by *P. cinnamomi* and previously affected sites which had been rehabilitated (one with dieback resistant jarrah) (Carter, 2003). Mardo capture rates were linked to three environmental variables: capture rates were highest when the amount of (i) leaf litter and (ii)
shrub densities were high and (iii) in areas with pre or active *P. cinnamomi* infection status (Carter, 2003). Interestingly, the percentage trap success for 1200 trap nights was 5.67% within active *P. cinnamomi* infested sites, 4.33% in healthy unaffected forests and 2.33% in rehabilitated sites (Carter, 2003). Rehabilitation of *P. cinnamomi* affected sites was also found to be important for native fauna (Carter, 2003).

The research which has been done to date provides some insight into secondary impacts of *Phytophthora cinnamomi* on fauna species however there is still much that is unknown and further research in this area would be invaluable.

### 1.2 THE HONEY POSSUM (*TARSIPES ROSTRATUS*)

#### 1.2.1 Biology of the Honey possum

The honey possum is a small marsupial endemic to the South West of WA. This tiny mammal (which usually weighs between 7-12g) is unique has adapted to feed exclusively on nectar and pollen, a diet which requires flowering plants to be available all year round (Wooller *et al.*, 1981; Wooller *et al.*, 1984). The honey possum is the only non-flying mammal that feeds solely on nectar and pollen (Turner, 1984). The honey possum has adapted a bristled tongue which has many papillae at the tip enabling feeding on floral pollen (Richardson *et al.*, 1986).

The majority of previous research on the honey possum has been conducted in the Fitzgerald River National Park (Garavanta, 1997; Garavanta *et al.*, 2000), Scott National Park (Bradshaw & Bradshaw, 2002; Philips *et al.*, 2004) and Mount Lesueur Nature Reserve in Jurien (Arrese & Runham, 2003). The ecology of the honey possum population at Cape Riche has not been studied before and a more diverse range of data examining populations from a diverse range of habitat types will be beneficial in improving our overall knowledge of honey possum ecology.
Lifecycle and reproduction

Honey possums have marked sexual dimorphism with females tending to be larger than males (Renfree et al., 1984). Honey possums are aseasonal breeders and females can be found with pouch young throughout the year (Garavanta, 1997; Wooller et al., 1981). Although they do not have a specific breeding season, more female honey possums carrying pouch young can be found when preferred food plants are in flower which varies with location (Garavanta, 1997; Wooller et al., 1981). This contrasts with other small native mammals such as some Phascogale and Antechinus species which exhibit semelparity (reproduction once in a lifetime) and have short, highly seasonal breeding periods, after which there is a major stress induced die-off of males (Braithwaite & Lee, 1979; Millis et al., 1999). Honey possums are the smallest newborn mammals with average birth weight between 21μg-5mg, varying depending on sperm or conceptus in uterus (Renfree, 1980). Female honey possums exhibit embryonic diapause (where the growth of fertilised embryos can be delayed within the uterus) which is thought to be under environmental control such as the flowering periods of foodplants (Russell & Renfree, 1989). Female honey possums have one to two litters of 2-3 young a year (Russell & Renfree, 1989). They carry young in their pouch for around 56-63 days until they reach about 2-2.5g (Renfree et al., 1984). Once they have left the pouch, young will be carried on the mothers back and she will suckle them until they are approximately 91 days old before they disperse on their own (Russell & Renfree, 1989).

The mating system of honey possums is promiscuous and as a result, male honey possums have large scrotums which are approximately 4.2% of their total body weight (Renfree et al., 1984). Interestingly, male honey possums have the longest sperm of any living mammal, which indicates competitive gamete selection (Renfree et al., 1984). Both male and female honey possums reach sexual maturity at around six months of age (Russell & Renfree, 1989).

From trapping records, the average lifespan of the honey possum is estimated to be one year (Wooller et al., 1981). Long term studies of honey
possum populations in the Fitzgerald River National Park estimate the annual mortality rate (determined by capture rates) to be greater than 80% (Garavanta, 1997). The surviving population of honey possums have a high reproductive potential and are sufficient to increase the population to previous numbers within a year (Wooller et al., 1981). The lifecycle of the honey possum is correlated to nectar availability (Garavanta, 1997; Wooller et al., 1981) and it is thought that the annual mortality of majority of the population is due to starvation when flowering foodplants are scarce (Wooller et al., 1993). Garavanta (1997) has suggested a seasonal model for honey possum population dynamics based on long term trapping records from honey possums in the Fitzgerald River National Park. Honey possum populations were highest in winter when preferred foodplant *Banksia baueri* was in flower and also in summer when *Banksia nutans* flowers (Garavanta, 1997). In autumn, nectar availability is variable and hence honey possum capture rates also tend to be variable (Garavanta, 1997). Spring was found to be the season with lowest nectar availability and hence lowest capture rates (Garavanta, 1997).

**Torpor in the honey possum**

Since honey possums are so small and live within a seemingly narrow range of limits, they need a mechanism to conserve energy when food is scarce. Torpor is a state in which the body temperature is allowed to fall (on a daily basis) such that metabolic rate can be reduced by up to 90% (Collins et al., 1987). It is thought that torpor is initiated when critical energy levels are reached at which time honey possums enter torpor to conserve energy (Figure 1.4) (Collins et al., 1987). It is difficult to study torpor in honey possums in the field as honey possums are generally only captured in pit fall traps meaning they have already undergone a period of fasting before they are found so the results obtained tend to be inconclusive (Collins et al., 1987). Honey possums were tracked in the Scott National Park and only two out of nine tracked animals entered torpor during the study (Philips et al., 2004). The ambient temperature was no different to other periods throughout the study; however the main food source of the honey possum population in this area, *Banksia ilicifolia*, was not in flower, suggesting the most probable
reason for periods of torpor to be food shortage (Philips et al., 2004). Torpid honey possums have been captured in pit traps in the Fitzgerald Range National Park during March, April, June and September and with the exception of June (mid-winter), these months had the lowest daily nectar production by plants, indicating food was relatively scarce (Collins et al., 1987).

![Honey possum in torpor](image)

**Figure 1.4:** Honey possum in torpor

Laboratory research demonstrates that honey possums can go into torpor for several hours at a time, usually when subjected to periods of environmental stress such as food scarcity and low temperature (Collins et al., 1987; Withers et al., 1990). Smaller honey possums enter torpor more readily when deprived of food especially when ambient air temperatures are low (Collins et al., 1987; Withers et al., 1990).

### 1.2.2 Food plants & feeding

The high biodiversity of native WA flora in the southwest can cater to the dietary needs of the honey possum, since different plant species have staggered flowering periods. The sandplain heathlands of the western and southern coastlines of WA support a diverse range of flowering plants dominated by Proteaceae species and consequently, this is where the greatest number of honey possums have been captured (Wooller et al., 1984). Honey possums are a locally common species and have been noted
as the most common mammal in the Fitzgerald River National Park (Chapman 1995). Honey possums feed on species primarily from Proteaceae and to a lesser extent Myrtaceae species which are rich in nectar (Wooller et al., 1984). *Banksia* species are especially favoured foodplants of honey possums (Richardson et al., 1986). Honey possums are crepuscular feeders and tend to feed actively at night (Arrese & Runham, 2003) as well as early morning and late afternoon (Hopper & Burbidge, 1982).

In terms of dietary requirements, a 15g honey possum requires 0.11g of protein daily (Turner, 1984). Faecal samples collected from wild honey possums indicates 95-100% of ingested pollen was digested (pollen empty of contents) (Richardson et al., 1986). Therefore during peak flowering periods, a 15g honey possum would be able to satisfy their nutritional requirements with 1-2 *Banksia* inflorescences (Wooller et al., 1984). Studies done 50km east of Albany records 15-30 open *Banksia* inflorescences in a 10m² area, hence honey possums would not need to move very far to satisfy their daily pollen requirements, a theory which was supported with trapping records (Wooller et al., 1984). More recent research estimates a 9.9g honey possum would need to consume 34.4 ± 11.1 kJ d⁻¹ (Nagy et al., 1995). The most recent update suggests a 9g honey possum has a field metabolic rate of 28.6 ± 3.0 kJ d⁻¹ which equates to 7ml nectar and 1g pollen which would need to consumed every day to maintain energetic balance (Bradshaw & Bradshaw, 1999). Energy requirements of honey possums will change with season as ambient temperature influences metabolic rate (Withers et al., 1990).

*Adaptations to feed on nectar and pollen*

The long snout and long bristled tongue of the honey possum are adapted to allow these animals to bury their head into inflorescences to feed on nectar (Russell & Renfree, 1989) much like the long beak and tongue of birds such as honeyeaters which feed on similar plant species. Pollen is brushed or licked off flowers (Russell & Renfree, 1989). In addition to feeding specialisations, honey possums are also adapted generally to an arboreal lifestyle. Honey possums have a semi prehensile tail which provides support and balance (Renfree et al., 1984). The toes on both the front and back feet
have wide pads with extra traction allowing honey possums to move easily over branches and flowers.

1.2.3 *Tarsipes rostratus* as an indicator species

There is a concern for the future of honey possum populations in the presence of the plant pathogen *Phytophthora cinnamomi*, particularly since this pathogen has an impact on susceptible Proteaceous species which the honey possum relies on for food. The spread of this pathogen is likely to have an effect on the abundance and movements of honey possums, as the availability of food sources becomes seriously depleted.

The significant relationship between nectar availability and honey possum population size (Wooller *et al.*, 1993) makes the honey possum an ideal species to study in terms of the secondary effects of *Phytophthora cinnamomi* infection in native bushland. Honey possum capture rates have previously been directly related to the amount of nectar present in the surrounding habitat (Wooller *et al.*, 1993). As a result of the unique feeding niche which honey possums fill (Wooller *et al.*, 1984), this species would be highly sensitive to any vegetation changes which would affect their food sources. Previously, honey possums have been thought of as a predominately sedentary species, occupying a relatively small area (Garavanta, 1997; Garavanta *et al.*, 2000). With size of utilisation areas becoming larger when flowering foodplants become scarce, honey possums have to move further to feed (Garavanta, 1997). Radio tracking provides an opportunity to determine where and how far honey possums are actually moving (Bradshaw & Bradshaw, 2002). Radio tracking is also useful in determining if areas affected by *P. cinnamomi* infection are still utilised by honey possums, despite the decrease in preferred food plants which are susceptible to infection.
1.3 Overall aim of this research project

The overall aim of this research project is to determine the extent to which the presence of *Phytophthora cinnamomi* affected vegetation impacts on habitat utilisation by honey possums.

1.3.1 Research Objectives

The research objectives are to:

- Confirm the change in vegetation structure due to the presence of *Phytophthora cinnamomi* at the Cape Riche study site (Chapter 2).
- Determine if the microclimate in *Phytophthora cinnamomi* affected areas differs from healthy areas and how this relates to honey possums (Chapter 2).
- Capture honey possums at Cape Riche over four seasons (Chapter 2).
- Determine specific food plants preferred by honey possums in the Cape Riche area from pollen samples (Chapter 3).
- Capture suitable honey possums for radio tracking (Chapter 4).
- Ascertain if the movements of honey possums are influenced by the presence of *P. cinnamomi* affected vegetation (Chapter 4).
- Identify specific honey possum habitat requirements and to determine if these are impacted in the presence of *P. cinnamomi*. (Chapter 4).

**Hypothesis 1** - Changes in vegetation structure and composition as a result of *Phytophthora cinnamomi* influences habitat selection by honey possums.

**Hypothesis 2** – Honey possums are capable of moving long distances in search of food sources.

**Hypothesis 3** – Honey possums will not utilise widespread *Phytophthora cinnamomi* affected areas.
CHAPTER 1: General introduction and Literature review

Microclimate changes in affected vs unaffected areas

CHAPTER 2: Study site location and experimental protocols

Confirm *P. cinnamomi* presence at site

Research objectives

CHAPTER 3: Pollen sampling to determine preferred foodplants

Observe honey possum population at Cape Riche

Capture honey possums for pollen collection and radio tracking

Determine honey possum preferred foodplants

Determine if movements influenced by *P. cinnamomi* affected vegetation

Determine specific honey possum habitat requirements

CHAPTER 4: Radio tracking of honey possums in *Phytophthora cinnamomi* infested areas to determine habitat preferences

CHAPTER 5: General discussion and Conclusion

Figure 1.5: Flowchart of thesis structure.


2  CHAPTER 2: STUDY SITE LOCATION AND SITE DESCRIPTIONS

2.1  Introduction

The heathlands of the south coast of WA are rich in Proteaceous and Myrtaceous species and provide the ideal habitat for honey possums; however many of these areas are under threat from Phytophthora dieback. This study was carried out in coastal heathlands at Cape Riche WA which have been affected by Phytophthora cinnamomi. The research objectives addressed in this chapter were firstly to confirm that the vegetation structural changes observed at the Cape Riche study site were a result of P. cinnamomi infestation. Secondly, to determine if the microclimate of affected and healthy areas differ and how that difference could impact on honey possums. The final research objective addressed in this chapter was to capture honey possums to observe a representative sample of the honey possum population at Cape Riche. Captured honey possums were also examined to determine preferred foodplants (Chapter 3) and for radio tracking (Chapter 4).

2.2  Methods and Materials

2.2.1  Study site location

This study was conducted in a proposed conservation park close to Cape Riche located on the south coast 119km east of Albany, WA (34.00°S and 118.43°E) (Figure 2.1). Pit traps at three study sites were installed in November 2006 and HOBOs were also set up at this time (see Section 2.2.8). This area has identifiable regions of Phytophthora dieback infection and is also the study area for a Department of Environment and Heritage funded project studying the eradication of P. cinnamomi from a site (W. Dunstan, pers comm.).
2.2.2 Climate

The Cape Riche area has a Mediterranean climate with warm, dry summers and cool, wet winters (Mercer & Leighton, 1999). As there was no single Bureau of Meteorology (BOM) weather station located near the site, weather information from two nearby BOM stations, the Mettler station (34.60 °S and 118.55 °E) and the Ongerup, a slightly more inland station at (33.96 °S and 118.49 °E) was used. These were deemed to be the most representative weather stations to the study site. Long term temperature and rainfall records were obtained from both of these stations.

Maximum temperatures (Figure 2.2a) during summer in Mettler reach about 25°C and minimum temperatures during winter get down to about 6°C. The Ongerup weather station is located further inland and summer maximum temperatures reach about 28°C and winter minimum temperatures get down to 6.5°C (Figure 2.2b). The long term mean annual rainfall at Mettler is 617.3mm and at Ongerup is 385.6mm (BOM, 2008). In 2007, most months experienced close to average annual rainfall except high rainfall in October at Mettler and at both stations, lower rainfall in November followed by above average December rainfall (Figure 2.3 a and b).
Figure 2.2: Minimum and maximum mean temperatures for a) Mettler and b) Ongerup. (Values from 1966 - 2007 from BOM, 2008).
Figure 2.3: Mean rainfall and rainfall in 2007 for a) Mettler and b) Ongerup (Values from 1971 - 2000 from BOM, 2008).
2.2.3 Soil and Geology

The geology of the study site is quite varied with distinct areas of different soil types. There are three main soil types found at the study site. The spongelite / granite ridges and slopes are characterised by laterite crests on the ridges with shallow soils and perched sand deposits (Mercer & Leighton, 1999). Deep sandy soils are characterised by trapped or perched Eolian sand (Mercer & Leighton, 1999). The third soil type is Sandplain A which encompasses laterite overlayed by gravelly yellow duplex soils (Mercer & Leighton, 1999). Each soil type supports a different range of vegetation (Mercer & Leighton, 1999).

2.2.4 Fire history

Historically, the majority of fires in the Cape Riche area have been caused by human carelessness (Mercer & Leighton, 1999). The most notable was a widespread fire which impacted upon the study area in 1994; a fire scar is still evident on aerial photos of the area (Figure 2.10). Site 3 is located on the border of the fire scar and site 2 is located within the fire scar. The most recent fire occurred in 2007, during the study period, due to lightning strike but was confined to a ridge out of the study area.

2.2.5 Vegetation assemblages at the study site

The vegetation of the Cape Riche area is classified as a mallee heath association merging into a scrub heath on deeper sands closer to the coast (Mercer & Leighton, 1999). Vegetation at Cape Riche is similar to that found in the Stirling Range National Park (Mercer & Leighton, 1999) with abundant Eucalyptus and Banksia species. Vegetation and fauna surveys were undertaken in the Cape Riche area in 1999 as part of a coastal survey which was incorporated into a revised Coastal Management Plan for the area (Mercer & Leighton, 1999). The vegetation surveys were extensive and provide detailed floral species lists (Mercer & Leighton, 1999). The survey also described a range of soil types and landforms in the area on which a varying array of vegetation types grow (Mercer & Leighton, 1999). There are
three distinct vegetation assemblages recognised in the area where this study took place. Spongelite ridges are characterised by an abundance of *Banksia, Eucalyptus* and *Hakea* species (Mercer & Leighton, 1999). Deep sand deposits support *Banksia baxteri* thickets (Mercer & Leighton, 1999). Sandplain A soils are characterised by *Eucalyptus* and *Banksia* species as well as *Lambertia inermis*. Analysis of vegetation at the study site is discussed in more detail in Chapter 4.

**N.B** The taxonomic amalgamation of genus *Dryandra* with *Banksia* occurred during the write up of this thesis and a list of all the plant species mentioned is listed in Appendix 1 and includes the old and new names as well as the authority for each species. For studies referenced herein, the new nomenclature will be used consistently.

### 2.2.6 Site selection and descriptions

Three sites were selected within the study area for the installation of pit trap lines. Site selection was based on the presence of an obvious dieback front, so that half of each trap line was located within affected vegetation and the other half was in unaffected vegetation (Figure 2.12 and Figure 2.13).

Similarity in dominant plant species was also a factor for site selection. *Banksia baxteri* is widespread throughout all 3 sites. Other species present at the sites in terms of potential honey possum food sources included *Adenanthes cuneatus, Banksia plumosa* subsp. *plumosa, Banksia nutans, Eucalyptus angulosa* and *Beaufortia anisandra*.

The specific sites selected for the installation of pit traps were initially thought to represent independent locations, assuming radio tracked honey possums were to remain roughly within a 100m x 100m area. This presumption was based on trapping studies in the Fitzgerald River National Park, where honey possums were observed to move 20-30m between traps (the furthest movement was 125m) (Garavanta, 1997; Garavanta *et al.*, 2000). This experimental design was however, quickly shown to be inadequate with the first honey possum tracked moving beyond the trap locations (see Section
4.3.2). The following site descriptions describe an area roughly represented by Figure 2.12 for each site.

Site 1 description

Site 1 consisted of 3 distinct areas. A healthy *Banksia baxteri* thicket dominated the deeper sand areas and this was where half of the traps (n=10) were located (Figure 2.4 S1UA). The banksia thicket was dominated by *Banksia baxteri* (Figure 2.4 S1UA) as well as some *B. nutans*. The other half of the pit traps (n=10) were located in the adjacent *Phytophthora cinnamomi* affected area (Figure 2.5 S1PA). The affected areas extended from the road and towards a drainage area to site 2 with a finger extending behind the healthy *B. baxteri* thicket (Figure 2.10). *Phytophthora cinnamomi* affected areas were dominated by low dense shrubs, consisting predominately of *Myrtaecae form* (*Melaleuca* and *Beaufortia* species were not in flower when examined and could not be identified to genus or species), sedge species and *Calytrix angulata* (Figure 2.5 S1PA). Most susceptible plant species were absent from affected areas, although paradoxically some healthy *Banksia nutans* and *B. attenuata* were still present in healthy ‘islands’. Recognised honey possum food plants (see section 3.4.1) such as *Beaufortia anisandra* and *Adenanthos cuneatus* were also present in affected areas. The *B. baxteri* thicket was located in a valley behind which was a spongelite ridge (Figure 2.10). The diverse vegetation associated with the spongelite ridge included many honey possum food plants including *Banksia plumosa* subsp. *plumosa* and *Eucalyptus* species.
Figure 2.4: Seasonal photos at the Cape Riche study site in the *Phytophthora cinnamomi* unaffected area at Site 1. Blue arrows indicate dominant *Banksia Baxteri*. 
Figure 2.5: Seasonal photos at the Cape Riche study site in the Phytophthora cinnamomi affected area at Site 1. Red arrow indicates low Myrtaceae-form shrubs (*Melaleuca* and/or *Beaufortia* species) and sedge species which dominate affected areas. Flowering shrubs with yellow flowers indicated by green arrow are *Calytrix angulata*. 
Site 2 description

The healthy area at site 2 (10 pit traps) was Banksia thicket dominated by B. baxteri and B. attenuata (Figure 2.6 S2UA). This healthy area tended to be confined to an elevated area at site 2 (Figure 2.10). The Phytophthora cinnamomi affected area (Figure 2.7 S2PA) is characterised by the lack of susceptible species, coupled with low scrub including Melaleuca-forms (see above) and sedge species present at the lower elevations (Figure 2.7 S2PA). As for site 1, there were a few individual plants of susceptible species scattered through the affected area including Banksia attenuata and Banksia coccinea (which tended to be stunted and in March 2008 some individual B. coccinea plants were dead) as well as healthy Adenanthos cuneatus plants. The patches of bare ground in affected areas compared to unaffected areas were more obvious at this site. Beyond the B. baxteri thicket was a spongelite ridge with the same vegetation structure to that in site 1 and site 3 (Figure 2.10).
Figure 2.6: Seasonal photos at the Cape Riche study site in the *Phytophthora cinnamomi* unaffected area at Site 2. Blue arrow indicates *Banksia baxteri* and yellow arrow indicates *Banksia attenuata.*
Figure 2.7: Seasonal photos at the Cape Riche study site in the Phytophthora cinnamomi affected area at Site 2. Red arrow indicates *Melaleuca* form shrubs (*Melaleuca* and/or *Beaufortia* species) and sedge species. Orange arrow indicates small *Banksia coccinea* plant.
**Site 3 description**

The influence of *Phytophthora cinnamomi* infestation was less defined at site 3 compared with the other sites as a result of site 3 being located on the border of the 1994 fire scar (Figure 2.10). The affected area at this site demonstrated an obvious lack of vegetation density (Figure 2.9 S3PA) however the independent influences of *P. cinnamomi* and fire on this site are difficult to differentiate. Many recognised honey possum food plants were present at site 3 including *Banksia plumosa* subsp. *plumosa*, *B. brunnea*, *B. tenuis* and *Beaufortia anisandra* in both the affected and unaffected areas. The majority of the plants in the affected area, however, were very small and tended to be stunted (Figure 2.9 S3PA). Half of the trap line (10 traps) at site 3 was located in the affected area and the other half in thick *B. baxteri* thickets (10 traps) which also contained *Hakea species* and large *Lambertia inermis* bushes (Figure 2.8 S3UA). Behind site 3 was a spongelite ridge supporting a similar vegetation assemblage as the ridges in site 1 and site 2 (Figure 2.10).
Figure 2.8: Seasonal photos at the Cape Riche study site in the *Phytophthora cinnamomi* unaffected area at Site 3. Light blue arrow indicates *Lambertia inermis* shrubs, purple arrow indicates *Hakea cucullata*. 
Figure 2.9: Seasonal photos at the Cape Riche study site in the *Phytophthora cinnamomi* affected area at Site 3. Note the spare vegetation coverage (red arrow) and stunted plants such as *Banksia plumosa* subsp. *plumosa* (grey arrow).
Figure 2.10: Aerial photo (obtained from Landgate, Midland) of study area at Cape Riche Western Australia with 100m trap lines at sites 1, 2 and 3 indicated. Green shading indicates spongelite ridges, yellow indicates Banksia baxteri thickets, red shading indicates *Phytophthora cinnamomi* affected areas (confirmed with plating of infected plant material and from visual assessments of the area), red line indicates drainage channel, blue arrow indicates 1994 fire scar visible at the study site.
2.2.7 *Phytophthora cinnamomi* status of the study area

To confirm the presence of *Phytophthora cinnamomi* at the three study sites, samples of plant material were collected by Associate Professor Giles Hardy (School of Biological Sciences and Biotechnology Murdoch University) from dying plants, most of which had obvious *P. cinnamomi* lesions (G. Hardy *pers. comm.*). Briefly, plants that were (i) exhibiting chlorosis an early symptom of *P. cinnamomi* infection, or (ii) recently dead were excavated to remove some root material and above ground stem tissue. The material was placed in cool boxes and returned to the laboratory. In the field, bark material was removed from the stem in order to find necrotic lesions. Wood material which included diseased (necrotic) and healthy wood (the lesion front) was cut into 1 cm sections, surface sterilised in 70% ethanol for 1 minute and washed in sterile water or briefly flamed. Approximately 5 x 5 mm sections were then plated onto NARPH, a *Phytophthora* selective agar (Huberli et al., 2000) and incubated at 20°C in the dark. Mycelial outgrowths were then confirmed as *P. cinnamomi* based on colony morphology and sporangial measurements. As *P. cinnamomi* was isolated directly from plant material, soil baiting was not considered necessary.

2.2.8 Microclimate analysis at study site

The microclimate of the three study sites was recorded with the use of 18 HOBO® H8 Pro series field data loggers set to record temperature and relative humidity every 30 minutes for a year (November 2006 – November 2007). Three HOBO data loggers were attached with wire to a star picket at 0, 0.5 and 1m from the ground (Figure 2.11). Pickets were placed halfway along the trap line in the affected side and halfway along the trap line in the unaffected side for each of the 3 study sites. Each star picket was fitted with a cardboard cover to provide some protection from rain and direct sunlight (Figure 2.11). Data was downloaded from HOBO data loggers with BoxCar (Onset_Computer_Corp., 2002).
Figure 2.11: HOBO® H8 Pro series field data loggers in the field with cardboard cover. Three HOBOs were mounted onto a star picket at 0m (indistinguishable behind vegetation at the bottom of the figure), 0.5m and 1m off the ground. Two of these were placed at each of the three study sites, one in the affected area and one in the unaffected area.

2.2.9 Animal trapping experimental design

Trapping and tracking took place during four, two week field trips during January / February 2007 (summer field trip), April / May 2007 (autumn field trip), August 2007 (winter field trip) and November 2007 (spring field trip) to reflect all seasons. Honey possums were captured in unbaited pit traps which is the standard and most effective method of capture for this species (Bradshaw & Bradshaw, 2002; Wooller et al., 1981). Twenty pit traps were installed at each of the 3 study sites (total 60 pit traps). The trap line stretched over an obvious dieback front with 10 traps in Phytophthora cinnamomi affected vegetation and 10 in unaffected vegetation (Figure 2.12 and Figure 2.13). Pit traps consisted of 40cm lengths of 15cm diameter stormwater PVC pipe which were buried up to the rim so they sat flush with the ground (Figure 2.14). Traps were closed with metal lids when not in use. Traps were arranged in pairs, 5m apart, in an alternating perpendicular and vertical manner (Figure 2.12). Drift fencing was also used to direct animals into the pit traps and increase capture rates. A 10m drift fence was installed either side and between each trap pair (Figure 2.12); drift fences were constructed of aluminium fly wire 33cm in width, the bottom 5cm of which was buried in soil to allow the fence to stand up (Figure 2.13). Shredded newspaper and a 10cm x 10cm piece of polystyrene tray were placed in
every pit trap to provide some shelter and refuge for captured honey possums. In summer months, ants proved to be a problem, especially in the affected areas and Mortein ant sand (active constituent Bifenthrin 2g/kg Reckitt Benckiser Australia) was initially sprinkled lightly in all pit traps as well as on any ant nests located close to the trap sites. When live ants were found in pit traps, another light sprinkle of ant sand was applied.

![Figure 2.12: Setup of trap lines (not to scale).](image)
This was replicated at all 3 sites.

![Figure 2.13: Trap line with 10m flywire drift fencing at site 2 in the Phytophthora cinnamomi affected area.](image)
Yellow arrow indicates dieback front in background. Red circles indicate location of traps.
Pit traps were opened just on dusk during the summer months and up to 2 hours after sunset during the autumn, winter and spring field trips in an effort to minimise the time honey possums were left in pit traps, especially during cold weather. Traps were checked at first light. Captured possums were weighed and ear tagged (Figure 2.15) before being rubbed around the nose and mouth with Wooller’s gel (Wooller et al., 1983a) to collect any pollen (see Section 3.2.1). Animals were then measured using digital callipers for head length, hind foot length, tail and body length. Each individual was then fed a saturated sugar water solution prior to release (Figure 2.16). Honey possums not fitted with radio transmitters were then released at point of capture. Honey possums fitted with transmitters (see Section 4.2.2) were kept in a calico bag for up to 15 minutes until the glue dried before release at point of capture.
Bycatch animals

Mammals other than honey possums were identified, weighed, ear tagged and measured with callipers (as described above for honey possums) prior to release at point of capture (see Appendix 4). Reptiles and frogs captured in pit traps were simply released at point of capture.

2.2.10 Statistical analysis

Average values for temperature including minimum, maximum, daily average, daily coefficient of variation (CV), proportion of records <5°C and >28°C were calculated and for each of the 18 HOBOs. Values for relative humidity including daily minimum, daily maximum, daily average and daily CV were also calculated. Statistical analyses of the data were carried out with the use of Statistica (StatSoft-Inc, 2002). A three way ANOVA was used to determine whether there were differences in temperature and relative humidity (for each of the values mentioned above as dependent variables) for Phytophthora cinnamomi status (affected versus unaffected areas), height of the HOBO from the ground (0, 0.5 and 1m) and season (summer, autumn, winter and spring). Three way ANOVAs were also applied to the average proportion of temperature records <5°C and >28°C for the same three independent factors. These temperatures were selected since they are of particular importance to honey possums (Section 2.4.3).
For honey possum capture data, capture success rates were calculated by dividing the number of animals captured by the number of trap nights. Capture success rates were calculated separately for each season and also the whole study period. Juveniles were classified as individuals weighing <7g (Garavanta, 1997). Chi squared tests were applied to the number of captures to determine significant differences in captures of adults versus juveniles, males versus females and differences in capture success rates in relation to season.

A multiple regression analysis was performed to determine if honey possum body mass, was correlated with season of capture. Measures of body size (head length, pes length, tail length, body length) and sex of captured honey possums were taken into account (included in the model as independent factors).

### 2.3 Results

#### 2.3.1 *Phytophthora cinnamomi* testing at the Cape Riche study site

*Phytophthora cinnamomi* was isolated from all three sites. Host species included *Adenanthos cuneatus*, *Banksia attenuata*, *B. baxteri*, *B. coccinea*, *B. repens* and *Lambertia inermis*. Furthermore, visual assessment of the study sites was undertaken by a dieback conservation officer from the Department of Environment and Conservation (DEC) and Associate Professor Giles Hardy, during which *P. cinnamomi* impacts at site 1 and 2 were identified (N. Moore pers. comm., G. Hardy pers. comm.). Site 3 was identified as heavily impacted from the 1994 fire making *P. cinnamomi* cryptic and diagnosis difficult at this site. *Phytophthora cinnamomi* was however isolated from selected plants collected from this area. Aerial canker was visually identified at site 3, most commonly in *Lambertia inermis* plants as well as in *Banksia baxteri* at sites 1 and 2 (N. Moore pers. comm., G. Hardy pers. comm.).
2.3.2 Microclimate at the Cape Riche study site

*Temperature and relative humidity at the study site*

There were only small differences in minimum and average temperatures between *Phytophthora cinnamomi* affected and unaffected areas (Figure 2.17 a and b, \( p < 0.05 \)), however daily maximum temperature was significantly higher for unaffected areas compared to *P. cinnamomi* affected areas (Figure 2.17 c, \( p < 0.001 \)). Unaffected areas subsequently recorded a significantly greater range of temperatures over the day (Table 2.1 and Figure 2.17 a-d). The interactions between season and height above the ground was significant with highest maximum temperatures at 1m during summer and lowest minimum daily temperatures at 0.5m during winter (Table 2.1 and Figure 2.17a-d). CV of daily temperatures was also significant for unaffected areas at 0.5m (Figure 2.17d). Combined effects of *P. cinnamomi* status and season were highly significant (\( p < 0.001 \)) for average and maximum temperature and significant (\( p < 0.05 \)) for daily CV (Table 2.1). Combined effects of *P. cinnamomi* status and height above ground on temperature were significant for daily CV and minimum temperature (\( p < 0.01 \) and \( p < 0.05 \), respectively) (Table 2.1).

The proportion of temperature records <5°C was related to season and *P. cinnamomi* status. Affected sites yielded more records <5°C (Figure 2.18 e). Unaffected sites yielded more records <28°C (Figure 2.18 f and Table 2.1). The interaction term between *P. cinnamomi* status and season was significant (\( p < 0.01 \)) for the proportion of records <28°C but not for the proportion of records <5°C (Table 2.1).

The relative humidity in areas unaffected by *Phytophthora cinnamomi* had greater variability in relative humidity and overall lower maximum relative humidity in comparison to affected areas (Table 2.2 and Figure 2.19 g-j).
Figure 2.17 (a-d): Average temperature data and standard deviations in *Phytophthora cinnamomi* affected and unaffected areas at the Cape Riche study site.

PA = *Phytophthora cinnamomi* affected, UA = Unaffected.
Figure 2.18 (e & f): Proportion of records <5°C (e) and >28°C (f) in Phytophthora cinnamomi affected and unaffected areas at the Cape Riche study site.

Temperatures <5°C are of importance to honey possums as their metabolic rate increases at ambient temperatures <5°C (Withers et al., 1990).

PA = Phytophthora cinnamomi affected, UA = Unaffected.
Figure 2.19 (g-j): Average relative humidity data and standard deviations in *Phytophthora cinnamomi* affected and unaffected areas over one year at the Cape Riche study site.
PA = *Phytophthora cinnamomi* affected, UA = Unaffected.
Table 2.1: Significance values determined by a three way ANOVA for temperature data collected in *Phytophthora cinnamomi* affected and unaffected areas over one year at the Cape Riche study site. (*p < 0.05, **p < 0.01, ***p < 0.001*)

<table>
<thead>
<tr>
<th></th>
<th>Affected / Unaffected</th>
<th>Season</th>
<th>Height (0m, 0.5m, 1m)</th>
<th>Affected / Unaffected and Season</th>
<th>Affected / Unaffected and Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily Minimum Temperature</td>
<td>*</td>
<td>***</td>
<td>***</td>
<td>NS</td>
<td>*</td>
</tr>
<tr>
<td>Daily Average Temperature</td>
<td>*</td>
<td>***</td>
<td>NS</td>
<td>***</td>
<td>NS</td>
</tr>
<tr>
<td>Daily Maximum Temperature</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>NS</td>
</tr>
<tr>
<td>Daily CV Temperature</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>*</td>
<td>**</td>
</tr>
<tr>
<td>Daily proportion records &lt; 5 °C</td>
<td>NS</td>
<td>***</td>
<td>-</td>
<td>NS</td>
<td>-</td>
</tr>
<tr>
<td>Daily proportion records &gt; 28°C</td>
<td>***</td>
<td>***</td>
<td>-</td>
<td>**</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 2.2: Significance values determined by a three way ANOVA for relative humidity data collected in *Phytophthora cinnamomi* affected and unaffected areas over one year at the Cape Riche study site. 

\((p < 0.05, \; ** \; p < 0.01, \; *** \; p < 0.001)\)

<table>
<thead>
<tr>
<th>Daily Minimum Relative Humidity</th>
<th>Affected / Unaffected</th>
<th>Season</th>
<th>Height (0m, 0.5m, 1m)</th>
<th>Affected / Unaffected and Season</th>
<th>Affected / Unaffected and Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>***</td>
<td>***</td>
<td>NS</td>
<td>***</td>
<td>NS</td>
<td>***</td>
</tr>
</tbody>
</table>

| Daily Average Relative Humidity  | *                     | ***    | ***                    | NS                               | ***                             |

| Daily Maximum Relative Humidity  | NS                    | ***    | ***                    | NS                               | ***                             |

| Daily CV Relative Humidity      | ***                   | ***    | ***                    | ***                              | ***                             |
2.3.3 Honey possum captures

A total of 102 honey possums were captured over 1314 trap nights representing an overall trap success rate of 7.76% (Table 2.3). There was no significant ($\chi^2=0.90, \ p>0.05$) difference in the number of males (48) versus females (52) captured, with two individuals recording unknown sex (Table 2.3). The overall number of juvenile honey possums (<7g) captured was 39.2%. There was no significant ($\chi^2=0.55, \ p>0.05$) difference in the number of adult honey possums captured in comparison with the number of juveniles captured (Table 2.3 and Figure 2.20). No significant difference was noted in the number of honey possums captured in unaffected areas (52%) versus affected areas (48%) ($\chi^2=0.69, \ p<0.05$) (Table 2.3). The trap success rate (Table 2.3) varied with season ($\chi^2=13.1, \ p<0.0005$) with the greatest trap success recorded during the summer field trip with a 17.8% trap success (Figure 2.20).

Table 2.3: Capture data for honey possums over 4 trapping sessions between January 2007 – November 2007 at the Cape Riche study site.

<table>
<thead>
<tr>
<th></th>
<th>Summer</th>
<th>Autumn</th>
<th>Winter</th>
<th>Spring</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Captures</td>
<td>53</td>
<td>12</td>
<td>16</td>
<td>21</td>
<td>102</td>
</tr>
<tr>
<td>Trap nights</td>
<td>320</td>
<td>280</td>
<td>255</td>
<td>459</td>
<td>1314</td>
</tr>
<tr>
<td>Trap success %</td>
<td>17.8</td>
<td>8.2</td>
<td>7.5</td>
<td>5.2</td>
<td>7.76%</td>
</tr>
<tr>
<td>Males</td>
<td>29</td>
<td>5</td>
<td>6</td>
<td>8</td>
<td>48</td>
</tr>
<tr>
<td>Females</td>
<td>22</td>
<td>7</td>
<td>10</td>
<td>13</td>
<td>52</td>
</tr>
<tr>
<td>Unknown sex</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Recaps</td>
<td>4</td>
<td>11</td>
<td>3</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>Captured in</td>
<td>32</td>
<td>8</td>
<td>5</td>
<td>8</td>
<td>53</td>
</tr>
<tr>
<td>unaffected area</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Captured in</td>
<td>21</td>
<td>4</td>
<td>11</td>
<td>13</td>
<td>49</td>
</tr>
<tr>
<td>affected area</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juveniles (&lt;7g)</td>
<td>19</td>
<td>6</td>
<td>4</td>
<td>11</td>
<td>40</td>
</tr>
</tbody>
</table>
Figure 2.20: Percentage trapping success of honey possums in each of the four trapping sessions for adults (>7g bodyweight) and juveniles (<7g bodyweight). Figures in brackets are the number of trap nights for each season.

Examination of honey possum condition by multiple regression indicated body mass of honey possum (and therefore condition) was not significantly correlated to season ($t_{(86)} = -0.670, p=0.50$) or sex ($t_{(86)} = 0.21, p=0.83$) once allometric relationships with body size were taken into account (head length: ($t_{(86)} = 2.34, p=0.05$), body length: ($t_{(86)} = 3.54, p=0.001$) and tail length: ($t_{(86)} = 2.17 , p=0.05$) and pes length: ($t_{(86)} = 1.60, p>0.10$).
2.4 Discussion

2.4.1 Phytophthora cinnamomi at the study site

*Phytophthora cinnamomi* was positively identified from all three study sites. The presence of *P. cinnamomi* was more distinctive at site 2 compared with the other sites. The movement of water through a sandy natural discharge area extending between site 1 to site 2 is the most likely way in which *P. cinnamomi* has been dispersed to this area (Figure 2.10) (N. Moore *pers. comm.*). The deep sands in the discharge area are also the preferred soil type for *Banksia baxteri* which in the absence of the pathogen, forms dense thickets (Mercer & Leighton, 1999). The areas identified as affected by the pathogen at Cape Riche are characterised by loss of susceptible species including *Banksia baxteri*, *B. coccinea*, *B. attenuata*, *B. plumosa* subsp. *plumosa*, *Isopogon trilobus* and *Lambertia inermis* and the persistence of less susceptible species including Myrtaceae-form species, rush and sedge species.

Older, patchy *P. cinnamomi* affected areas were visually identified on top of the spongelite ridge above site 1 (N. Moore *pers. comm.*) and honey possums were radio tracked to the vegetation on these ridges (see Section 4.3.2). The spongelite ridges support a diverse floristic community which includes many *Banksia* and *Eucalyptus* species (Mercer & Leighton, 1999). Many of the honey possum preferred food plants were far more prevalent on these ridges than in the lower areas (see Section 3.4.1). The presence of individual plants possibly affected by *P. cinnamomi* above these rich floristic communities as well as below (in the valleys) means infestation of these areas by *P. cinnamomi* is inevitable as the pathogen spreads (N. Moore *pers. comm.*). Root to root contact of affected plants can result in slow movement up the slope from the affected valley but water movement will rapidly spread the pathogen down-slope (Shearer, 1994). Further spread of *P. cinnamomi* through the study area at Cape Riche is inevitable and the loss of susceptible plant species, in particular the *Banksia* species, will have a significant effect on the vegetation assemblages. This loss will significantly impact upon the honey possum population in the area.
2.4.2 Microclimate in *Phytophthora cinnamomi* affected areas versus unaffected areas

The differences in the range of temperatures recorded in unaffected and affected sites were surprising since it was expected affected sites would have greater temperature ranges due to the exposed nature of these sites in comparison to unaffected sites. The explanation for this discrepancy may lie in differences in wind exposure which would move the air around the more exposed HOBOs in affected areas keeping the temperatures more constant than in unaffected areas which have the buffering effect of the surrounding dense vegetation. This may also be the reason for the differences noted in temperatures at the three heights of the HOBOs. At 0m, the HOBO temperatures recorded will be influenced by the temperature of the ground whereas at 1m, the movement of air around the HOBO influences temperatures more than at 0.5 and 0m. The relative humidity of unaffected versus affected at the three heights is also likely to be influenced to some extent by the movement of air around the HOBO and the buffering effect of vegetation. There is no previous published research which has utilised HOBOs to compare microclimate differences in affected and unaffected areas in the same manner as the current study. HOBOs were used to determine differences in microclimate within burnt and unburnt grasstrees in relation to habitat for mardo in southwest jarrah forest (Swinburn, 2005) however the results obtained from this study are not entirely relevant to the current study. The value of comparison is most likely limited as different areas are likely to record different microclimate trends. The difference in the microclimate of vegetation assemblages in affected versus unaffected areas has the potential to impact upon the animals living in these areas.

2.4.3 Ambient temperature and torpid state in honey possums

Honey possums can enter a state of torpor when they undergo food deprivation and cold stress (See section 1.2.1) (Withers *et al.*, 1990). In the laboratory, honey possums deprived of food for 24 hours enter torpor when ambient temperatures fall below 20°C (Withers *et al.*, 1990).
The basal metabolic rate calculated for honey possums is 2.9 mL $\text{O}_2$ g$^{-1}$ h$^{-1}$ (Withers et al., 1990). When honey possums undergo torpor, body temperature is maintained within 1-2°C of ambient temperatures and oxygen consumption can drop to less than 0.5 mL $\text{O}_2$ g$^{-1}$ h$^{-1}$ (Withers et al., 1990). However, when the ambient temperature drops below 5°C, the oxygen consumption rate of torpid honey possums increases to maintain a minimal body temperature of 5°C (Withers et al., 1990). This means if honey possums are regularly exposed to temperatures <5°C they need to consume more food since, even when they utilise torpor, they experience metabolic costs at these low temperatures (Withers et al., 1990). On the other end of the scale the lowest oxygen consumption rate (which suggests metabolic rate) for honey possums was observed between 28 - 34°C in the laboratory (Withers et al., 1990). At ambient temperatures above 34°C honey possum metabolic rate increases, most likely in response to heat stress (Withers et al., 1990).

The relevance of calculating the proportion of time ambient temperature fell below 5°C or increased above 28°C (as determined from the HOBOs) was to compare the amount of time that honey possums foraging in unaffected and affected areas would be exposed to these temperatures. In affected areas, the temperature was <5°C more often than in unaffected areas at 0m and 0.5m (but not 1m) which is the vegetation height range where honey possums were most often observed foraging during radio tracking. Consequently during winter and spring especially, honey possums need to forage more in *Phytophthora cinnamomi* affected areas, (where foodplants tend to be scarce already), as they incur greater metabolic costs due to thermal demands compared with foraging in unaffected vegetation. In unaffected areas temperatures were above >28°C more often than in affected areas. Consequently honey possums foraging in unaffected areas during summer, autumn and spring (no temperatures over 28°C were recorded in winter), require less food to meet metabolic demands than in affected areas. Interestingly, the highest maximum temperatures were observed in unaffected areas and it may be that honey possums are less likely to experience heat stress as a result of temperatures exceeding 34°C (when oxygen consumption increases) in affected areas in comparison to unaffected areas. This would be an interesting area for further study.
During the current study, torpid honey possums were found in pit traps primarily during winter, although smaller honey possums were also noted in torpor during autumn. Two honey possums radio tracked during winter were found in torpor every morning for 3-4 days in a row (see Section 4.3.4). In the Fitzgerald River National Park, a significant inverse relationship was observed between occurrence of torpid honey possums in pit traps and mean air temperature (Withers et al., 1990).

The difference in air temperature between affected and unaffected areas could potentially impact honey possums. Longer periods of cool temperatures mean honey possums have to utilise torpor more often coupled with fewer foodplants in these areas could mean in Phytophthora cinnamomi affected areas, fewer animals would survive over the coldest winter months. Further research into the effect of small scale microclimate changes as a result of P. cinnamomi infestation as they relate to fauna would be of value.

2.4.4 Capture of honey possums

Honey possums were the most numerous small mammal captured during this study which is likely to be a result of the use of pit traps as well as the selection of sites with a good coverage of known food plants. The overall trap success achieved in this study (7.76%) compares well to the 7.3% overall trapping success of honey possums trapped during long term studies in the Fitzgerald River National Park (FRNP) (Garavanta, 1997) and is almost double the 3.81 ± 0.96% annual trap success rate in the Scott National Park (Bradshaw & Bradshaw, 1999). Trapping sessions done in each season gave more insight into the population dynamics of honey possums in this area. The highest capture rate of honey possums at Cape Riche was observed during summer when trap success (17%) was at its highest. Previous studies have demonstrated a strong relationship between nectar availability and honey possum population size (as determined by capture rates) (Everaardt, 2003; Garavanta, 1997; Philips et al., 2004; Wooller et al., 1981; Wooller et al., 1993). In Cape Riche, summer coincides with the peak flowering for a number of plant species which were found to be preferred by honey possums.
(Section 3.4.1). At Cape Riche low capture rates (in comparison to summer) were observed during autumn, winter and spring although interestingly no significant ($p>0.50$) difference was observed in condition of captured honey possums in relation to season. In the FRNP, honey possum trap success is highest during winter when Banksia baueri is flowering (Garavanta, 1997; Saffer, 1998). In the FRNP and Scott National Park, honey possum populations were greatly reduced (determined by the relative number of animals captured) when the primary food plants had finished flowering (Garavanta, 1997; Philips et al., 2004). The annual reduction in honey possum population size has been attributed to individuals dying of starvation (Wooller et al., 1993).

The varying trap success of honey possums observed at Cape Riche could be indicative of a number of factors. Given the long distances honey possums were recorded moving in the current study (Section 4.4.3), season is the first factor which could influence how far honey possums travel and therefore their chances of encountering a trap. The second influencing factor could be that the honey possum populations at Cape Riche are smaller during autumn, winter and spring compared to summer and so lower trap success could correctly reflect lower population density. The third influencing factor relates to the number of juveniles recaptured. The highest number of recaptures was observed during autumn 48% (11 animals) where 91% (10 animals) of these were juveniles (animals <7g) primarily captured at site 3. Furthermore, over all four seasons, juveniles represented 75% (15 animals) of all recaptures. Honey possums produce young all year round but females with pouch young were more numerous in the Fitzgerald River National Park when nectar was most abundant (which in the Fitzgerald River National Park is during winter when Banksia baueri is flowering) (Wooller et al., 2000). The peak number of juveniles captured at Cape Riche during autumn could have been the result of significant food resources available to females during the summer (including Banksia plumosa subsp. plumosa and B. nutans which were flowering at this time). The small numbers of juveniles captured during winter and spring may be a result of (i) fewer females producing young as food resources as not as plentiful or (ii) lower survival rate of juveniles during
winter and spring as a result of less food. During autumn, more juvenile honey possums may have been captured not only because there were more of them but possibly because they are more likely to remain in a limited area close to foodplants, which was also where the traps were located. This pattern links in with the greater distances larger radio tracked animals moved in comparison with smaller individuals (see Section 4.3.2). Larger honey possums may be capable of moving further, and are therefore not recaptured as often. Smaller honey possums are unlikely to be able to sustain long distance foraging movements and it makes sense that young animals would not be capable of moving very far. Further radio tracking studies could support the suggestions of the present study that trapping records alone are insufficient to predict honey possum population dynamics, since many other factors influence trap success.

Honey possums appear to be common in the Cape Riche area despite the large areas of *Phytophthora cinnamomi* infestation. The honey possum population peak was observed to be during summer which is most likely associated with the flowering periods of preferred foodplants within the study area. It may also be a result of honey possums moving smaller distances in summer compared to the other three seasons when trap success was much lower when honey possums are probably moving further to forage. Further *P. cinnamomi* infestation is likely to impact on the numbers of honey possums at Cape Riche as foodplants become more dispersed.
3  CHAPTER 3: POLLEN SAMPLING TO DETERMINE PREFERRED FOOD PLANTS

3.1  Introduction

In Western Australia, many Proteaceous and Myrtaceous plant species attract birds and small mammals to their flowers with nectar and pollen with the intent of aiding dispersal of pollen (Saffer, 1998; Turner, 1982). In visiting a flower to feed, pollen is inadvertently deposited on the head and body which is then transferred to subsequent flowers visited. In this manner, birds and small mammals become vectors for pollen dispersal. Honey possums feed exclusively on nectar and pollen (Wooller et al., 1981). The collection of pollen deposited on the head and whiskers can provide an insight into the plant species on which honey possums feed. The research objective for the current study was to determine which foodplants are being utilised by honey possums and to relate these species to *Phytophthora cinnamomi* susceptibility. The loss of susceptible foodplants has the potential to influence honey possum habitat utilisation at Cape Riche and possibly the loss of honey possums from areas that have been impacted upon by *P. cinnamomi*.

*Phytophthora cinnamomi* not only poses a threat to susceptible plant species but could possibly have more far reaching impacts. Dispersal of pollen by vertebrates potentially increases genetic diversity of plant species due to out-crossing (Wooller & Wooller, 2003). In the absence of vertebrate pollinators (such as honey possums and honeyeaters), species such as *Banksia nutans*, a typically mammal pollinated plant, is capable of self pollination but at the cost of genetic out-crossing (Wooller & Wooller, 2003). The loss of animal pollinators such as honey possums as a result of loss of preferred foodplants could therefore potentially influence the reproductive success of the less susceptible plants remaining within affected areas which rely on vertebrate pollinators.
3.2  Methods and Materials

3.2.1  Pollen sampling from captured honey possums

In order to determine the food plants that were visited by honey possums, samples of pollen were obtained from captured animals. Animals were collected from pit traps at first light and following weighing, small cubes approximately 2 x 2 x 2mm of Wooller’s gel (Wooller et al., 1983a) were used to collect pollen from honey possums (Section 2.2.9). The same method of pollen collection was also carried out on tracked honey possums found in torpor in the field. Wooller’s gel is a sticky gelatine mixture with added basic fuchsin to stain pollen grains (Wooller et al., 1983a). The gel was wiped over the dorsal and ventral aspects of the head as well as over the chest of honey possums approximately six times. The gel was then gently melted onto a glass slide and examined under an Olympus CX31 light microscope at 100x or 400x magnification. Pollen grains were identified to plant species by comparison with reference slides. Pollen for the reference slides was collected from flowering plants identified in the study area (Figure 3.1). Wooller’s gel was wiped on the flower anthers and the gel was gently melted onto a slide in the same manner as the samples collected from honey possums. All pollen grains on each sample slide were thus identified and counted individually under the microscope. A total of 44 species were observed flowering during this study. Reference samples were collected for each.

3.2.2  Statistical analyses

A Shannon’s Diversity index to determine diversity pollen species carried by honey possums for each season was calculated from pollen counts recorded for each individual sample slide (Figure 3.3) (Zar, 1999). Statistical analyses were carried out using Statistica (StatSoft-Inc, 2002). A one-way ANOVA was performed to compare differences in the diversity of pollen species in relation to season. Post hoc Tukey HSD tests for unequal numbers were carried out to determine significant differences in pollen diversity between seasons.
Beaufortia anisandara

Calothamnous gracilis

Eucalyptus angulosa

Lambertia inermis

Grevillea fasciculata

Nuytsia floribunda
Papilionaceae sp.

**Figure 3.1**: Reference photomicrographs used for pollen identification for the 18 observed foodplants used by honey possums during this study. Papilionaceae sp. collected from captured honey possums and was not a reference slide. Pollen grains were collected from inflorescences using Wooller’s gel (Wooller *et al.*, 1983a) and are stained with basic fuchsin. All photo micrographs are shown at the same magnification. See Appendix 1 for new nomenclature (*Dryandra* to *Banksia*) species.

### 3.3 Results

A total of 20 different plant species were represented in the 78 samples collected from captured honey possums (Figure 3.2). Of these, nine plant species were present in 14% or more of samples (Table 3.1). *Banksia plumosa* subsp. *plumosa* appears to be the preferred food plant of honey possums in the Cape Riche area throughout the year. Of the 78 sample slides collected, 94% (73 samples) contained *Banksia plumosa* subsp. *plumosa* pollen (Table 3.1). *Banksia plumosa* subsp. *plumosa* and was the dominant pollen present in samples collected in spring averaging 90% of all pollen grains collected (Figure 3.2). *Adenanthos cuneatus* was the next preferred honey possum food plant with 73% of 78 slides containing pollen from this species. Both of these preferred food plants flower all year round (Table 3.1) as does *Calothamnus gracilis*, which was present in 40% of samples. *Eucalyptus angulosa* pollen and *Beaufortia anisandra* pollen were identified in 46% (36 samples) and 45% (35 samples) respectively. *Eucalyptus angulosa* flowers for 8 months of the year (except during the winter months) whilst *Beaufortia anisandra* flowers for 10 months of the year (except during the spring months of August and September) with a notable flowering peak during February and March (Table 3.1). Seasonal flowering
prostate *Banksia* species including *Banksia tenuis* and *Banksia brunnea* were identified in 11 samples (14%) and 24 samples (31%), respectively during winter. *Banksia tenuis* only flowers during the winter months and *Banksia brunnea* is even more restrictive, flowering only during August (Table 3.1). *Banksia nutans* flowers during the summer months and was identified on 93% of samples (14 out of 15 samples) during summer, but overall was only identified on 15 samples (19%). *Banksia baxteri* was identified in 16 samples (21%) however 13 of these samples had only 1-2 pollen grains per slide.

Shannon’s Diversity Indices showed a significant difference (one way ANOVA $F_{(3,74)} = 12.052, p < 0.001$) between the number of pollen species carried by honey possums for each season. The diversity of foodplant species (identified from foodplant pollen grains) was significantly lower ($p < 0.05$) in spring compared with all other seasons (Figure 3.3). This result reflected the high numbers of *B. plumosa* subsp. *plumosa* and very few pollen grains from other species collected in honey possum samples during spring (Figure 3.2).
Banksia plumosa plumosa
Adenanthos cuneatus
Eucalyptus angulosa
Beaufortia anisandara
Calothamnus gracilis
Banksia brunnea
Banksia baxteri
Banksia nutans
Banksia attenuata
Papilionaceae sp.
Banksia falcata
Lambertia inermis
Banksia coccinea
Acacia sp.
Banksia gardneri
Banksia repens
Acacia subcaerulea
Grevillea fasciculata
Nuytsia floribunda
Figure 3.2: Percentage of pollen species collected from captured honey possums. A total of 20 foodplants were identified from pollen grains. Two of these (Acacia sp. and Papilionaceae sp.) could not be identified to species. (TR number represents individual honey possum ID with n = total number of pollen grains counted on each slide).
Table 3.1: Flowering phenology for 44 common plant species found at the Cape Riche study site.

Grey shades indicate relative length of flowering period (FloraBase CALM 2008) for pollen species. Chequered boxes indicate flowering peaks noted during field trips, arrows indicate field trips summer, autumn, winter and spring). The percentage of honey possum samples containing each of the pollen species is indicated. Flowering period references for previously *Dryandra* species (Cavanagh & Pieroni, 2006).

<table>
<thead>
<tr>
<th>Plant species</th>
<th>% of individual samples (n=78) with pollen present</th>
<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>J</th>
<th>A</th>
<th>S</th>
<th>O</th>
<th>N</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Banksia plumosa plumosa</em></td>
<td>94</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Adenanthos cuneatus</em></td>
<td>73</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Eucalyptus angulosa</em></td>
<td>46</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Beaufortia anisandra</em></td>
<td>45</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Calothamnus gracilis</em></td>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Banksia brunea</em></td>
<td>31</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Banksia baxteri</em></td>
<td>21</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Banksia nutans</em></td>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Banksia tenuis</em></td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Banksia attenuata</em></td>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Banksia falcata</em></td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Banksia gardneri</em></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Lambertia inermis</em></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Banksia coccinea</em></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Banksia repens</em></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Grevillea fasciculata</em></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Acacia subcaerulea</em></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Nuytsia floribunda</em></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Actinodium cunninghamii</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Banksia praemorsa</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Beaufortia micrantha</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Calectasia grandiflora</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Calytrix angulata</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Calothamnus quadrifidus</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Calothamnus villosus</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Chorizema uncinatum</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Conospermum polycephalum</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Daviesia incrassata</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Eucalyptus decurva</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Eucalyptus lehmannii</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Eucalyptus pressiana</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Eucalyptus staeri</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Eucalyptus x tetragona</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Gompholobium scabrum</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Hakea cucullata</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Hakea corymbosa</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Hakea denticulata</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Hakea laurina</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Isopogon formosus</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Isopogon trilobus</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Lysinema ciliatum</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Melaleuca striata</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Melaleuca suberosa</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Synaphea polymorpha</em></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 3.3: Mean (±1SD) Shannon’s Diversity Index for foodplant species identified from pollen grains collected from honey possums captured during each season. Bars with similar letters are not significantly different from each other, asterisks indicate a significant difference from Spring (* \( p < 0.05 \), ** \( p < 0.01 \)).
3.4 Discussion

Pollen from 20 plant species were identified from pollen samples collected from honey possums at Cape Riche, with animals feeding primarily on nine plant species. The most preferred honey possum foodplants throughout the year were *Banksia plumosa* subsp. *plumosa* and *Adenanthis cuneatus*. *Banksia* species were predominant as honey possum preferred foodplants with five of the nine preferred foodplants being *Banksia* species. Of these nine preferred foodplant species, five were identified as being susceptible to *Phytophthora cinnamomi*. The susceptibility status of the other four species being unknown. The presence of *P. cinnamomi* could therefore pose a serious threat to honey possum foodplants in the Cape Riche area.

3.4.1 Observed food plant preferences at Cape Riche study site

*Banksia plumosa subsp. plumosa* is the preferred food plant in the Cape Riche area as determined from pollen samples obtained from captured honey possums and torpid radio tracked honey possums, with 94% of the individuals carrying this pollen species. *Banksia plumosa* subsp. *plumosa* (Figure 3.4) flowers all year round, providing a food source even when other food plants are scarce. The nectar content and concentration and the number of pollen grains per presenter of *B. plumosa* subsp. *plumosa* is low in comparison with other preferred food plants (Table 3.3) (Saffer, 1998). Individual records of nectar collected from *B. plumosa* flowers, however, indicate that there is a great deal of variability in nectar production in this species with some flowers containing far greater amounts of nectar than the average (Saffer, 1998). Given this observation, and the obvious preference for *B. plumosa* subsp. *plumosa* (observed at Cape Riche and Fitzgerald River National Park (FRNP)) it is likely that honey possums are able to seek out these particularly nectar-rich flowers. The susceptibility of *B. plumosa* subsp. *plumosa* to *P. cinnamomi* is a concern, since honey possums in the Cape Riche area appear to be relying primarily on this foodplant all year which requires established *B. plumosa* subsp. *plumosa* plants in reasonable numbers. Further spread of *P. cinnamomi* infestation is likely to result in a
few isolated plants in unaffected areas that may be unlikely to provide sufficient sustenance for honey possums.

In addition to food resources in the Cape Riche area, *Banksia plumosa* subsp. *plumosa* was also found to be a preferred refuge for honey possums (Section 4.3.3). Studies in the FRNP record that *B. plumosa* was a preferred foodplant throughout the year especially during autumn, although but pollen counts of this species tended to be lower than other seasonally-preferred foodplants such as *B. baueri* (winter), *B. nutans* (summer) and *B. obovata* (spring) (Saffer, 1998).

**Figure 3.4:** *Banksia plumosa* subsp. *plumosa* shrub (left) and flower (right). Flower approximately 3cm across.
Second to *Banksia plumosa* subsp. *plumosa*, *Adenanthos cuneatus* was the next preferred food plant of honey possums in the Cape Riche area, where 73% (57 samples) of honey possums carried this pollen species. Like *B. plumosa* subsp. *plumosa*, the presence of flowers all year provides honey possums with a food source when other plant species are scarce. Despite being identified as a plant species susceptible to *Phytophthora cinnamomi*, *A. cuneatus* was present in many of the *P. cinnamomi* affected areas (where *Banksia* species were absent). In affected areas at Cape Riche, *A. cuneatus* may provide vital food resources where other plant species have already succumbed to *P. cinnamomi* infestation. It is likely however that over time, *A. cuneatus* plants in affected areas will die off, hence impacting on honey possum food resources in these areas.

The nectar content of this species is not as high as for some *Banksia* species, but flowers generally have more nectar than *B. plumosa* subsp. *plumosa* flowers (Table 3.3) (Saffer, 1998). *Adenanthos cuneatus* has been observed in pollen samples obtained from honey possums in other studies (Table 3.3) but tends to be more prevalent in samples collected from honeyeaters (Table 3.2) (Hopper, 1980; Saffer, 1998; Wooller *et al.*, 1983b). This finding is not surprising since *A. cuneatus* flowers tend to be more like bird-visited flowers in general morphology (Saffer, 1998) (Table 3.3).

![Figure 3.5: *Adenanthos cuneatus* shrub. Arrow indicates tiny pink flowers approximately 1cm in length.](image)
**Eucalyptus angulosa** is a small spreading mallee that flowers over eight months (August – March) and is primarily found in clumps within the study area (Figure 3.6). Pollen from this foodplant species was identified in 36 samples (46%) from honey possums. *Eucalyptus angulosa* pollen was identified most frequently in August, during the winter field trip, whilst the peak flowering of this species is between August to December (Hopper & Burbidge, 1982). *Eucalyptus angulosa* plants flowering out of season were noted in the area and these may provide limited but much needed food when other species are not in flower since pollen from this species was collected off honey possums in small amounts over all four trapping sessions. This species has been noted to flower intermittently throughout the year (Brooker & Kleinig, 1990). The susceptibility of *E. angulosa* to *P. cinnamomi* is unknown but being that is not a monocalyptus, it is unlikely to be susceptible to the pathogen (G. Hardy *pers. comm.*). The widespread loss of other susceptible species and their associated pollinators, however, is likely to have a flow-on impact on this species. *Eucalyptus* species do not appear to be significant honey possum foodplants at other study sites (Table 3.2). The flowers of *E. angulosa* contain copious amounts of nectar, and honey possums have been observed licking pollen off the anthers of this species (unlike honyeaters which only probed for nectar) (Hopper & Burbidge, 1982). *Eucalyptus angulosa* is most likely a rich food source for honey possums in terms of nectar and pollen.

![Figure 3.6: Eucalyptus angulosa tree and flowers (approx. 2.5 - 3cm in length)](image-url)
**Beaufortia anisandra** was a relatively common species throughout the study site and 45% (35 samples) of pollen samples collected from honey possums contained pollen from this species. The maroon flowers *Be. anisandra* are pungently scented. The susceptibility of this species to *Phytophthora cinnamomi* has not been assessed, but other *Beaufortia* species tend to be susceptible (G. Hardy pers. comm.). Like *A. cuneatus*, however, this species was often seen in affected areas, suggesting it could be less susceptible and may provide honey possums with a food resource in *P. cinnamomi* affected areas. In the Fitzgerald River National Park, *Be. anisandra* is an important food source for honey possums during summer, when 50% of individuals sampled carried this pollen (Table 3.2) (Wooller et al., 1983b). The bottlebrush-like flowers (Figure 3.7) could easily be visited by both birds and mammals and in Cheyne Beach, *Be. anisandra* was carried on 54% of honey possums (Table 3.2) and 50% of honeyeaters sampled (Hopper, 1980).

![Figure 3.7: Beaufortia anisandra flowers (approx. 2cm long).](image)

**Calothamnus gracilis** was the more common of the *Calothamnus* species at Cape Riche and was identified in 40% of pollen samples from honey possums, especially during the winter field trip. Samples from torpid radio tracked honey possums had large amounts of *Calothamnus* pollen, and this plant may therefore be an important food resource during the low seasons. Torpid honey possums were also found under *C. gracilis* shrubs, despite being quite sparse plants (Figure 3.8 and see Section 4.3.4). The susceptibility of this species to *P. cinnamomi* is unknown, however, at Cape Riche, *C. gracilis* grew in *P. cinnamomi* affected areas. Like other preferred
foodplants such as *Be. anisandra* and *A. cuneatus*, this species may provide food when more susceptible *Banksia* species have been killed off. However the long term persistence of these less susceptible plants in affected areas is unknown. In the Fitzgerald River National Park, *C. gracilis* pollen was identified on 24.6% of samples collected from honey possums, however it was more commonly found on birds with 48% of sampled honeyeaters carrying pollen from this species (Table 3.2) (Saffer, 1998). At Cheyne Beach, *C. gracilis* is also present (Table 3.3) and was found on honey possums (22% of samples) (Hopper, 1980).

**Figure 3.8**: *Calothamnus gracilis*. (Photos courtesy of FloraBase 2008 online database). Flowers (left) are approx. 3cm long.

*Banksia nutans* flowers primarily during the summer months. At Cape Riche this is a preferred honey possum foodplant during this time with 93% (14 samples) of pollen samples collected during summer containing this pollen species. *Banksia nutans* forms very dense shrubs in which the distinctive downward hanging flowers tend to be hidden within the plant (Figure 3.9). During radio tracking, honey possums were tracked to *B. nutans* bushes, indicating this plant species may also provide a refuge to honey possums outside of the summer months. *Banksia nutans* is susceptible to *P. cinnamomi* and a loss of this species could result in the depletion of food resources and refuge / nesting areas for honey possum populations during
summer at Cape Riche. *Banksia nutans* contains the most nectar of all honey possum foodplants (Table 3.3) as well as significant amounts of pollen, and provides substantial food resources to honey possums (Saffer, 1998). In the Fitzgerald River National Park (FRNP), *B. nutans* is recognised as a key honey possum food plant and the flowering period of *B. nutans* is longer in FRNP than at was observed at Cape Riche (Everaardt, 2003; Garavanta, 1997; Saffer, 1998; Wooller *et al.*, 1993).

![Figure 3.9: *Banksia nutans*. Flowers (left) are 4 - 7cm in length (George, 1996) and forms dense shrubs (right). Photos courtesy of Bill Dunstan.](image)

*Banksia brunnea* and *Banksia tenuis* are both prostrate *Banksia* species which were present within the study site especially on the spongelite ridges. Both species have limited flowering periods of 1 to 3 months of the year (Cavanagh & Pieroni, 2006). *Banksia brunnea* only flowers during August, however 92% (24 samples) of pollen samples collected during the winter field trip in August contained this pollen species. *Banksia tenuis* was identified in 79% (11 samples) of pollen samples collected during the autumn field trip (May). The presence of flowers close to the ground may be part of the appeal of these species as honey possum foodplants (Figure 3.10 and 3.11).

*Banksia tenuis* is susceptible to *P. cinnamomi* whilst the susceptibility status of *B. brunnea* is unknown. Both species provide honey possums with a highly seasonal food source and the potential loss of these *Banksia* species due to *P. cinnamomi* infestation at Cape Riche is likely to have a significant impact on honey possums in the cooler months. Both species are classic mammal pollinator type plants (see section 3.4.4) but neither has been identified as
foodplants in other honey possum studies (Table 3.3) possibly due to their limited distributions around the vicinity of Albany (Cavanagh & Pieroni, 2006).

**Figure 3.10:** Banksia tenuis (flower 4cm across) (Cavanagh & Pieroni, 2006).

**Figure 3.11:** Banksia brunnea plant (left) and flower (right) 3.5 – 4cm across (Cavanagh & Pieroni, 2006).

*Banksia baxteri* was the most common *Banksia* species in the study area and trap lines were installed using dense *B. baxteri* patches as an indicator of absence of *Phytophthora cinnamomi*. Although *B. baxteri* pollen was identified in 16 samples (21%), the low counts recorded for this pollen species in the majority of the slides indicates this species is unlikely to be a preferred food plant. The pollen of *B. baxteri* is quite distinctive as it is more than double the size of the pollen of other *Banksia* species in the area and can be easily differentiated. If honey possums were actually feeding on this species, *B. baxteri* pollen should have been more numerous in samples, (even after animals had time to clean themselves while sitting in a pit trap). Additionally, the high densities of *B. baxteri* flowers at all three trapping sites means it is quite likely pollen from this species was picked up incidentally by
animals. Studies at Cheyne Beach, which has a similar floral diversity to the current study, similarly recorded *B. baxteri* pollen rarely on honey possums, despite the study site being in *B. baxteri* thickets (Hopper, 1980). *Banksia baxteri* is susceptible to *P. cinnamomi* and even though honey possums do not rely directly on this species as a food source, the loss of *B. baxteri* thickets could have consequences for honey possums at Cape Riche. Honey possums were captured and radio tracked in areas in or near *B. baxteri* thickets indicating they are utilising these areas as the thickets support complex vegetation assemblages which are preferred by honey possums (see section 4.3.2).

The estimated total energy yield per day for *B. baxteri* is comparable with other *Banksia* species at Cape Riche (Table 3.3). Researchers studying honey possums in *B. baxteri* thickets 50km east of Albany (unnamed site), reasoned that nectar from *B. nutans* (which has a similar flowering period to *B. baxteri*) was more accessible to honey possums as flowers are closer to the ground (Wooller et al., 1983b). The large yellow flowers of *B. baxteri* (Figure 3.12) are more typical of bird pollinated plants (Hopper, 1980) and as the flowers are held high on open branches, it is possible that a honey possum feeding on a *B. baxteri* inflorescence may be highly visible and vulnerable to predators. *Banksia baxteri* pollen was found on 15% of sampled honeyeaters compared to 3% on sampled honey possums at the Fitzgerald River National Park (Saffer, 1998).

![Figure 3.12: Banksia baxteri in flower.](image)

Flowers (left) are 7.5 - 8.5cm wide (George, 1996). Banksia baxteri forms dense thickets at the study site (right) (photo courtesy of Bill Dunstan).
As for *Banksia baxteri*, in the present study, *B. coccinea* (Figure 3.13) and *B. attenuata* (Figure 3.14) pollen were only identified on 2 (3%) and 7 samples (9%) respectively. This was despite there being a number of both species scattered throughout the study area.

![Figure 3.13: Banksia coccinea. Flowers are 3-6cm long, 8-10cm wide (George, 1996).](image)

![Figure 3.14: Banksia attenuata. (Flowers are 5-26cm long, 3.5-5cm wide (George, 1996)).](image)

*Lambertia inermis* is a common plant species at Cape Riche and, since it appears to have significant amounts of nectar (Table 3.3) it was thought that it could also be a possible honey possum foodplant. Despite this, very few samples contained *L. inermis* pollen, even in the winter months when other flowering plants were scarce and there were a few *L. inermis* flowers open. *Lambertia inermis* is susceptible to *P. cinnamomi* as well as an aerial canker which was identified in site 3 (see section 2.2.7). There were many well established *L. inermis* plants throughout the study site and these were often associated with *B. plumosa* subsp. *plumosa* plants which tended to grow beneath them. The loss of *L. inermis* plants could also potentially mean the loss of associated of vegetation assemblages which honey possums utilise.

A honey possum would have to exert a significant amount of effort to reach the flowers of *L. inermis* where they would most likely be more visible to potential predators. The nectar in tubular flowers of *L. inermis* is held high on the shrub are more accessible to birds rather than mammals (Figure 3.15) (Saffer, 1998). In the Fitzgerald River National Park, 79% of honeyeaters
sampled carried this pollen species compared to 24% of honey possums sampled (Saffer, 1998).

Figure 3.15: *Lambertia inermis*. Red arrow indicates flowers approx. 5cm long.

There were a few surprising discoveries in terms of preferred foodplants. During the August field trip, significant amounts of pollen were obtained from four captured honey possums that were identified as Papilionaceae species. More than 7800 pollen grains from this species were collected from one radio tracked animal. There were a number of Papilionaceae species flowering at the time including *Daviesia* and *Gompholobium* species, however none of the reference slides (from six species) collected matched the pollen found on honey possums, making identification to genus difficult. Some of the Papilionaceae species in the area (including *Daviesia incrassata*) flower profusely and a honey possum would be able to collect significant amounts of pollen from a single plant. Studies conducted 50km east of Albany identified small amounts of *Daviesia* sp. pollen collected from captured honey possums (Wooller *et al.*, 1983b).
Table 3.2: Comparison of foodplants identified from pollen collected from captured honey possums at different study sites.

S = susceptible to \( P. \) cinnamomi, NS = not susceptible, LS = less susceptible, ? = susceptibility unknown, † = susceptibility status noted at study site, A = not present at site, P = present in area but not in pollen samples, p = present but in small numbers, U = presence of species unknown at site, * = presumed not to be present in study site, numbers indicate % composition of pollen species collected from samples for the particular study, # = utilized by honey possums at site but no % available. Results derived from Fitzgerald River National Park (Saffer, 1998), estimated (-) counts from (Wooller et al., 1983b) Cheyne Beach (Hopper, 1980), Scott National Park (Bradshaw & Bradshaw, 1999; Philips et al., 2004).
<table>
<thead>
<tr>
<th>Plant Name</th>
<th>Susceptibility to P. cinnamomi</th>
<th>Cape Riche</th>
<th>Fitzgerald River National Park</th>
<th>Cheyne Beach</th>
<th>Scott National Park</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adenanthos cuneatus</td>
<td>LS†</td>
<td>73</td>
<td>21</td>
<td>4</td>
<td>A*</td>
</tr>
<tr>
<td>Adenanthos meisneri</td>
<td>?</td>
<td>A</td>
<td>U</td>
<td>U</td>
<td>94</td>
</tr>
<tr>
<td>Banksia attenuata</td>
<td>S</td>
<td>9</td>
<td>6.5</td>
<td>1</td>
<td>A</td>
</tr>
<tr>
<td>Banksia baueri</td>
<td>S</td>
<td>A</td>
<td>22</td>
<td>A*</td>
<td>A</td>
</tr>
<tr>
<td>Banksia baxteri</td>
<td>S</td>
<td>21</td>
<td>3</td>
<td>7</td>
<td>A</td>
</tr>
<tr>
<td>Banksia brunnea</td>
<td>S†</td>
<td>31</td>
<td>U</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>Banksia coccinea</td>
<td>S</td>
<td>3</td>
<td>3</td>
<td>P</td>
<td>A</td>
</tr>
<tr>
<td>Banksia falcata</td>
<td>S</td>
<td>8</td>
<td>1</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>Banksia formosa</td>
<td>?</td>
<td>A</td>
<td>~20</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>Banksia gardneri</td>
<td>?</td>
<td>8</td>
<td>U</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>Banksia grandis</td>
<td>S</td>
<td>p</td>
<td>~60</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>Banksia heliantha</td>
<td>?</td>
<td>0.5</td>
<td>A*</td>
<td>#</td>
<td></td>
</tr>
<tr>
<td>Banksia ilicifolia</td>
<td>?</td>
<td>A</td>
<td>A*</td>
<td>A*</td>
<td>19</td>
</tr>
<tr>
<td>Banksia meisneri</td>
<td>S</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>Banksia nivea</td>
<td>NS</td>
<td>A</td>
<td>11</td>
<td>A*</td>
<td>A</td>
</tr>
<tr>
<td>Banksia nutans</td>
<td>S</td>
<td>19</td>
<td>36</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>Banksia obovata</td>
<td>NS</td>
<td>A</td>
<td>30</td>
<td>A*</td>
<td>A</td>
</tr>
<tr>
<td>Banksia occidentalis</td>
<td>?</td>
<td>A</td>
<td>A*</td>
<td>11</td>
<td>44</td>
</tr>
<tr>
<td>Banksia plumosa subsp. plumosa</td>
<td>S</td>
<td>94</td>
<td>86</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>Banksia repens</td>
<td>NS</td>
<td>3</td>
<td>4</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>Banksia sessilis</td>
<td>S</td>
<td>A</td>
<td>0.1</td>
<td>A*</td>
<td>A</td>
</tr>
<tr>
<td>Banksia sphaerocarpa</td>
<td>S</td>
<td>A</td>
<td>A*</td>
<td>1</td>
<td>A</td>
</tr>
<tr>
<td>Banksia tenuis</td>
<td>S</td>
<td>14</td>
<td>U</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>Beaufortia anisandra</td>
<td>LS†</td>
<td>45</td>
<td>~50</td>
<td>54</td>
<td>U</td>
</tr>
<tr>
<td>Beaufortia empetrofelia</td>
<td>?</td>
<td>A</td>
<td>2.5</td>
<td>U</td>
<td>A*</td>
</tr>
<tr>
<td>Beaufortia sparsa</td>
<td>?</td>
<td>A</td>
<td>U</td>
<td>U</td>
<td>81</td>
</tr>
<tr>
<td>Calothamnus gracilis</td>
<td>LS†</td>
<td>40</td>
<td>25</td>
<td>22</td>
<td>U</td>
</tr>
<tr>
<td>Corymbia calophylla</td>
<td>NS</td>
<td>A</td>
<td>A*</td>
<td>A*</td>
<td>13</td>
</tr>
<tr>
<td>Eucalyptus anguina</td>
<td>?</td>
<td>46</td>
<td>U</td>
<td>U</td>
<td>A*</td>
</tr>
<tr>
<td>Eucalyptus buprestium</td>
<td>?</td>
<td>p</td>
<td>9</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td>Hakea victoria</td>
<td>NS</td>
<td>A</td>
<td>0.5</td>
<td>A*</td>
<td>A</td>
</tr>
<tr>
<td>Lambertia inermis</td>
<td>S</td>
<td>5</td>
<td>24</td>
<td>P</td>
<td>A</td>
</tr>
</tbody>
</table>

**Study period and time of year**

<table>
<thead>
<tr>
<th>6 months: (Jan, Feb, Apr, May, Aug, Nov)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of samples</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>12 months: (Jan – Dec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of samples</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3 days: (Mar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of samples</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2 weeks: (Feb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of samples</td>
</tr>
</tbody>
</table>
Table 3.3: Comparison of major honey possum foodplants at Cape Riche.
Values for nectar content given are estimated total energy yield per day per inflorescence as determined by (Saffer, 1998). NM = has not been quantitatively measured. Plant heights are approximate and reflect size of plants observed at Cape Riche. The daily energetic requirement for a 9g honey possum is 28.6 ± 3.0 kJ d⁻¹ (Section 1.2.2) (Bradshaw & Bradshaw, 1999). See section 3.4.4 for a discussion of mammal and bird type flowers.

<table>
<thead>
<tr>
<th>Species description</th>
<th>Nectar content (Saffer, 1998)</th>
<th>Pollen content (Saffer, 1998)</th>
<th>Mammal or bird type flowers</th>
<th>Honeyeater preference in other studies</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Banksia plumosa</em> subsp. <em>plumosa</em></td>
<td>Dense shrub, numerous inconspicuous yellow flowers to 1.5m in height</td>
<td>2.2 ± 0.2 joules</td>
<td>± 3000 grains per presenter</td>
<td>Mammal</td>
</tr>
<tr>
<td><em>Adenanthos cuneatus</em></td>
<td>Open leafy shrub to approx 1m in height few small inconspicuous flowers at each terminal branch</td>
<td>32.9 ± 3.0 joules</td>
<td>± 12,000 grains per presenter</td>
<td>Bird</td>
</tr>
<tr>
<td><em>Eucalyptus angulosa</em></td>
<td>Small spreading mallee usually grows in clumps</td>
<td>NM but large amount of nectar observed (Hopper &amp; Burbidge, 1982)</td>
<td>Observed to have large amount (Hopper &amp; Burbidge, 1982)</td>
<td>Bird?</td>
</tr>
<tr>
<td><em>Beaufortia anisandra</em></td>
<td>Dense branching shrub with bottlebrush-like flowers on the terminal ends of branches to 80cm in height</td>
<td>NM</td>
<td>NM</td>
<td>Mammal?</td>
</tr>
<tr>
<td><em>Calothamnus gracilis</em></td>
<td>Small sparse shrub with red, tubular flowers arising from along branches to 50cm in height.</td>
<td>NM</td>
<td>NM</td>
<td>Bird</td>
</tr>
<tr>
<td><em>Banksia brunnea</em></td>
<td>Prostrate banksia forms bushy clumps of distinctive blue green leaves up to 70cm in height (Cavanagh &amp; Pieroni, 2006)</td>
<td>NM</td>
<td>NM but significant amount pollen observed on radio tracked honey possum</td>
<td>Mammal</td>
</tr>
<tr>
<td><strong>Species</strong></td>
<td>Description</td>
<td>Energy (Joules)</td>
<td>Pollen Presenters</td>
<td>POLLINATOR</td>
</tr>
<tr>
<td>-------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-----------------</td>
<td>-------------------</td>
<td>------------</td>
</tr>
<tr>
<td><em>Banksia baxteri</em></td>
<td>Branching shrub average 2.5m bright yellow flowers held high on the plant</td>
<td>$539.1 \pm 105.4$</td>
<td>$\pm 3000$ grains per presenter</td>
<td>Bird</td>
</tr>
<tr>
<td><em>Banksia nutans</em></td>
<td>Very dense shrub with distinctive downward hanging hidden flowers to 1.5m</td>
<td>$1216.1 \pm 984.8$</td>
<td>$581.6 (\pm 59.9)$ pollen presenters per flower</td>
<td>Mammal</td>
</tr>
<tr>
<td><em>Banksia tenuis</em></td>
<td>Prostrate banksia forms dense mats over the ground or can grow in a bushy shrub to 1.5m in height, (Cavanagh &amp; Pieroni, 2006).</td>
<td>NM</td>
<td>NM</td>
<td>Mammal</td>
</tr>
<tr>
<td><em>Banksia attenuata</em></td>
<td>Shrub to 2m with bright yellow flowers</td>
<td>NM</td>
<td>NM</td>
<td>Bird</td>
</tr>
<tr>
<td><em>Banksia falcata</em></td>
<td>Dense prickly shrub up to 2 – 3m in height, yellow flowers</td>
<td>NM</td>
<td>NM</td>
<td>Bird</td>
</tr>
<tr>
<td><em>Banksia gardneri</em></td>
<td>Prostrate banksia spreading over the ground</td>
<td>NM</td>
<td>NM</td>
<td>Mammal</td>
</tr>
<tr>
<td><em>Lambertia inermis</em></td>
<td>Large shrub to 4m+ with orange tubular flowers high on the branches</td>
<td>$105.8 \pm 11.9$</td>
<td>-</td>
<td>Bird</td>
</tr>
<tr>
<td><em>Banksia coccinea</em></td>
<td>Bright red flower one per branch often single flower per plant up to approx. 1.2m</td>
<td>$477.1 \pm 127.6$</td>
<td>$401.5 (\pm 13.0)$ pollen presenters per flower</td>
<td>Bird</td>
</tr>
<tr>
<td><em>Banksia repens</em></td>
<td>Prostrate banksia spreading over the ground</td>
<td>NM</td>
<td>NM</td>
<td>Mammal</td>
</tr>
</tbody>
</table>
3.4.2 Seasonal pollen diversity

In the spring months, the diversity of pollen species collected from honey possums was lower than in any other season. The seasonal pollen diversity on honey possums observed at the study site is congruent with capture rates (see section 2.3.3) with spring yielding fewest honey possum captures and lowest diversity of foodplant pollen samples. This is not surprising as the lifecycle of honey possums is strongly correlated to the flowering periods of preferred foodplants (see section 1.2.2) (Wooller et al., 1993). These results compare to a previous study conducted in an unnamed study site located 50km east of Albany where fewer species of pollen were carried during spring and more were carried in summer and early winter (Wooller et al., 1983b). In the Fitzgerald River National Park, autumn is noted as the low season where the majority of preferred foodplants are not flowering and during which time B. plumosa was the principal pollen species found on captured honey possums (Saffer, 1998).

3.4.3 Relative pollen counts carried by honey possums

During the winter field trip, an opportunity arose to collect pollen samples from torpid honey possums in the field for comparison with samples taken from honey possums captured in pit traps. Field pollen samples had higher pollen counts than pollen samples taken from trapped honey possums during the same period. This was evident for Animal TR 76 which had an initial pollen grain count of 47 collected after the animal was trapped compared with an average of 1448 (± 728) pollen grains collected on four occasions when the radio tracked honey possum was found in torpor. This honey possum had a preference for A. cuneatus, B. plumosa subsp. plumosa and B. brunnea. The difference in field pollen counts versus trapping pollen counts was also shown for honey possum TR 70 which had an initial pollen count of 456 when collected from the trap and a subsequent average pollen count of 4031 (± 2117) from four field samples when the animal was torpid. This honey possum had a particular preference for Calothamnus gracilis.
One major drawback of pollen sampling from trapped honey possums, which has also been noted in other studies (Hopper, 1980; Wooller et al., 1983b), is that honey possums are quite fastidious cleaners and they have the opportunity to clean their snout and whiskers whilst trapped. Seasonal differences in activity whilst trapped (due to differences in overnight ambient temperature) mean that it is not possible to compare pollen loads between seasons. Furthermore, it is not possible to estimate how long honey possums have been in the trap. This cleaning activity reduces the observed pollen loads on trapped animals compared to when pollen samples are collected from torpid animals found whilst radio tracking. Consequently, pollen samples off torpid honey possums are more likely to be representative of feeding activities than from trapped animals. The relative numbers of pollen grains from each plant species could provide an indication as to when the animal fed on the plant species. Large numbers of pollen from a particular plant species are more likely to indicate that the honey possum fed on this species most recently and vice versa.

3.4.4 Mammal type (theriophily) plants versus bird type (ornithophily) plants.

There is much overlap of pollen species found on honeysuckle and honey possums and both are thought to be opportunistic when foraging for nectar however there are a number of characteristics which make some plants preferable to either birds or nectarivorous mammals (Wooller et al., 1983b). Mammal-type plant species (theriophilily) refers to a pollinator syndrome, which is a set of floral adaptations that fit a class of pollinators (Thomson et al., 2000). For example, Banksia species thought to be mammal pollinated have inconspicuous strongly scented flowers located close to the ground and hidden within dense foliage, a classic example of this is Banksia nutans (Wooller et al., 1983b) which is pollinated by honey possums (Wooller & Wooller, 2003). In contrast, species traditionally pollinated by birds (ornithophilily) (Thomson et al., 2000) such as Banksia baxteri and B. coccinea tend to have large, brightly flowers held high on the plant (Wooller et al., 1983b). Other floral characteristics of plant species regularly frequented by birds are tubular flowers with small amounts of concentrated
nectar at the base of the flower with no obvious odour such as *Adenanthes cuneatus, Lambertia inermis* and *Calothamnus gracilis* (Saffer, 1998). Mammal-type plant species which conform to the theriophilic pollinator syndrome at Cape Riche include *B. plumosa* subsp. *plumosa* and two prostrate *Banksia* species, *B. tenuis* and *B. brunnea*. The latter two species are highly favoured by honey possums even though they have very limited flowering periods. Less favoured prostrate *Banksia* species at both Cape Riche (present study) and Fitzgerald River National Park (Saffer, 1998) were *B. repens* and *B. gardneri*. Despite these suggested ‘syndromes’ (Thomson et al., 2000), honey possums at Cape Riche also regularly fed on traditionally bird type plants (Table 3.3) with *A. cuneatus* being the second most preferred honey possum foodplant. In the Fitzgerald River National Park there was much overlap between the preferred foodplants of honey possums and honeyeaters (Saffer, 1998).

Honey possums are capable of utilising a reasonably diverse range of plants for food, some of which appear to less susceptible to infestation by *P. cinnamomi*. The most preferred honey possum foodplant at Cape Riche (*Banksia plumosa* subsp. *plumosa*) is susceptible to the pathogen, however other preferred foodplants such as *A. cuneatus, Be. anisandra* and *C. gracilis* appear to be less susceptible and individual plants are present in affected areas. The ability of honey possums to rely on these less susceptible food resources long term is unknown, as is the long term persistence of these plants in affected areas. The loss of susceptible species as a result of *P. cinnamomi* infestation is likely to have further reaching consequences than just the loss of honey possum preferred foodplants. For example, the loss of associated vegetation assemblages which are often associated with foodplants (such as the *Banksia* thickets at Cape Riche) are likely to have an impact on honey possum habitat preferences (Chapter 4). Additionally, the dispersal of food resources as a result of *P. cinnamomi* infestation will also put pressure on honey possum populations due to the need to forage over further distances to healthy vegetation if it is available. These suggestions are discussed further in the next chapter.
CHAPTER 4: RADIO TRACKING OF HONEY POSSUMS IN PHYTOPHTHORA CINNAMOMI AFFECTED AREAS TO DETERMINE HABITAT PREFERENCES

4.1 Introduction

In order to understand the ecology of native mammals and to determine the important aspects which define the habitats they utilise, it is critical to monitor their activities with minimal disturbance. A number of methods have been used to do this, including spool and line tracking, fluorescent powder tracking, mark and recapture and radio-telemetry. Radio tracking using radio transmitters attached to the animal is an extremely powerful tool especially on larger animals as it is a relatively unobtrusive tracking method and animals can be followed at a distance for long periods of time. Radio tracking has the benefit over other tracking methods in that a tracked animal can be located night or day and can provide detailed information on home ranges, nest locations and habitat selection. In the mid 1980s the smallest radio transmitters weighed 1g so ideally only animals weighing more than about 20g could be fitted with a transmitter (Holohil Systems Ltd., Canada). This does not include the weight of application (collar or glue) which altogether should meet the suggested transmitter weight restriction of 5 -10% of total body mass, otherwise the movements of the animal could be influenced by the presence of the radio transmitter (Aldridge & Brigham, 1988). Since the 1990s, technology has advanced and much smaller animals can be radio tracked successfully with smaller transmitters weighing 0.36 - 0.9g (Holohil Systems Ltd., Canada). To date, minimal radio tracking of honey possums has been carried out and the present study is the first time honey possums have been radio tracked using the smallest commercially available transmitters which weigh 0.36g and became available in late 2002 (Holohil Systems Ltd., Canada). These transmitters, due to their small size and attachment by glue instead of a collar, have the considerable advantage of potentially imposing less influence on honey possum movements. In addition these transmitters allow smaller individuals to be radio tracked. Honey possums have been radio tracked previously in three published studies, two conducted in the Scott National Park (Bradshaw & Bradshaw, 2002; Philips
et al., 2004) and the other conducted in the Mount Lesueur Nature Reserve in Jurien (Arrese & Runham, 2003). Larger transmitters were used in these studies (0.4g LTM glued transmitters: Arrese & Runham, 2003; 0.9-1.3g radio collars: Bradshaw & Bradshaw, 2002; 0.7g BD-2T glued transmitters: Philips et al., 2004).

Frequently, the indirect impact of *Phytophthora cinnamomi* on fauna is mentioned in mammal studies, and honey possums which are dependent on nectar and pollen as food sources are often suggested to be detrimentally impacted by the pathogen (Garkaklis et al., 2004; Wilson et al., 1994). Despite this, no research, prior to the current study, has actually investigated whether the effects of *P. cinnamomij* on vegetation assemblages impact upon habitat utilisation by honey possums. The research objectives of this study were to ascertain if (i) honey possum movements are influenced by the presence of *P. cinnamomij* affected areas, and (ii) to identify specific honey possum habitat requirements at Cape Riche to determine if these are being impacted as a result of *P. cinnamomij* infestation.

4.2 Materials and Methods

4.2.1 Experimental Design

Three study sites located 140 to 340m apart were selected at the Cape Riche study and 20 pit traps were installed at each site to capture honey possums (see section 2.2.9). Each trap line incorporated a *Phytophthora cinnamomij* affected area and an unaffected area separated by the dieback front. The surrounding vegetation in the area tended to be a mosaic of affected and healthy areas through which honey possums were radio tracked. Captured honey possums deemed suitable for radio transmitter attachment (based on body weight >5.9g) were fitted with a transmitter and released at the point of capture (see next section). The locations of radio tracked honey possums were recorded via GPS (Garmin GPS 60) when the tracked honey possum could be honed to an area within a <3m radius circle. These locations were compared with 50 stratified random locations both of which were measured for density, vegetation coverage, plant species present, *P. cinnamomij* status
and average vegetation height to determine whether honey possums are selective in terms of feeding in areas of specific vegetation structure or composition.

4.2.2 Transmitter attachment

The radio transmitters used in this project were Holohil Systems Ltd (Canada) LN-2N and BD–2 which weigh 0.36g and 0.9g and have a battery life estimated at 12 and 45 days, respectively. Transmitters were glued to the backs of suitable honey possums, just above the scapular (Figure 4.1). The fur on the back was trimmed with scissors before attachment with super glue (Selleys Pty. Ltd. Australia). Transmitter attachment was a problem in some instances as the longevity of the glue attachment varied significantly between animals. During the second field trip, glue attachment was especially problematic owing to the cool weather, and it was found that the glue was taking too long to dry and the animals would move before a bond had formed. In-house tests were subsequently carried out in a cool room (≈5°C) with a variety of glues to determine which product adhered best in cooler temperatures (Appendix 3). It was concluded that a combination of Selleys non drip gel (which is slower drying but holds the transmitter in place) and Selleys liquid gel (which dries quickly but does not stick if the animal moves when the transmitter is being attached) was the most effective solution.

Honey possums were kept in a calico bag up to 15 minutes following transmitter application to allow the glue to dry. All animals were fitted with transmitters early in the morning (6am – 8am) when pit traps were checked. They were also fed a saturated sugar water solution to provide extra energy. All animals were released at point of capture and were lively on release. The first radio fixes were carried out in the afternoon or early evening since honey possums are not active during the day, generally.
4.2.3 Radio tracking honey possums and transmitter ranges

Radio tracking was carried out with the use of an iCOM IC-R10 handheld receiver and 3 element Yagi antennae (Sirtrak NZ). Honey possum locations were determined by the method of triangulation with the use of 2 receivers and antennae (Kenward, 1987). Radio tracking was carried out at various times during the day and night. During the summer months, most tracking was during the evening when honey possums are considered to be most active (Garavanta, 1997; Russell & Renfree, 1989). During the winter months, honey possums were also tracked during the day as individuals tended to move further (presumably in search of food) and would go out of range if not tracked periodically. Radio tracked honey possums were not seen very often in the field as the animals were tracked at a distance so disturbance was minimised. Honey possums are also fast moving and are exceedingly difficult to see in vegetation, despite being close. This is especially true at night.

In the initial planning stages of this project, a 100m x 100m area at each of the three study sites was envisioned as being the location in which tracked honey possums would remain. Estimated honey possum home ranges determined from trapping records are 0.13ha for males and 0.07ha for females (Garavanta, 1997; Garavanta et al., 2000) As a result, the sites
were thought to be far enough away from each other so as to be independent. Once radio tracking of honey possums started, it became clear that the animals were moving much further than anticipated and consequently each of the study sites were no longer independent. The location of capture of each animal is therefore not a valuable tool for this study.

The range on the transmitters varied and given that the study area consisted of ridges and valleys, this was sometimes a problem. When signals were absent or difficult to locate, the antennae was mounted onto a broom handle (therefore raised 3m off the ground) to increase the range. Frequent trips were also made up ridges which overlook the valley to improve the transmitter range. Tests carried out in the field showed that the LN-2N transmitter and the BD-2 transmitter had varying ranges. The main benefit of the BD-2 transmitter was the longer battery life however the smaller LN-2N adhered to honey possums better, and as a result, stayed on for a longer period. On a ridge located approximately 600m away (elevation 57m) from the study site, signals for both transmitter types could be picked up, although the BD-2 transmitter gave a stronger signal. Over flatter areas, the range of both transmitters decreased to about 100m before a signal was audible and given the distance some honey possums were recorded moving (250m+ between radio tracking fixes), this meant that a great deal of searching from various points in the landscape had to be carried out. Transmitter range tended to vary with factors such as vegetation density and elevation. The most effective method to ensure that honey possums were relocated was to check each individual every few hours.

4.2.4 Vegetation analysis of honey possum selected and random locations

Each radio tracking location was recorded on a GPS and subsequently mapped. All locations (109 in total) were marked with flagging tape and evaluated for vegetation structure at a later date. Briefly, this involved flagging a 3m circle around each location where a honey possum was recorded. For comparison, 50 vegetation analyses were also done at
stratified random locations (selected to represent similar vegetation assemblages to the areas in which honey were radio tracked). These random vegetation locations allowed a representative subset of the vegetation in the area to be recorded.

At each location, the presence or absence of *Banksia plumosa* subsp. *plumosa*, *Adenanthos cuneatus*, *B. nutans* and *Beaufortia anisandra* were recorded as these were the important foodplants at Cape Riche (see section 3.4.1). Percentage of vegetation coverage for each location was estimated by visual assessment. Each location was recorded as either affected or unaffected in terms of *P. cinnamomi* status or uninterpretable for areas not clearly identifiable as either. Vegetation density was determined with the use of a 1.5m vegetation pole (2cm diameter) marked at 10cm intervals (which was also used to measure average vegetation height). The pole was placed in a random spot within the flagged location and the number of times vegetation touched the pole at each 10cm interval was recorded. This was replicated 10 times at each recorded honey possum location or 5 times for the random locations, and for each 10cm interval the number of touches were totalled and averaged to take into account the difference in replicate number.

### 4.2.5 Statistical analysis

Statistical analysis to compare honey possum selected locations versus random locations, as well as the difference between *Phytophthora cinnamomi* affected and unaffected vegetation was carried out using Statistica (StatSoft-Inc, 2002). The average number of vegetation touches at each height class was calculated. Two-way MANOVAs were calculated for each vegetation height class to 230cm to determine the significance of differences between the number of vegetation touches (representing vegetation density) between honey possum selected locations versus random locations and *P. cinnamomi* affected versus unaffected locations. Post hoc Tukey unequal N HSD tests were also calculated for each vegetation height class up to 230cm to determine differences in vegetation density.
density between the four categories; (1) honey possum selected locations unaffected by *Phytophthora cinnamomi*, (2) honey possum selected locations affected by *P. cinnamomi*, (3) random locations unaffected by *P. cinnamomi* and (4) random locations affected by *P. cinnamomi*. The normal distribution of data assumption of the MANOVA was violated as a result of the low number of touches recorded above 100cm. There are however, no suitable two-way non parametric analyses suitable for a data set such as this and highly significant (*p*<0.001) differences were noted between many groups. In an effort to rectify this, Shannon’s Diversity Indices were calculated for each sample to quantify the spread of vegetation structure. Additionally, averages were calculated for five vegetation structure parameters; (1) mean vegetation height (2) % vegetation coverage (3) number of touches for 0 – 230cm (4) number of touches for 40 – 140cm (as significant differences were calculated for this height range between affected / unaffected locations and honey possum selected / random locations) and (5) Shannon’s Diversity Indices to create a more even distribution of the data. Factorial MANOVAs were calculated to determine the significance of differences between honey possum selected and random locations and between *P. cinnamomi* affected and unaffected locations. Post hoc Tukey unequal N HSD tests were calculated to determine differences between each of the four location categories mentioned previously in relation to the vegetation structure parameters. Percentage occurrence was calculated for four honey possums foodplants (*Banksia plumosa* subsp. *plumosa*, *Adenanthos cuneatus*, *Banksia nutans* and *Beaufortia anisandra* as determined by presence or absence at each of the honey possum selected and random selected locations surveyed) to determine differences in foodplant occurrence at the four location categories.

Non-metric multi dimensional scaling (MDS) was conducted using Bray - Curtis similarity measures with Primer v5 (Primer-E Ltd, 2005) to determine similarity between all locations (including honey possum selected and random locations identified as affected or unaffected) in terms of vegetation structure parameters and the presence of four plant species (*Banksia plumosa* subsp. *plumosa*, *B. nutans*, *Adenanthos cuneatus* and *Beaufortia anisandra*).
Data were standardised using \((y_{\text{obs}} - y_{\text{min}}) / (y_{\text{max}} - y_{\text{min}})\) prior to analysis. Two dimensional graphs provide a visual representation of the rank order of locations (Clarke & Warwick, 1994). Relative distances between points indicate relative dissimilarity between locations (Clarke & Warwick, 1994). A stress level, which indicates how well the model fits the data, is then generated for the data set. A stress level of <0.10 indicates a very good fit of the data, a stress level of <0.20 indicates a reasonable fit although points lying on the outer limits are unlikely to be unreliable and stress levels <0.30 are not reliable (Clarke & Warwick, 1994).

Additionally, a two way crossed analysis of similarity (ANOSIM) was conducted using 999 permutations in Primer v5 (Clarke & Warwick, 1994) to separately test the null hypotheses that affected locations do not differ from unaffected locations and honey possum selected locations do not differ from random locations. The sample statistic (global \(R\)) and subsequent significance value are determined from the similarity of factors (honey possum selected and random and \(P. cinnamomi\) affected and unaffected locations) (Clarke & Warwick, 1994). The \(R\) value is a comparative measure as to the degree of separation of locations (Clarke & Warwick, 1994).

For all calculations and data analyses (except where indicated) touches from height classes 240cm and 250cm were removed due to lack of data for analysis. In twenty of the 109 honey possum selected locations and 5 of 50 random locations, \(Phytophthora\) dieback status was uninterpretable and were not included; 16 locations where honey possums were moving were similarly excluded.

A regression summary was carried out using Statistica (StatSoft-Inc, 2002) to determine if there was any significant correlation between the distance moved by radio tracked honey possums per night with four independent variables; (1) body mass of honey possums, (2) sex of honey possums (3) season and (4) transmitter weight.
Locations of honey possums were plotted with ArcGIS (ESRI, 2008). The features of the background map which includes vegetation assemblages and *Phytophthora cinnamomi* affected areas was determined from surveys (vegetation type and *P. cinnamomi* status) conducted at honey possum selected locations. The *P. cinnamomi* status and coverage at the study site was confirmed with plating of affected plant material and visual assessment of the study area (See section 2.2.7).

4.3 Results

4.3.1 Vegetation analysis of *Phytophthora cinnamomi* affected and unaffected areas

Overall vegetation density (represented as the average number of vegetation touches at height classes 0cm - 230cm) was significantly different between affected and unaffected vegetation (two-way MANOVA $F_{25,94} = 2.40$, $p<0.01$) and also differed between honey possum selected and random vegetation (two-way MANOVA $F_{25,94} = 3.63$, $p<0.0001$). Significant differences ($p<0.05$) were observed in the average vegetation density in vegetation height classes between 50 - 140cm in *P. cinnamomi* affected versus unaffected locations and 40 – 170cm in honey possum selected versus randomly selected locations (Post hoc analyses) (Figure 4.2). Unaffected vegetation has a more diverse vegetation height structure and is taller and denser than vegetation affected by *P. cinnamomi* (Table 4.1). Honey possums selected more locations unaffected by *P. cinnamomi* and showed a preference for taller than the average vegetation in both affected and unaffected areas (Figure 4.2 and Table 4.1). Affected vegetation in honey possum is dense between 0 – 50cm but lacks taller dense mid-storey vegetation where as unaffected vegetation shows higher vegetation density above 50cm (Figure 4.2). The honey possum foodplant *Banksia plumosa* subsp. *plumosa* occurred more often in honey possum selected locations (in both affected and unaffected areas) in comparison to randomly selected locations. In affected areas honey possums selected locations containing the foodplant *Beaufortia anisandra* (which occurred less frequently in *P. cinnamomi* affected, randomly selected locations) and but in honey possum-selected unaffected areas, these plant
species occurred less often in comparison to random locations. Adenanthos cuneatus occurred more often in honey possum-selected locations in P. cinnamomi affected areas compared to honey possum selected locations in unaffected areas however the occurrence of this species was higher in both affected and unaffected randomly selected locations.

Non-metric multi dimensional scaling (MDS) tested the similarity between all of the honey possum selected and randomly selected locations (affected and unaffected by P. cinnamomi) in relation to the five vegetation structure parameters and four honey possum foodplants (Table 4.1). Two dimensional plots show that locations affected by P. cinnamomi are generally dissimilar to unaffected locations (Figure 4.3). Honey possum selected locations are generally more similar to each other than random locations (Figure 4.4). The stress level calculated for this data set was 0.19 which means the plot is a satisfactory representation of the data however the locations lying on the outer limits of the graph are unreliable. A further analysis of similarity (ANOSIM) was conducted on the data set to test the null hypotheses that unaffected locations do not differ from affected locations and that honey possum selected locations do not differ from randomly selected locations. This test indicated more reliably that selected locations were significantly different to random locations ($R= 0.244, p<0.001$) and affected locations were significantly different to unaffected locations ($R=0.295, p<0.001$) and both null hypotheses can be rejected.
Average number of touches

Height (cm)

honey possum, Pc-
honey possum, Pc+
Random, Pc-
Random, Pc+
Comparison is between locations selected by honey possums (determined from radio tracking) compared with randomly selected locations representative of vegetation in the study area. (Honey possum *Phytophthora cinnamomi* unaffected locations (Pc-) *n = 50*, Honey possum *P. cinnamomi* affected locations (Pc+) *n = 38*, Randomly selected *P. cinnamomi* unaffected locations (Pc-) *n = 21*, Randomly selected *P. cinnamomi* affected locations (Pc+) *n = 24* where *n* = number of locations included for each category). Locations not determined as either *P. cinnamomi* affected or unaffected are not included, nor are locations where honey possums were moving. Hashes represent significant differences between affected and unaffected sites (# *p*<0.05, ## *p*<0.01, ### *p*<0.001), asterisks represent significant differences between honey possum selected and random sites (* *p*<0.05, ** *p*<0.01, *** *p*<0.001) as determined by factorial MANOVA with Tukeys unequal n HSD post-hoc analysis (represented by letters).

Figure 4.2.: Average (± 1 SD) number of vegetation touches at height classes 0 – 230cm.
Table 4.1: Comparison of average vegetation structure parameters for the four location categories. Asterisks represent significant differences between honey possum selected and random sites or affected and unaffected sites as determined by factorial ANOVA (* $p<0.05$, ** $p<0.01$, ***$p<0.001$). Letters indicate groups not significantly different from each other at $p<0.05$ (each vegetation parameter tested separately and letters on each row only indicate differences between the four categories for that parameter) as determined by Tukey's unequal n HSD tests. Values are ± 1 SD. % occurrence of four plant species present at the study site determined by presence or absence at each of the sampled locations.
<table>
<thead>
<tr>
<th></th>
<th>Selected unaffected</th>
<th>Selected affected</th>
<th>Random unaffected</th>
<th>Random affected</th>
<th>Significance</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Selected vs. random (includes affected and unaffected locations)</td>
<td>AFFECTED vs. UNAFFECTED (includes random and selected locations)</td>
</tr>
<tr>
<td>Average Mean vegetation height (cm)</td>
<td>90.2 ± 23.7 a</td>
<td>71.8 ± 26.2 ac</td>
<td>77.1 ± 23.9 ab</td>
<td>56.3 ± 9.20 c</td>
<td>(F_{1,118} = 11.46 ^{***})</td>
<td>(F_{1,118} = 21.57^{***})</td>
</tr>
<tr>
<td>Average % Vegetation coverage</td>
<td>76.4 ± 15.9 a</td>
<td>67.6 ± 17.9 ab</td>
<td>70.0 ± 19.0 ab</td>
<td>58.8 ± 15.4 b</td>
<td>(F_{1,118} = 5.68 ^*)</td>
<td>(F_{1,118} = 9.88 ^*)</td>
</tr>
<tr>
<td>Average # touches per height class (0-230cm)</td>
<td>1.22 ± 0.33 a</td>
<td>0.98 ± 0.31 b</td>
<td>0.84 ± 0.21 bc</td>
<td>0.62 ± 0.19 c</td>
<td>(F_{1,118} = 47.56 ^{***})</td>
<td>(F_{1,118} = 18.74^{***})</td>
</tr>
<tr>
<td>Average # touches per height class (40-140cm)</td>
<td>1.77 ± 0.66 a</td>
<td>1.17 ± 0.61 b</td>
<td>1.01 ± 0.42 bc</td>
<td>0.58 ± 0.33 c</td>
<td>(F_{1,118} = 41.29 ^{***})</td>
<td>(F_{1,118} = 24.83^{***})</td>
</tr>
<tr>
<td>Average of Shannon’s Diversity Index</td>
<td>1.04 ± 0.09 a</td>
<td>0.91 ± 0.13 b</td>
<td>0.90 ± 0.07 b</td>
<td>0.79 ± 0.08 c</td>
<td>(F_{1,118} = 54.00 ^{***})</td>
<td>(F_{1,118} = 42.70^{***})</td>
</tr>
<tr>
<td>% occurrence of (Banksia plumosa) subsp. (plumosa)</td>
<td>67</td>
<td>20</td>
<td>52</td>
<td>8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>% occurrence of (Adenanthos cuneatus)</td>
<td>18</td>
<td>35</td>
<td>24</td>
<td>54</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>% occurrence of (Banksia nutans)</td>
<td>8</td>
<td>10</td>
<td>14</td>
<td>17</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>% occurrence of (Beaufortia anisandra)</td>
<td>10</td>
<td>23</td>
<td>43</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Figure 4.3: Non-metric Multi-Dimensional Scaling (MDS) graph representing a 2D visual representation of the rank order of *P. cinnamomi* affected and unaffected locations. The relative distances between points (which represent the locations) indicates the dissimilarity between locations.

Figure 4.4: Non-metric Multi-Dimensional Scaling (MDS) graph representing a 2D visual representation of the rank order of honey possum selected locations and random locations. The relative distances between points (which represent the locations) indicate the dissimilarity between locations.
Table 4.2: Individual honey possums radio tracked in during the study.
The number of fix locations includes original trap site, locations were honey possums were moving and the location where the radio transmitter was lost.
* = transmitter lost within 30 minutes following attachment.

<table>
<thead>
<tr>
<th>Animal ID</th>
<th>Season</th>
<th>Sex</th>
<th>Weight (g)</th>
<th>Capture site</th>
<th>Transmitter type</th>
<th>Number of fix locations</th>
<th>Number of nights tracked</th>
<th>Total distance travelled between recorded locations (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR 1</td>
<td>Summer</td>
<td>♀</td>
<td>7.6</td>
<td>S1UA10</td>
<td>BD-2 (0.9g)</td>
<td>3</td>
<td>1</td>
<td>64</td>
</tr>
<tr>
<td>TR 5</td>
<td>Summer</td>
<td>♂</td>
<td>7.9</td>
<td>S3PA07</td>
<td>LN-2N (0.36g)</td>
<td>4</td>
<td>1</td>
<td>48</td>
</tr>
<tr>
<td>TR 9</td>
<td>Summer</td>
<td>♂</td>
<td>6.5</td>
<td>S3UA01</td>
<td>LN-2N (0.36g)</td>
<td>3</td>
<td>1</td>
<td>285</td>
</tr>
<tr>
<td>TR 10</td>
<td>Summer</td>
<td>♂</td>
<td>9.9</td>
<td>S3UA03</td>
<td>BD-2 (0.9g)</td>
<td>2</td>
<td>1</td>
<td>6*</td>
</tr>
<tr>
<td>TR 14</td>
<td>Summer</td>
<td>♀</td>
<td>11.0</td>
<td>S1PA07</td>
<td>BD-2 (0.9g)</td>
<td>2</td>
<td>1</td>
<td>4*</td>
</tr>
<tr>
<td>TR 15</td>
<td>Summer</td>
<td>♂</td>
<td>8.4</td>
<td>S1PA06</td>
<td>LN-2N (0.36g)</td>
<td>8</td>
<td>3</td>
<td>257</td>
</tr>
<tr>
<td>TR 19</td>
<td>Summer</td>
<td>♂</td>
<td>7.4</td>
<td>S2PA06</td>
<td>LN-2N (0.36g)</td>
<td>4</td>
<td>2</td>
<td>46</td>
</tr>
<tr>
<td>TR 20</td>
<td>Summer</td>
<td>♂</td>
<td>6.4</td>
<td>S1UA05</td>
<td>LN-2N (0.36g)</td>
<td>9</td>
<td>4</td>
<td>626</td>
</tr>
<tr>
<td>TR 21</td>
<td>Summer</td>
<td>♂</td>
<td>7.8</td>
<td>S1UA09</td>
<td>LN-2N (0.36g)</td>
<td>5</td>
<td>3</td>
<td>141</td>
</tr>
<tr>
<td>TR 24</td>
<td>Summer</td>
<td>♀</td>
<td>5.9</td>
<td>S2UA05</td>
<td>LN-2N (0.36g)</td>
<td>4</td>
<td>2</td>
<td>268</td>
</tr>
<tr>
<td>TR 58</td>
<td>Autumn</td>
<td>♀</td>
<td>9</td>
<td>S3UA01</td>
<td>LN-2N (0.36g)</td>
<td>3</td>
<td>1</td>
<td>303</td>
</tr>
<tr>
<td>TR 67</td>
<td>Winter</td>
<td>♂</td>
<td>6.5</td>
<td>S3PA09</td>
<td>LN-2N (0.36g)</td>
<td>6</td>
<td>1</td>
<td>117</td>
</tr>
<tr>
<td>TR 70</td>
<td>Winter</td>
<td>♂</td>
<td>6.7</td>
<td>S3PA01</td>
<td>LN-2N (0.36g)</td>
<td>25</td>
<td>9</td>
<td>903</td>
</tr>
<tr>
<td>TR 71</td>
<td>Winter</td>
<td>♀</td>
<td>16</td>
<td>S3UA05</td>
<td>LN-2N (0.36g)</td>
<td>4</td>
<td>1</td>
<td>720</td>
</tr>
<tr>
<td>TR 76</td>
<td>Winter</td>
<td>♀</td>
<td>10</td>
<td>S3PA10</td>
<td>LN-2N (0.36g)</td>
<td>10</td>
<td>5</td>
<td>136</td>
</tr>
<tr>
<td>TR 83</td>
<td>Spring</td>
<td>♂</td>
<td>10.7</td>
<td>S1PA03</td>
<td>BD-2 (0.9g)</td>
<td>28</td>
<td>9</td>
<td>1400</td>
</tr>
<tr>
<td>TR 86</td>
<td>Spring</td>
<td>♀</td>
<td>8.3</td>
<td>S3UA09</td>
<td>LN-2N (0.36g)</td>
<td>5</td>
<td>2</td>
<td>40</td>
</tr>
<tr>
<td>TR 90</td>
<td>Spring</td>
<td>♀</td>
<td>7.9</td>
<td>S1UA05</td>
<td>LN-2N (0.36g)</td>
<td>2</td>
<td>1</td>
<td>251</td>
</tr>
</tbody>
</table>
Figure 4.5: Locations of individual honey possums as determined by radio tracking in relation to the study site. Red lines represent the trap lines at sites 1, 2 and 3. *Phytophthora cinnamomi* affected areas are indicated by red shaded areas, green shading indicates spongelite ridges and associated vegetation assemblages, yellow shading indicates *Banksia baxteri* thicket, grey line indicates sand track into study site. Honey possum locations plotted with ArcGIS (ESRI, 2008).
4.3.2 Movements of radio tracked honey possums

A total of 18 animals (9 ♀ and 9 ♂) were fitted with transmitters, however only nine animals (4 ♀ and 5 ♂) could be tracked for more than one night as transmitters fell off the other nine animals within 24 hours following attachment. Tracked animals varied in weight from 5.9g to 16g.

The distances moved by honey possums per night correlated significantly to honey possum body weight ($t_{(11)} = 3.28, p=0.01$). Interestingly the distances radio tracked honey possums moved per night did not correlate significantly to sex of honey possum ($t_{(11)} = -0.52, p=0.61$), season during which animal was radio tracked ($t_{(11)} = -0.52, p=0.61$) or weight of the transmitter ($t_{(11)} = -0.94, p=0.37$).

Honey possums are capable of moving relatively large distances for an animal with an adult weight of 7-12g. Distances travelled by honey possums varied considerably between individuals and some radio tracked individuals moved long distances within a matter of hours. Some specific honey possum habitat preferences were observed during radio tracking studies and longer tracking periods were especially informative. Figure 4.5 shows the locations honey possums were radio tracked to (locations where honey possums were trapped is not shown) are shown in relation to the different healthy vegetation assemblages and *P. cinnamomi* affected areas at the study site. The movements of individual honey possums will be discussed in order of season.

During summer, ten honey possums were radio tracked, although transmitters fell off five animals within 24 hours (Table 4.2). Honey possum TR9 (6.5g ♀) moved 254m in 5 hours to a clump of flowering *Eucalyptus angulosa*. The transmitter was subsequently found 1m off the ground within the branches. Honey possum TR 20 (6.4g ♂) moved an estimated 626m over four nights from site 1 to site 2 (essentially negating the assumption that each of the study sites were independent from each other). This honey possum
moved between the borders of *P. cinnamomi* affected and unaffected areas which are patchy between sites 1 and 2. Honey possum TR 15 was observed to have a preference for the rich vegetation assemblages on the spongelite ridge where this animal remained for the three night tracking period (Figure 4.6 and Figure 4.7). This was the only honey possum to return back to a previously visited *B. plumosa* subsp. *plumosa* shrub, however this only occurred once during the tracking period. Honey possum TR1 (7.6g ♀) was initially located in the *Banksia baxteri* thicket near the site 1 trap line (Figure 4.5). She then moved to a flowering *Banksia nutans* in an affected area behind the thicket before the transmitter fell off.

![Figure 4.6: Healthy vegetation assemblage on spongelite ridge characterised by taller, thicker vegetation including Banksia species. Banksia plumosa subsp. plumosa (blue arrow) Taller vegetation in background dominated by Lambertia inermis (red arrow) and Eucalyptus species (yellow arrow).](image-url)
Honey possum TR 58 (Table 4.2) was the only animal radio tracked during autumn and she was recorded moving 279m in 4 hours. This honey possum had moved up a spongelite ridge during the day, presumably to forage since 2 hours later she was located only 20m away in a *Banksia plumosa* subsp. *plumosa* plant before the signal was lost.

Four honey possums were radio tracked during winter. Honey possum TR 71 was a very large female at 16g. This honey possum moved 480m over 7 hours during the same day the transmitter was attached. Tracking before dusk indicated this animal was in a similar location, but after dusk this honey possum had moved another 230m before the signal was lost. Honey possum TR 70 (6.7g ♀) was tracked over nine nights and 25 locations were recorded. She moved across the road from site 3 and showed a preference for a *P. cinnamomi* affected area for the remainder of the tracking period (Figure 4.5 and Figure 4.8). Locations were recorded during the day and night for this
honey possum in order to gain greater insight into the habitat preferences of this individual. She was found in torpor at early morning locations five times during the tracking period (Figure 4.12). A pattern became evident as this animal appeared to favour a particular area at night (presumably to forage) and was then found in torpor in a different area during the day (presumably a preferred day time refuge). These foraging excursions were repeated on at least four occasions over which time she moved approximately 120m a day. Pollen collected from this honey possum when found in torpor (see Section 3.3) indicated a foodplant preference for *Calothamnus gracilis*, which was present in *Phytophthora cinnamomi* affected areas. One sample collected contained large amounts of *Eucalyptus angulosa* pollen and since no flowering *E. angulosa* trees were noted close to the radio tracked locations, it is estimated this animal would have had to move a fair distance to feed on this species suggesting the estimated daily movement of 120m (totalling 717m over the course of nine days) was a significant underestimate. Honey possum TR 76 (10g ♀) was tracked over winter and yielded 10 fixes. She remained in the area around site 3 and utilised *Banksia plumosa* subsp. *plumosa* plants which were present in healthy “islands” generally located under large *Lambertia inermis* plants (Figure 4.9). This animal was located in six separate *Banksia plumosa* subsp. *plumosa* shrubs over the tracking period of five nights. Honey possum TR67 (6.5g ♂) was only tracked over 1 night and 6 locations were obtained for this individual before the signal was lost. This honey possum also utilised the healthy “islands” within site 3 where *Banksia plumosa subsp. plumosa* was present under *L. inermis* plants (Figure 4.9).
Figure 4.8: *Phytophthora cinnamomi* affected area at Cape Riche. Characterised by low vegetation around 0.5m in height and the lack of susceptible species (primarily lacking *Banksia* species except the less susceptible prostrate *B. repens*). Clumps of *Eucalyptus* species (indicated by blue arrow) are scattered throughout affected areas.

Figure 4.9: Healthy vegetation ‘island’ utilised by honey possums at site 3. *Banksia plumosa* subsp. *plumosa* (blue arrow) were common under *Lambertia inermis* (orange arrow).
Three honey possums were radio tracked during spring however, only two were tracked for longer than one night. Honey possum TR83 (10.7g ♂) was tracked over 9 nights and 28 locations were recorded. He initially moved through the *Phytophthora cinnamomi* affected area near site 1 but showed a particular habitat preference for the vegetation assemblages on the spongelite ridge and spent majority of the tracked period there (Figure 4.5). This area is floristically diverse and contained large numbers of *Banksia plumosa* subsp. *plumosa* plants (Figure 4.6 and Figure 4.7). This animal was usually located on top of the ridge during the day, often in a *B. plumosa* subsp. *plumosa* plant. At night he was observed foraging along the side of the spongelite ridge in an area thick with *B. plumosa* subsp. *plumosa* bushes, many of which were flowering at the time. The following morning this honey possum was observed either on the top of the ridge or close to the top of the ridge. This pattern continued over about 6 days. *Banksia plumosa* subsp. *plumosa* had a notable flowering peak during the spring field trip when this honey possum was radio tracked (See section 3.4.1). Honey possum TR86 (8.3g ♂) was radio tracked for two nights and yielded five fixes. This animal remained in the area unaffected by *P. cinnamomi* near site 3 and utilised *B. plumosa* subsp. *plumosa* shrubs as well as a large *Banksia nutans* which was not in flower before the transmitter fell off.

### 4.3.3 Honey possum preference for *Banksia plumosa* subsp. *plumosa*

Honey possums actively selected locations containing *B. plumosa* subsp. *plumosa* at the Cape Riche study site. *Banksia plumosa* subsp. *plumosa* plants were present in 46% (40 out of 87) of locations selected by honey possums as determined by radio tracking. This compares to the presence of this species in 28% (14 out of 50) of randomly selected locations. *Banksia plumosa* subsp. *plumosa* was a common *Banksia* species within the study site (Figure 4.6 and Figure 4.7) but is susceptible to *P. cinnamomi* infection and was generally not present in affected sites. Radio tracking studies indicated that honey possums utilise this species for more than food. Honey possums were tracked to healthy *B. plumosa* subsp. *plumosa* bushes (dead bushes did not appear to be used) during the day and night. During winter, TR76 was found in torpor in three different *B. plumosa* subsp. *plumosa* plants
on three separate occasions (Figure 4.10). Closer investigation of a *B. plumosa* subsp. *plumosa* shrub to which a honey possum was radio tracked, showed the presence of narrow tunnels throughout the plant which allow easy entry by honey possums into the dense foliage (Figure 4.11).

**Figure 4.10:** Torpid honey possum TR 76 (indicated by red arrow) with attached radio transmitter in a *Banksia plumosa* subsp. *plumosa*, sitting within a dried *Hakea cucullata* leaf.

**Figure 4.11:** Ground view of tunnel through *Banksia plumosa* subsp. *plumosa* to which a honey possum was radio tracked.

Given the size of this tunnel, it is most likely used by other small mammals as well. Smaller tunnels (suggesting they are more specifically used by honey possums) were present throughout the dense foliage of this *B. plumosa* subsp. *plumosa* plant.
4.3.4 Resting/Nesting locations

During the winter trapping sessions, honey possums were radio tracked during the early morning and were often found in torpor which provided an opportunity to see where honey possums nested and to obtain samples of pollen from their faces and chests. Honey possum TR 76 favoured *B. plumosa* subsp. *plumosa* bushes (Figure 4.10). Honey possum TR 70 favoured more sparse bushes, often near *Calothamnus gracilis* (Figure 4.12), and one morning was found in torpor on the top of a sparse bush very open to the elements and possible predators. During spring, early morning locations of honey possum TR 83 were most often in *B. plumosa* subsp. *plumosa* shrubs although this honey possum was not found in torpor.

![Figure 4.12: Torpid honey possum TR 70 in dig out under *Calathamnous gracilis* shrub.](image)
4.4 Discussion

This study shows for the first time that habitat utilisation by honey possums is clearly influenced by *Phytophthora cinnamomi* infestation in vegetation assemblages at Cape Riche, Western Australia. The main effects impacting on honey possums is the loss of preferred foodplants and refuge sites as well as the loss of vegetation structural diversity. These effects of *Phytophthora cinnamomi* on the habitat of honey possums will be discussed in detail below.

4.4.1 Change in vegetation as a result of *Phytophthora cinnamomi* infestation and honey possum habitat selection

The loss of *Phytophthora cinnamomi* susceptible species influences habitat selection by honey possums in the Cape Riche area. Honey possums actively selected areas with vegetation significantly higher, denser and with a more complex structure than the average vegetation in the study area. Honey possums are most likely to prefer these unaffected areas at Cape Riche because of the presence of preferred food plants and sufficient refuge sites. *Banksia plumosa* subsp. *plumosa* occurred more frequently in honey possum selected locations in comparison to randomly selected locations. This species was heavily impacted by the presence of *P. cinnamomi* and was generally not found in *P. cinnamomi* affected areas. Another honey possum foodplant, *Beaufortia anisandra* occurred most frequently in randomly selected unaffected areas. This species however, occurred more often in *P. cinnamomi* affected honey possum selected locations compared to honey possum locations in unaffected areas. *Adenanthos cuneatus* is another honey possum preferred foodplant which occurred most frequently in randomly selected *P. cinnamomi* affected areas and honey possums selected locations contained this species more frequently in affected areas in comparison to unaffected areas. This may indicate honey possums are utilising *Beaufortia anisandra* and *Adenanthos cuneatus* as preferred foodplants in affected areas, where *Banksia plumosa* subsp. *plumosa* is generally absent.

In fire impacted environments, which in some ways are comparable to *P. cinnamomi* infestation, the capture rate of honey possums corresponded to
vegetation density (Everaardt, 2003). Honey possums appear to be reliant upon vegetation density in the vertical plane (in comparison to the horizontal plane), the former of which was slower to return post fire (Everaardt, 2003).

Capture rates of *Antechinus stuartii* in the Brisbane Ranges, Victoria are associated with larger vegetation volumes up to 40cm in height (Newell & Wilson, 1993). The volume of vegetation between 0-60cm in areas affected with *P. cinnamomi* were significantly lower in comparison to unaffected areas (Newell & Wilson, 1993). *Antechinus stuartii* has a preference for *Xanthorrhoea australis* and the lower capture rates and lower vegetation volume were attributed to loss of this species in diseased areas (Newell & Wilson, 1993). The impact of *P. cinnamomi* infestation on structural changes and changes to vegetation cover influenced capture rates of small carnivorous mammals in Victorian coastal heathlands, more than changes to floristic diversity (Laidlaw & Wilson, 2006). For honey possums, floristic composition following *P. cinnamomi* infestation may be more important than for *Antechinus* spp. as they have more specific habitat requirements that are intrinsically linked with particular plant species. The importance of habitat components for carnivorous mammals is expected to be very different compared with those for nectar feeding mammals, an aspect which needs to be explored further.

**4.4.2 Importance of *Banksia plumosa* subsp. *plumosa* used for refuge by honey possums at Cape Riche**

Honey possums have a preference for *B. plumosa* subsp. *plumosa* as a food source (see section 3.4.1) but this plant species is also important to honey possums for other resources. *Banksia plumosa* subsp. *plumosa* shrubs were utilised for refuge by honey possums, presumably because they provide suitable resting spots as well as protection from predators. In the Fitzgerald River National Park, researchers observed three honey possums utilising a single *B. plumosa* bush over three nights, presumably as a daytime sleeping refuge (Garavanta, 1997). It appears, however, that some honey possums are opportunistic in refuge selection whilst others may be more selective. In *P. cinnamomi* affected areas, one honey possum utilised more exposed
shrubs, including *Calothamnus gracilis*, which this animal also utilised for food. The reason for the selection of these exposed refuge sites was unclear but may have been as there were no other alternatives as the risk of predation in these exposed areas is presumably high. Another honey possum captured at the same site remained closer to areas containing *Banksia plumosa* subsp. *plumosa* which were used for refuge. Not much is known about the nesting habits of honey possums but females with young are thought to utilise old bird nests, hollow branches or forked branches within dense shrubs (Russell & Renfree, 1989). As honey possums utilise a variety of foodplants, they often need to travel reasonable distances to obtain nectar resources; the building of a permanent nest would therefore seem a pointless exertion of energy. For an animal that may already be energetically stressed due to a relatively specialist diet that requires relatively vast distances to be travelled to source, nest building would not be cost effective in terms of energy use. Suitable refuge is an important aspect in the habitat of most fauna species. For the honey possum, dense shrubs such as *B. plumosa* subsp. *plumosa* provide suitable refuge without the requirement to build a nest, and the loss of *B. plumosa* subsp. *plumosa* plants to *P. cinnamomii* infection is likely to have serious implications for honey possums in terms of loss suitable refuge as well as food in the Cape Riche area.

### 4.4.3 Distances travelled by radio tracked honey possums

Longer tracking sessions provide more substantiated information on specific habitat preferences. Two honey possums were able to be tracked for 9 consecutive nights each owing to transmitters sticking on for longer. One of the drawbacks of the smaller transmitters is the short battery life which is sacrificed to decrease the weight of the transmitter. The 0.36g transmitters used in this study only have a battery life of 10-12 days (with signal strength decreasing considerably after 10 days). Despite these limitations, radio tracking of honey possums, even for short periods, provided more detailed information on habitat preferences and movement trends than could have been determined from trapping alone.
The presumption that honey possums are relatively sedentary and would remain within a 100m x 100m study site was based on previous long term honey possum research which suggests that most honey possums only moved on average 20-30m between traps (the longest recorded movement between traps being 125m), with an estimated average home range size of 0.13ha for males and 0.07ha for females (Garavanta, 1997; Garavanta et al., 2000). These studies determined honey possum movements from mark and recapture records as radio telemetry at the time was not suitable for use on honey possums given the large size of transmitters (Garavanta, 1997). In the current study, radio tracked honey possums were observing moving considerably further than these distances. At Cape Riche, both male and female honey possums made long distance movements and sex did not correlate significantly to the distances travelled by honey possums ($t_{11} = -0.52$, $p=0.61$). The daily long distance foraging trips observed in the current study were also evident in a previous study at Scott National Park with one animal in the moving 250m away to forage in a Beaufortia thicket before returning to an area close to point of capture, a trend that was observed over a number of days (Bradshaw & Bradshaw, 2002).

The distances travelled by honey possums was observed to reflect the distances required to forage for food and find refuge and the presence of *P. cinnamomi* affected areas appears to have an influence on how far honey possums need to move to find preferred plant species. The furthest distance travelled by one honey possum observed in the current study was the only animal radio tracked during autumn. Honey possums were also observed to move reasonable distances during the winter field trip but season did not correlate significantly ($t_{11} = -0.52$, $p=0.61$) to the distances honey possums travelled. In previous radio tracking studies at Mount Lesueur Nature Reserve, female honey possums were observed to move 20-80m and males 50-200m between fixes during January in comparison to winter when they were observed to move up twice that distance between fixes (Arrese & Runham, 2003).
Radio tracking was useful to obtain information on long distance movements and movement trends however future research should ideally be focused on maximising tracking periods and locations to provide more detailed information on honey possum movements. As radio tracking techniques become more practised, this will be possible.

4.4.4 Distribution of *Phytophthora cinnamomi* at Cape Riche in relation to areas utilised by honey possums

The distribution of *Phytophthora cinnamomi* affected areas at Cape Riche tends to be patchy (Figure 2.10). Areas of unaffected vegetation with significant floristic diversity are most notably observed on the spongelite ridges. Small ‘islands’ within affected areas where susceptible species are still present were also observed within the study area. The importance of these currently unaffected areas of healthy vegetation within *P. cinnamomi* affected areas was highlighted as radio tracked honey possums were often located in these healthy areas because of foodplant abundance and suitable refuge. The importance of healthy patches of vegetation was also noted in fire impact studies in which pollen samples collected from honey possums indicate that animals rely on nearby unburnt patches for food and shelter (Everaardt, 2003). Healthy vegetation ‘islands” surrounded by bare ground in *P. cinnamomi* affected areas are noted in the Brisbane Ranges, Victoria, and these islands restrict movements of small mammal species requiring dense vegetation (Newell & Wilson, 1993). In widespread areas of *P. cinnamomi* infestation, these patches of healthy vegetation are important and should be recognised when considering conservation measures for honey possums as well as other small mammal species.

The presence of *P. cinnamomi* at the bottom of ridges and around vegetation “islands” means infestation of these areas in the future is inevitable as the pathogen spreads, unless measures such as the use of control tools like the application of phosphite to induce resistance in susceptible species. Further spread of *P. cinnamomi* at Cape Riche, especially through the vegetation assemblages on the spongelite ridges is likely to have serious consequences to the honey possums which appear to have a preference for these
unaffected areas. The cost of *P. cinnamomi* control measures needs to be weighed up against the benefits however the conservation of a unique endemic mammal such as the honey possum deserves serious consideration and appropriate resource allocation.

4.4.5 Usefulness of radio tracking to determine habitat utilisation by honey possums

The trapping of honey possums in the present study was originally thought to be sufficient to determine if honey possums were captured in and hence utilising affected areas by comparing with capture rates in unaffected areas. The first radio tracked honey possums changed this assumption and radio tracking of honey possums proved to be far more useful in determining habitat use by honey possums. When the data collected from one year of radio tracking is compared with one year of trapping data, trapping was shown to be seriously insufficient in being able to highlight the difference in honey possum use of affected and unaffected locations. Pollen collected from captured honey possums was useful in determining preferred foodplants but radio tracking indicated the importance of *B. plumosa* subsp. *plumosa* as a preferred honey possum refuge plant at Cape Riche. In addition, other habitat preferences such as taller, denser vegetation were observed, information which could not have been obtained from trapping alone.

Limitations exist when using just trapping data to determine distances moved by small mammals. These studies rely on recaptures and the distances moved are determined by distances between traps. It is difficult to determine distances travelled by trapped animals. For example, an animal may move 500m from one location and encounter traps on their way to another foraging spot 500m beyond the trap lines. This technique relies heavily on the chance of animals falling into traps and brings up the point if animals are being captured regularly, do they represent the population accurately or being influenced by the presence of the trap. Radio tracking is not fool proof as animals can move fair distances between fixes but this technique can provide more information on habitat use beyond trapping grids. The capacity of
honey possums to move long distances sometimes on a daily basis could not have been determined from trapping let alone other tracking methods.

Significant trends have been established in honey possum populations and habitat use from extensive 12 year honey possum trapping records from studies in the Fitzgerald River National Park (Garavanta, 1997; Garavanta et al., 2000). Although this was a commendable effort, in terms of habitat conservation and especially in the case of *P. cinnamomi* infestations, extensive long term research to determine species specific requirements could prove to be too late to be able to act. As technology keeps improving, radio tracking will potentially be an invaluable tool to determine habitat use as shown in the present study for the honey possum. This will allow conservation efforts to focus on areas where they will have the greatest impact on conserving native fauna.
Chapter 5: General Discussion, Conclusions and Suggestions for further research

This study demonstrated for the first time that the presence of *Phytophthora cinnamomi* in vegetation communities has an impact on food and habitat resources of a unique nectarivorous marsupial, the honey possum. Further spread of *P. cinnamomi* through vegetation assemblages in south west WA is likely to have a devastating effect on honey possum populations if this pathogen is not controlled. As food resources become more dispersed and honey possums are unable to sustain themselves throughout the year in affected areas, it could mean the eventual loss of this unique marsupial.

This chapter represents the three hypotheses posed at the beginning of this thesis and each will be addressed individually in relation to the findings of the current study. The overall conclusions of this study are discussed and suggestions for management and further research and are proposed.

5.1 Overall aim of this research project

To determine the extent to which the presence of *Phytophthora cinnamomi* affected vegetation impacts on habitat utilisation by honey possums.

5.1.1 Hypothesis 1 - Changes in vegetation structure and composition as a result of *Phytophthora cinnamomi* influences habitat selection by honey possums

The vegetation assemblage in *Phytophthora cinnamomi* affected areas was characterised by low, sparse vegetation, and change in composition, in particular loss of species (primarily *Banksia* species). Honey possums demonstrated a selective preference for foraging amongst vegetation that is significantly taller, denser and has a more complex structure compared with a random sample. Honey possum habitat use is influenced by *P. cinnamomi* affected vegetation therefore as a result of (i) the loss of foodplants including the preferred honey possum foodplant at Cape Riche, *Banksia plumosa* subsp. *plumosa*, (ii) large affected areas requiring honey possums to move...
longer distances to unaffected areas to forage, and (iii) the loss of suitable refuge in sparser vegetation.

5.1.2 Hypothesis 2 – Honey possums are capable of moving long distances in search of food sources

Honey possums were observed to move long distances (~250m) within a few hours. One (9g) honey possum moved 279m in just four hours. Honey possums radio tracked for longer periods were regularly observed making relatively long distance foraging excursions. Floristically diverse vegetation assemblages (unaffected by *P. cinnamomi*), located on ridges at the study site, were commonly utilised by honey possums. Honey possums were shown to be far more mobile than was first assumed given their body mass of 5.9 – 16g. Foraging honey possums were observed to move relatively long distances which were considerably further than the 20-30m observed in previous trapping studies (Garavanta, 1997; Garavanta et al., 2000).

5.1.3 Hypothesis 3 – Honey possums will not utilise widespread *Phytophthora cinnamomi* infested areas.

Honey possums were captured and radio tracked within *Phytophthora cinnamomi* infested areas where some foodplants such as *Adenantheros cuneatus*, *Beaufortia anisandra* and *Calothamnus gracilis* were present. These species appearing to be less susceptible to *P. cinnamomi* and individual plants remain in affected areas and were utilised by honey possums as food resources. The future of these *P. cinnamomi* impacted areas is unknown and they may be unlikely to be floristically diverse enough to support large numbers of animals over a full 12 months.

5.2 The indirect impact of *Phytophthora cinnamomi* on honey possums

The presence of *Phytophthora cinnamomi* in vegetation assemblages has many potentially detrimental flow-on effects to honey possums, illustrated in
The presence of *P. cinnamomi* initially causes a decline in vegetation health which results in the loss of foodplants and refuge and consequently, honey possums have to move longer distances to forage on preferred foodplants. In the Cape Riche area, some honey possums were observed to utilise *P. cinnamomi* infested areas, presumably due to the presence of foodplants which have not yet succumbed to infection. The future of *P. cinnamomi* affected areas which were utilised by honey possums is unknown, however, such areas are unlikely to support sustainable honey possum populations in the long term. The lack of refuge in affected areas may also have an impact on honey possums which could potentially be more vulnerable to predators in these areas.

Honey possums demonstrated a particular preference for *Banksia plumosa* subsp. *plumosa* at the Cape Riche study site. Radio tracked honey possums use *Banksia plumosa* subsp. *plumosa* for food as well as refuge. At Cape Riche, unaffected areas which are floristically diverse and contain *Banksia plumosa* subsp. *plumosa* in high densities were present on spongelite ridges surrounding the study area. These areas were regularly frequented by radio tracked honey possums and may provide vital food resources for honey possums.

This study demonstrates that honey possums are capable of moving relatively long distances to obtain food. A flow-on effect as a result of the spread of *P. cinnamomi* is that foodplants become more and more dispersed and there may be a point when there are insufficient foodplants to support the honey possum population (Figure 5.1). Honey possum populations are intrinsically linked to availability of foodplants with the annual mortality of majority of the population most likely a result of food deprivation (Wooller et al., 1993). With a reduction in the amount of food available as more plants succumb to *P. cinnamomi*, fewer individuals are likely to survive periods of food shortage (i.e. during winter when their food requirements are high). Given the estimated annual mortality rate of honey possums is exceptionally high, at 86% (Garavanta, 1997), very small populations of honey possums would presumably struggle to replace individuals dying off each year given
that the mortality of juveniles is also very high (79%) (Garavanta, 1997) making the population quite vulnerable to any long lasting changes in habitat. The final flow-on effect as a result of the spread of \textit{P. cinnamomi} in vegetation communities may be the loss of honey possums from these communities (Figure 5.1).

With limited data on \textit{Phytophthora cinnamomi} infection and animals, other environmental impacts such as fire and their impact on animals could possibly be used as homologues to the effects of environmental disturbances on animals. A study conducted in the Fitzgerald River National Park examined the effects of fire on honey possum populations (Everaardt, 2003). The study utilised 19 years of trapping data and found there was a significant relationship between honey possum captures and burning history (Everaardt, 2003). It takes 4-5 years for burnt vegetation to recover sufficiently to provide floral resources for honey possums after which honey possum populations increase (Everaardt, 2003). Unburnt patches act as valuable refuges for honey possums the location from where new populations recolonised (Everaardt, 2003). The main difference in comparison with \textit{P. cinnamomi} infection is that the effects of dieback are permanent, with little recolonisation back to a former vegetation state, whilst the fire-prone flora of WA is resilient to conflagration and re-grows reasonably rapidly.
Figure 5.1: Flowchart of the potential impacts of the presence of *Phytophthora cinnamomi* in vegetation assemblages on honey possums.
5.3 Conservation priorities at Cape Riche

Ideally, future efforts to conserve the honey possum populations in the Cape Riche area should involve \textit{P. cinnamomi} control in the form of phosphite application to the vegetation assemblages on the ridges and in the \textit{B. baxteri} thickets. These areas are floristically diverse and both contain susceptible \textit{Banksia} species. Honey possum preference for \textit{B. plumosa} subsp. \textit{plumosa} should be recognised as an important conservation priority and this plant species should form the basis of conservation efforts. \textit{Banksia plumosa} subsp. \textit{plumosa} is susceptible to \textit{P. cinnamomi} and the loss of this species, together with other susceptible plant species at Cape Riche, would no doubt have serious implications for honey possums in the area. The susceptibility of many of the species recognised as honey possum foodplants have not been formally tested and the susceptibility for some foodplant species at the study site only came to light from observations during the current study. A better knowledge of \textit{P. cinnamomi} susceptibility of specific honey possum foodplant species would be of use for future research and targeted conservation efforts.

5.4 Suggestions for further research

Research on honey possum habitat utilisation is an excellent starting point to gain greater understanding of how the presence of \textit{Phytophthora cinnamomi} affected vegetation impacts on fauna. Honey possums represent an extremely specialised (nectarivorous) mammal, and are likely to be impacted before other fauna species based on their reliance on foodplant availability. A comparison of honey possum habitat requirements to the habitat requirements of other small mammal species with different diets could be informative. For example, examining the effects of \textit{P. cinnamomi} on \textit{Cercartetus cocinnus} (western pygmy possum), which feeds on nectar, pollen and insects, \textit{Rattus fuscipes} (bush rat) which feed on insects and mycophagous fungi and a small carnivorous marsupial such as \textit{Smithopsis griseventer} (grey bellied dunnart) would allow for a more rounded understanding of the impacts of \textit{P. cinnamomi} affected vegetation on fauna. The significant benefits associated with the use of radio telemetry to study habitat utilisation by small mammals has been shown in this study and the
availability of smaller transmitters presents many possibilities for future studies.

Accurate estimation of population densities of small mammals, where possible, for comparison in *P. cinnamomi* affected and healthy bushland would be worthwhile. The study of fauna present in older, widespread *P. cinnamomi* affected areas lacking healthy areas close by may provide greater insight into what habitat resources mammals such as honey possums are relying on (if they are actually present in these areas). This could provide invaluable information to salvage heavily affected areas in terms of providing suitable habitats for fauna in the presence of *P. cinnamomi*. The study of mammals in old, widespread infested areas compared with the healthy equivalent could yield some interesting results. The current study showed honey possums are capable of moving long distances, and further studies to determine the distances which honey possums can move, especially in extensively affected habitats, may provide greater insight into how honey possums cope in the presence of *P. cinnamomi*.

Further long term study on the secondary impacts of *P. cinnamomi* on fauna species (especially the honey possum) is needed, and studies over a more diverse range of habitats would be of great value. A diverse range of habitats are under threat from *P. cinnamomi* in WA including jarrah forests, *Banksia* heathlands, northern sandplains, whilst National Parks such as the Stirling Range National Park, Cape Arid, Two Peoples Bay Nature Reserve and Fitzgerald River National Park have already been affected. Consequently the secondary impacts on fauna within this diverse range of vegetation assemblages needs to be examined to gain a better understanding of specific fauna habitat requirements so that suitable conservation efforts can be targeted appropriately in these areas before it is too late.

5.5 Conclusion

The spread of the introduced plant pathogen *Phytophthora cinnamomi* throughout vegetation assemblages of the south-west of WA is a serious concern not only for susceptible plant species but also for the native fauna
species which rely on these assemblages for habitat. The honey possum, a unique marsupial endemic to the southwest of WA is the only non-flying mammal entirely dependent upon nectar and pollen for food and is therefore especially at risk from this plant pathogen. The habitat utilisation of honey possums is impacted upon in areas affected by *P. cinnamomi*. Honey possums at the Cape Riche study site demonstrate a preference for foraging amongst taller, denser vegetation with a more complex structure, whilst *P. cinnamomi* infested areas were characterised by low sparser vegetation lacking susceptible species such as *Banksia* species. *Banksia plumosa* subsp. *plumosa* was favoured by honey possums for both food and refuge. This species, however, is susceptible to *P. cinnamomi* and was generally absent from affected areas. Honey possums are capable of travelling relatively long distances to forage and radio tracked honey possums regularly utilised floristically diverse vegetation assemblages located on ridges around the study sites (not affected by *P. cinnamomi*). Conservation of the areas at Cape Riche should focus on control of *P. cinnamomi* via phosphite application, with particular attention being paid to protect *Banksia plumosa* subsp. *plumosa* found throughout these rich areas utilised by honey possums.
6 References


ESRI (2008) ArcGIS, California, USA.


WWF Australia (2004). *Arresting Phytophthora Dieback: The Biological Bulldozer*.


7 Appendices

7.1 Appendix 1 Species list with authorities

Adenanthos cuneatus Labill.
Adenanthos meisneri Lehm.
Acacia subcaerulea Lindl.
Actinodium cunninghamii Schauer
Banksia attenuata R.Br.
Banksia baueri R.Br
Banksia baxteri R.Br.
Banksia coccinea R.Br.
Banksia gardneri A.S.George
Banksia grandis Willd.
Banksia ilicifolia R.Br.
Banksia meisneri Lehm.
Banksia nutans R.Br.
Banksia occidentalis R.Br
Banksia praemorsa Andrews
Banksia repens Labill.
Banksia sphaerocarpa R.Br.
Beaufortia anisandra Schauer
Beaufortia empetrifolia (Rchb.) Schauer
Beaufortia micrantha Schauer
Beaufortia sparsa R.Br
Dryandra brownii Meisn. (=Banksia brunnea) A.R.Mast & K.R.Thiele
Dryandra cuneata R.Br (=Banksia obovata) A.R.Mast & K.R.Thiele
Dryandra nivea (Labill.) R.Br. (=Banksia nivea) Labill.
Dryandra plumosa plumosa R.Br. (= Banksia plumosa plumosa) (R.Br.) A.R.Mast & K.R.Thiele
Dryandra quercifolia Meisn.(=Banksia heliantha) A.R.Mast & K.R.Thiele
Dryandra sessilis Knight (=Banksia sessilis) (Knight) A.R.Mast & K.R.Thiele
Dryandra tenuifolia R.Br. (=Banksia tenuis) A.R.Mast & K.R.Thiele
Calectasia grandiflora L.Preiss
Calothamnus gracilis R.Br.
Calothamnus quadrifidus R.Br.
Calothamnus villosus R.Br.
Calytrix angulata Lindl.
Chorizema uncinatum C.R.P. Andrews
Conospermum polyccephalum Meisn.
Corymbia calophylla (Lindl.) K.D.Hill & L.A.S.Johnson
Daviesia incrassata Sm.
Eucalyptus angulosa Schauer
Eucalyptus buprestium F.Muell
Eucalyptus decurva F.Muell.
Eucalyptus lehmannii (Schauer) Benth.
Eucalyptus preissiana Schauer
Eucalyptus staeri (Maiden) Kessell & C.A.Gardner
Eucalyptus tetragona (R.Br.) F.Muell. (=Eucalyptus x tetragona) (R.Br.) F.Muell.
Gompholobium scabrum Sm.
Grevillea fasciculata R.Br.
Hakea denticulata R.Br.
Hakea corymbosa R.Br.
Hakea cucullata R.Br.
Hakea denticulata R.Br.
Hakea laurina R.Br.
Hakea victoria J.Drumm.
Isopogon formosus R.Br.
Isopogon trilobus R.Br.
Lambertia inermis R.Br.
Lysinema ciliatum R.Br.
Melaleuca striata Labill.
Melaleuca suberosa (Schauer) C.A.Gardner
Nuytsia floribunda (Labill.) G.Don
Synaphea polymorpha R.Br.
7.2 Appendix 2: Article which appeared in 1st May 2007 edition of “The Whisper” the local Wellstead community newsletter

Honey Possum study at Cape Riche

Shannon Dundas

The Cape Riche area supports diverse flora and fauna which is under threat as a result of an introduced plant pathogen, the cause of _Phytophthora_ dieback. The pathogen affects the roots of susceptible plants preventing them from being able to take up water and nutrients resulting in the eventual death of the infected plant. _Phytophthora_ is spread primarily by the movement of infested soil and water from humans and vehicles. Studies have examined how the pathogen affects plants but we understand very little about how changes due to the death of primary plants in an ecosystem affect fauna.

The honey possum is a small (7 – 12g) marsupial found only in the South West of WA. Despite its name it is not a possum and does not feed on honey but has adapted to feed only on nectar and pollen, usually from Banksias and Eucalypts. It is a unique species with no close relatives. This species is ideal to study the effects of dieback as it relies on a diverse range of plant species to provide food resources through out the year. Many of the food plants preferred by honey possums are extremely susceptible to dieback. With the Centre for Phytophthora Science and Management at Murdoch University and permission from the Department of Environment and Conservation, I am capturing and radio tracking honey possums to determine the effects of _Phytophthora_ dieback on their foraging behaviour. Honey possums are captured in pit fall traps and suitable animals are fitted with tiny (0.35g) radio transmitters. Tagged animals are then tracked at night (as they are nocturnal feeders). Radio tracking honey possums is the primary purpose for this study however other mammals have been captured in the pit fall traps. To date 54 honey possums, 2 Grey bellied dunnarts and 1 Ash grey mouse have been captured as well as a number of small frogs, a gecko and 2 small dugite snakes! If you have any questions or want to know more about my study, please contact me via email at s.dundas@murdoch.edu.au.

Ash Grey mouse (*Pseudomys albocinereus*)

Honey possum with attached radio transmitter

Honey Possum (*Tarsipes rostratus*)
Appendix 3 Glue trials in cool room (5°C)

Methods

To test the effectiveness of seven different glues at 5°C, simulated radio transmitters were created from a small amount of solder and thin pieces of wire. A single piece of fur was used to glue the transmitters onto. The fur was trimmed with scissors prior to application (the method used with applying the radio transmitters to the honey possums) of the simulated radio transmitters. Glue setting time was when the glue adhered the transmitter to the fur.

<table>
<thead>
<tr>
<th>Glue type</th>
<th>Approx. setting time &lt;5 C</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selleys Gel</td>
<td>2 minutes sticky</td>
<td>Thicker consistency, slow to set</td>
</tr>
<tr>
<td></td>
<td>7 minutes setting time</td>
<td></td>
</tr>
<tr>
<td>Selleys liquid</td>
<td>1.5 minutes sticky</td>
<td>Runny consistency, easy to over apply</td>
</tr>
<tr>
<td></td>
<td>3 minute setting time</td>
<td></td>
</tr>
<tr>
<td>Selleys liquid and gel combo</td>
<td>4.5 minutes setting time</td>
<td>Best alternative for ease of use and sticking time</td>
</tr>
<tr>
<td>Locktite Quick Gel</td>
<td>4 minute setting time</td>
<td>Bottle too fiddly to open and dispense</td>
</tr>
<tr>
<td>Locktite Quick Liquid</td>
<td>2 minute setting time</td>
<td>Sticks quickly</td>
</tr>
<tr>
<td>Eyelash adhesive</td>
<td>3.5 minutes sticky</td>
<td>Dries white and does not set at cold temperatures</td>
</tr>
<tr>
<td></td>
<td>5 minutes still not set</td>
<td></td>
</tr>
<tr>
<td>Vetbond</td>
<td>&lt;1 min setting time</td>
<td>Dries very quickly, sets hard within 1 minute but consistency too liquid and transmitter didn’t adhere at all</td>
</tr>
</tbody>
</table>
7.4 Appendix 4 Bycatch

Other small mammals besides honey possums which were captured in pit traps were weighed, ear tagged and measured before being released at the capture point. Reptiles and frogs captured in pit traps were identified then released at point of capture.

Two species of small mammals besides honey possums were captured in pit traps during the study (Table 7.4). Four individual grey bellied dunnart (*Smithopsis griseoventer*) (Figure 7.1 a) were captured on seven occasions and a single ash grey mouse (*Pseudomys albocinereus*) was caught once (Figure 7.1 b). Interesting, neither of these species were captured in the previous fauna survey done in the area (Mercer & Leighton, 1999). Previous fauna surveys were conducted at locations close to the study site for a total of 2 weeks between 1996 & 1997 (Mercer & Leighton, 1999). Pit traps as well as baited Elliott traps and various sized wire cage traps were used and the most commonly trapped species was found to the native bush rat (*Rattus fuscipes*) followed by honey possums (Mercer & Leighton, 1999).

![Image of grey bellied dunnart and ash grey mouse](image)

**Figure 7.1**: (a) *Smithopsis griseoventer* (grey bellied dunnart) and (b) *Pseudomys albocinereus* (ash grey mouse)
Table 7.1: Mammals other than honey possums captured during pit fall trapping during four field trips between January 2007 – November 2007.

<table>
<thead>
<tr>
<th>Animal Id</th>
<th>Species</th>
<th>Season</th>
<th>Sex</th>
<th>Weight (g)</th>
<th>Capture site</th>
<th># Captures</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM1</td>
<td><em>Smithopsis griseoventer</em></td>
<td>Sum &amp; Spr</td>
<td>♂</td>
<td>20.7</td>
<td>S2PA10, S1PA05</td>
<td>2</td>
</tr>
<tr>
<td>SM2</td>
<td><em>Smithopsis griseoventer</em></td>
<td>Sum</td>
<td>♂</td>
<td>20.8</td>
<td>S2PA07</td>
<td>1</td>
</tr>
<tr>
<td>SM4</td>
<td><em>Smithopsis griseoventer</em></td>
<td>Win</td>
<td>♀</td>
<td>17.0</td>
<td>S3PA01</td>
<td>1</td>
</tr>
<tr>
<td>AGM1</td>
<td><em>Pseudomys albocinereus</em></td>
<td>Sum</td>
<td>♀</td>
<td>9.2</td>
<td>S2UA07</td>
<td>1</td>
</tr>
</tbody>
</table>