Impact of wildfire on the spotted-tailed quoll
*Dasyurus maculatus*
in Kosciuszko National Park.

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A spotted-tailed quoll captured in the Jacobs River study area in 2004.

Photo: J. Dawson.
Certificate of Originality

I hereby declare that this submission is my own work and to the best of my knowledge it contains no materials previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at UNSW or any other educational institution, except where due acknowledgement is made in the thesis. Any contribution made to the research by others, with whom I have worked at UNSW or elsewhere, is explicitly acknowledged in the thesis.

I also declare that the intellectual content of this thesis is the product of my own work, except to the extent that assistance from others in the project’s design and conception or in style, presentation and linguistic expression is acknowledged.

James Patrick Dawson

April 2005
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Firstly, I am sincerely grateful for the advice, assistance and support provided by my supervisors, Dr. Andrew Claridge and Dr. David Paull. From the start through to the conclusion of the project Andrew provided ideas, encouragement, enthusiasm and (most importantly) focus. In addition to the many instructive discussions, I am also thankful for Andrew’s company and unique humour that made tramping around the not-insignificant hills of Byadbo and playing with quolls so much fun. I also thank David for his generous time and advice. Above all else however, I will most remember David for his remarkable and inspirational positiveness and encouragement in reassuring me that all was not lost when the same fires that looked to have destroyed the study destroyed his home in Canberra.

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This work was carried out under NSW National Parks and Wildlife Service (NPWS) Animal Ethics Committee Approval No. 020214/05 and NPWS Section 120 Scientific Investigation Licence Nos. A3137 and S11103.
Abstract

A population of spotted-tailed quolls *Dasyurus maculatus* was studied for three years (2002-2004) in the lower catchment of the Jacobs River, in the Byadbo Wilderness Area of southern Kosciuszko National Park, south-eastern New South Wales, Australia. Survey and monitoring of quoll latrine sites and prey populations, dietary analysis and live-trapping was carried out for one year before and two years after the widespread wildfires of January 2003, which had a very high impact on the study area.

Survey for spotted-tailed quoll latrine sites was successful in locating a total of 90 latrine sites in the Jacobs River study area over the three years of the study. These were found throughout all parts of the topography among large, complex granite outcrops and along rocky sections of riparian habitat. After the fire in 2003, lower numbers of latrines were in use than observed pre-fire, and there was a lower level of usage (number of scats) of individual latrines. Continued monitoring in 2004 revealed that many latrines that had become inactive in 2003 following the fire were re-activated in the second breeding season following fire.

1466 spotted-tailed quoll scats were collected from latrines and live-trapped quolls over the three years of the study. Hair analysis from scats identified twenty-two different species of mammal in the diet of the spotted-tailed quoll from the Jacobs River study area, representing the majority of all prey identified (98.5% occurrence) and contributing almost all of the biomass consumed (99.6%). Medium-sized mammals were the most important prey category, followed by small mammals, large mammals (most likely taken as carrion) and non-mammalian prey (birds, reptiles, insects and plants). Brushtail possums were the most important single prey item by both frequency of occurrence and percentage biomass in all years, followed by lagomorphs (rabbits and hares), *Rattus* spp., and swamp wallabies.

There was a significant difference in the composition of the diet by major prey category across the years of the study as a result of the fire, indicated by a shift in utilisation of food resources by quolls in response to significant changes in prey
availability. Monitoring of prey populations revealed that brushtail possums, lagomorphs and bandicoots were all significantly less abundant in the study area in the winter directly following the fire, followed by a significant increase in abundance of lagomorphs, but not of possums, in the second winter after the fire.

Quolls adapted well to this altered prey availability. While there was a significant decrease in occurrence of brushtail possum in scats after the fire, significantly more scats contained hair of lagomorphs, to the point where almost equal proportions of lagomorphs and possum hair occurred in scats by the winter of 2004. Other fire-induced changes to the diet were evident, such as a significant drop in the occurrence of small mammals in scats for both winters after the fire, and a peak in occurrence of large mammals in the winter directly following the fire that strongly suggests there was a short-term increase in the availability of carrion.

A large, high-density population of spotted-tailed quolls was live-trapped and marked during the winter breeding season of 2002. Twenty-two quolls (13 male and 9 female) were present in the study area in 2002, and subsequent trapping over the 2003 and 2004 winter breeding seasons following the fire revealed that the high-intensity wildfire did not result in the extinction of the local population. There was evidence of a small, short-term decline in the number of quolls present in the study area in the 2003 breeding season, with 16 individual quolls captured. Males were outnumbered two-to-one by females, due either to mortality or emigration. Trapping in 2004 showed a recovery of the population to numbers exceeding that observed prior to the fire, with 26 individuals captured (16 male, 10 female), most likely as a result of immigration. There was some evidence that recruitment of young from the post-fire breeding season in 2003 was reduced because of the fire.

This study took advantage of an unplanned wildfire event to monitor the response of a population of spotted-tailed quolls and their prey. In this regard it was fortuitous since it has been recognised that the use of replicates and controls in the study of the impacts of wildfire on such species is likely to be logistically impossible. Consequently, the effects of fire on forest and woodland fauna such
as the spotted-tailed quoll are poorly understood, with many authors expressing concern that, potentially, wildfires are likely to be highly detrimental to resident quoll populations. The results of this study, however, concur with the few other studies in which forest mammal populations have been monitored before and after wildfire in suggesting that wildfires may not be as destructive to fauna as that imagined. The results of this work will provide information to assist in the preparation of management strategies for the species, such as recovery plans, as well as information for land managers preparing management plans, including fire management plans, for habitats in which spotted-tailed quolls are found throughout their range.
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Chapter 1: Introduction

1 Introduction

1.1 Context

This thesis describes the survival and recovery from wildfire of a population of spotted-tailed quolls *Dasyurus maculatus*. The spotted-tailed quoll, like much of the fauna of Australia’s forests and woodlands has, until relatively recently, received little attention from researchers (Lunney 1991, Körtner *et al.* 2004). There are still many gaps in our knowledge of the basic ecology of Australia’s forest fauna and the effects of fire are poorly understood and have not been quantified for most animals (Recher 1991, 2004). As such, this study aims to provide the first information on the impact of wildfire on the spotted-tailed quoll, adding one more important piece to our understanding of the response to disturbance of forest fauna in general. It also examines the latrine ecology of the spotted-tailed quoll, describes in detail the changes brought by fire to the diet of the species in an unusual habitat – dry rain-shadow woodland – and discusses the impacts of the wildfire on the local population of quolls and their prey in the Byadbo Wilderness Area of southern Kosciuszko National Park.

The spotted-tailed quoll is a medium-sized, cryptic marsupial carnivore of eastern Australia (Edgar and Belcher 1995). As a result of two centuries of European influence all populations throughout the entire range of the species, including the two recognised subspecies *D. m. maculatus* (south-eastern Australia) and *D. m. gracilis* (northern Queensland) are now listed as threatened on the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act) (DEH 2004). Field-based study of the spotted-tailed quoll has always been problematic due to the species cryptic nature and preference for forest and woodland habitats in remote and rugged areas (Belcher and Darrant 2004). As a result, the distribution, biology and ecology of the species is relatively poorly known, and only recently have targeted studies been published that begin to examine the diet, demographics and habitat utilisation of this enigmatic marsupial (Belcher 1995, 2003; Burnett 2001; Belcher and Darrant 2004; Körtner *et al.* 2004).
Remaining habitat for the spotted-tailed quoll continues to be variously under pressure from intensification of both land-use and/or land management (Jones et al. 2003; Long and Nelson 2004). On freehold land, clearing for agricultural production and the expansion of residential development is resulting in the shrinking and fragmentation of large forested areas (Jones et al. 2003; Long and Nelson 2004). By default, publicly managed conservation reserves and areas retained for timber production are now those places that mainly provide the requisite habitats for the species in areas large enough to support sustainable populations. Within these publicly owned lands there is growing pressure for more intensive management, often for the purpose of protection of private interests on adjoining lands. The control of introduced feral animals such as wild dogs, foxes, pigs and cats through the widespread use of poisons such as 1080 is undertaken primarily for the protection of stock and pasture on neighbouring private land, resulting in potential threats for the spotted-tailed quoll in these areas (Belcher 1998, 2003; McIlroy 1999; Körtner et al. 2003; DEH 2004; Murray and Poore 2004). The potential impacts of the use of 1080 on populations of the spotted-tailed quoll have only started to be addressed through targeted research relatively recently (e.g. Körtner et al. 2003). The increased use of fire as a management tool on both public and private land is an ongoing issue, exacerbated by recent large scale destructive wildfires over the last decade, and yet there is no published research on the effect of fire on the spotted-tailed quoll. Consequently it is now recognised that there is a need to understand the effects of fire on the spotted-tailed quoll and its habitat, food resources and den sites to provide information for adjustment of current conservation management practices for the species (Jones et al. 2003).

1.2 Original design and aims

This study was originally conceived to investigate the diet and use of latrines (specific communal defecation sites) by a population of spotted-tailed quolls in the Byadbo Wilderness Area, in southern Kosciuszko National Park. At the outset of the project the major aims were to:

i. identify habitat features that could assist in the prediction of occurrence
of quoll latrine sites at the landscape level, using field survey and analysis within a geographic information systems platform. In practice, this would have involved analysis of a randomly selected sample of sites by topographic position, aspect and substrate;

ii. investigate aspects of latrine use by the spotted-tailed quoll within the study area through observations of use and analysis of spacing of latrines within the landscape, with further reference to known home ranges of individual quolls;

iii. describe the diet of the spotted-tailed quoll in the dry rain shadow woodland habitat of the Jacobs River area through the collection of scats from live-captured animals and from latrine sites, and;

iv. investigate patterns of distribution of medium-sized mammalian prey of the spotted-tailed quoll throughout the study site by use of spotlighting surveys and indices derived from ground-based activity plots.

The initial field season, during winter 2002, was very successful in locating numerous latrine sites and a large population of the spotted-tailed quoll in the Jacobs River area of Kosciuszko National Park. This established the viability of the project, providing the following information relevant to the original aims outlined above:

i. location of a large number of active latrine sites;

ii. data on use of latrines from scat counts over the winter breeding season;

iii. information on the winter diet of the quolls living in the study area;

iv. data on abundance and distribution of key medium-sized mammalian prey from activity plots;

v. a census of the population of spotted-tailed quolls occupying the study area during the 2002 breeding season.
Chapter 1: Introduction

1.3 Fire and its impact on the original project objectives

Starting in late December 2002 and continuing until early February 2003, extensive wildfires burnt across much of south-eastern NSW, north-eastern Victoria and almost all of the ACT. In Kosciuszko National Park alone approximately 450,000 hectares, or almost 70% of the reserve, was impacted by fires of varying severity (DEC 2004). On 30 January 2003 a fire that had originally started in Victoria on 8 January, reached the Jacobs River study area on a day of extreme fire weather (P. Zylstra, DEC, personal communication 2003). The resulting very high intensity wildfire resulted in complete removal of ground cover and canopy across almost the entire study area, and the destruction of large numbers of hollow-bearing trees, dramatically altering the habitat. Significant mortality of fauna, evidenced by numerous burnt carcasses, was one obvious result of the fire (J. Dawson, personal observation).

Initially it was feared that the extreme impact of the fire may have resulted in the loss of the local study population of spotted-tailed quolls. While this ultimately proved unfounded, the fire did have an impact on the original intent of the project in a number of ways. In relation to the aims stated above, these limitations were:

i. a lack of information on ‘negative’ or non-latrine sites in the pre-fire habitat to compare to the known positive latrine sites. This effectively precluded any analysis of prediction of location of latrine sites within the study area;

ii. lack of data on distribution and abundance of arboreal prey within the study area, particularly of brushtail possums *Trichosurus* spp. This affected my ability to examine the relationship between prey in diet and availability in an unburnt environment.

The magnitude of the fire was such that it had an unknown affect on quoll behaviour, resulting in an inability of the stated aims of the project to realistically discern whether the patterns subsequently observed were typical or a product of the fire.
1.4 Final project objectives

As a result of the fire the primary aims of the study were revised. In doing so, I attempted to stay as close as possible to the original objectives, while remaining cognisant of the impact of the fire on the habitat and the likely impacts on populations of both quolls and their prey. The aims of the project were amended to:

i. enumerate and broadly describe features and attributes of latrines within the study area pre- and post-fire, including reference to topographic position and substrate;

ii. investigate the impact of wildfire on latrine use through comparison of scat counts pre- and post-fire;

iii. describe quoll diet in dry rain shadow woodland habitat through analysis of scats collected from latrines and live-trapped animals, and to compare the diet pre- and post-fire;

iv. investigate the impact of the fire on prey resources within the study area by comparing results of spotlighting surveys and indices derived from ground-based activity plots in unburnt and burnt habitat. Estimates of pre-fire abundance of arboreal prey were derived from surveys undertaken at nearby unburnt sites of similar habitat within the Byadbo Wilderness; and

v. describe the size and structure of the quoll population within the study area over three winter breeding seasons, including comparison of results from before and after the fire.

1.5 Thesis structure

The following chapter (Chapter 2) provides a review of existing literature, including general information and detailed descriptions of latrine use, diet and population biology of the spotted-tailed quoll. In addition, Chapter 2 reviews the literature on the use of latrines by carnivores more broadly, as well as investigating the available information on the effect of fire on mammalian fauna
in Australia. Chapter 3 describes the climate, geology, vegetation and fire history of the study area, and also provides descriptive information on the fires of 2003 that are the subject of this work. Chapters 4, 5 and 6 present methods, results and discussion relating to fieldwork undertaken as part of this study over the three consecutive winter breeding seasons from 2002 to 2004. Chapter 4 describes the patterns of usage of latrines by quolls within the Jacobs River study area and discusses the changes that resulted following the fires. Chapter 5 details the diet of quolls in the study area and examines the differences between years pre- and post-fire in relation to concurrent changes in prey availability. Chapter 6 describes the size and structure of the quoll population within the study area in each of the three winter breeding seasons and compares the results from the year prior to the fire to the two years after. Finally, Chapter 7 presents a general discussion of the findings presented in the three previous chapters before assessing what work is further required in obtaining a greater understanding of the effect of fire on the spotted-tailed quoll.
2 Literature Review

This chapter provides background information on the spotted-tailed quoll including aspects of the species ecology relevant to this study, such as diet, latrine use and population biology, and response to disturbance by fire. In addition, illustrative examples from the species’ congeners and ecological equivalents in the order Carnivora are presented to provide context for the study. Latrine use by carnivores is examined with a focus on the role latrines play in social organisation and communicative function of populations. The effect of fire on mammalian fauna is also examined in this chapter, with emphasis on studies on the impact of different fire regimes (wildfires, controlled burning) on carnivores, both native and introduced.

2.1 General information on the spotted-tailed quoll

2.1.1 Description

The spotted-tailed quoll (also referred to as the spot-tailed quoll, tiger quoll, tiger cat or native cat) is one of the most striking and recognisable of all Australian animals, yet surprisingly few people have ever seen one or are even aware of their existence. Of the four species of quoll occurring in Australia, the spotted-tailed quoll is the largest and only member of the genus Dasyurus still extant in south-eastern mainland Australia (Edgar and Belcher 1995). A detailed description of appearance and morphological characteristics of the species is given by Jones et al. (2001).

2.1.2 Taxonomy and conservation status

As previously mentioned, two sub-species of the spotted-tailed quoll are currently formally recognised; D. m. maculatus that occurs in the south-east of the mainland and in Tasmania, and the smaller D. m. gracilis that is found only in northern Queensland (Edgar and Belcher 1995) (Figure 2.1). Recent genetic research into the phylogenetic relationships between extant populations of the
spotted-tailed quoll suggests a review of taxonomy may be warranted (Firestone et al. 1999). This research has determined that the southeast mainland and Tasmanian spotted-tailed quoll populations form two distinct evolutionarily significant units (ESU) and should perhaps be considered separate sub-species, while the genetic differences between *D. m. gracilis* and *D. m. maculatus* indicate that they should be treated as different management units within the same ESU (Firestone et al. 1999).

This information has most recently been used in a review of the conservation status of the spotted-tailed quoll under the Commonwealth EPBC Act. This legislation now administratively recognises the south-eastern mainland population of *D. m. maculatus* as distinct from Tasmanian populations of *D. m. maculatus*, until formal taxonomic revision is recognised through publication (DEH 2004). Subsequently, *D. m. maculatus* south-eastern mainland population is now listed as endangered and *D. m. maculatus* Tasmanian population is listed as vulnerable under the EPBC Act (DEH 2004). *D. m. gracilis* remains listed as endangered under the EPBC Act.

The conservation status of the spotted-tailed quoll varies between the States and Territories in which it is either known to be extant or considered to be extinct (Table 2.1). It is interesting to note that the listing under Commonwealth legislation is at a higher level of threat (endangered), than occurs in the majority of States.

Unless otherwise specified, references to the spotted-tailed quoll in this thesis refer to the species as a whole and are inclusive of identified sub-specific distinctions.
<table>
<thead>
<tr>
<th>State</th>
<th>Listing</th>
<th>Legislation</th>
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</thead>
<tbody>
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<td>Vulnerable</td>
<td>Threatened Species Conservation Act 1995</td>
</tr>
<tr>
<td>Queensland</td>
<td>Vulnerable</td>
<td>Nature Conservation Act 1992</td>
</tr>
<tr>
<td>ACT</td>
<td>Threatened</td>
<td>Nature Conservation Act 1980</td>
</tr>
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<td>Rare</td>
<td>Threatened Species Protection Act 1995</td>
</tr>
<tr>
<td>South Australia</td>
<td>Endangered (presumed extinct)</td>
<td>National Parks and Wildlife Act 1972</td>
</tr>
</tbody>
</table>

Table 2.1: Conservation status of the spotted-tailed quoll at State and Territory level

2.1.3 Distribution

The spotted-tailed quoll once ranged throughout south-eastern Queensland, eastern NSW, Victoria, south-eastern South Australia and Tasmania, including islands in Bass Strait (Figure 2.1; Mansergh 1984; Maxwell et al. 1996). The distribution extended along both sides of the Great Dividing Range and it has been suggested that at the western edge of the distribution the species is likely to have been limited to areas receiving greater than 600 mm annual rainfall (Mansergh 1984; Edgar and Belcher 1995). It should be noted however, that the population described in this study occurs in an area where the mean annual rainfall is only 583 mm (Pulsford et al. 1993).
In terms of the influence of broad scale environmental factors, distribution of spotted-tailed quolls in Tasmania correlates closely with areas of highly predictable seasonality of rainfall (Jones and Rose 1996). It has also been suggested that distribution is confined to areas of high rainfall in Queensland and Victoria (Mansergh 1984; Burnett 1993).

The distribution of the species has contracted considerably since European settlement and remaining populations are highly fragmented (Mansergh 1984; Edgar and Belcher 1995). Reviews into the extant distribution of the spotted-tailed quoll have been undertaken at the national scale (Mansergh 1984; Maxwell et al. 1996; Jones et al. 2001; DEH 2004) and within most jurisdictions.
within the species’ historic range (Mansergh 1984; Green and Scarborough 1990; Watt 1993; Jones and Rose 1996; ACT Government 2003; Backhouse 2003). The species is now thought to be most abundant in Tasmania and parts of north-eastern New South Wales (Mansergh 1984; Maxwell et al. 1996; Jones et al. 2001). Spotted-tailed quolls have always been rarely observed in Victoria and no population or density estimates are available for that State (Mansergh 1984; Backhouse 2003). Spotted-tailed quolls occur at low densities throughout their range in south eastern Queensland (Watt 1993). An extant population in the Australian Capital Territory was only confirmed in mid-2003 from surveys for latrines (ACT Government 2003).

The only published estimate of current total population size suggests that numbers do not exceed 10,000 and may be as low as 5,500 (Jones et al 2003). Unfortunately, the species’ widespread distribution, cryptic nature, solitary habits, large home range and the lack of an efficient and effective survey methodology means that such broad scale assessments are speculative. Ultimately this has resulted in a lack of systematic and comprehensive broad scale survey data, more of which is required, particularly within NSW (Maxwell et al 1996; DEH 2004). It is highly likely that current assessments significantly underestimate the distribution and abundance of the species throughout its range. The northern sub-species of the spotted-tailed quoll is now restricted to six small, fragmented populations in tropical rainforest in northern Queensland (Figure 2.1; Burnett 1993, 2001; Maxwell et al. 1996).

2.1.4 Habitat

The spotted-tailed quoll is a highly adaptable species that has been recorded in a wide variety of vegetation types ranging from closed forest, wet and dry tall open forest, woodland, coastal heath, riparian areas and even open pasture (Watt 1993; Edgar and Belcher 1995). This adaptability is evident in the fact that records of the species are known from sea level to above the tree line, with altitudinal range extending above 1600 metres in New South Wales (Edgar and Belcher 1995; Green 2002). Spotted-tailed quolls have been recorded to
approximately 1000 metres in Tasmania (Green and Scarborough 1990), and 1100 metres in Victoria (Backhouse 2003).

The spotted-tailed quoll is often described as being most common in, or having a ‘preference’ for, wet forest habitat (Green and Scarborough 1990; Watt 1993; Jones and Rose 1996; Maxwell et al. 1996; Burnett 2001; Jones et al. 2001; Backhouse 2003). This is certainly true in northern Queensland where the species is now restricted entirely to high elevation tropical wet forest (Burnett 2001). In south-eastern Australia, however, the spotted-tailed quoll is frequently recorded in dry open forest and woodland habitat on the western fall of the Great Divide and rain shadow areas to the east of the Divide (Mansergh 1984; Belcher 1995, 2000b; Maxwell et al. 1996; Reside 1997). For example, the dry rain shadow woodland habitat of the upper Snowy River area is among those areas with the highest frequencies of spotted-tailed quoll records in Victoria (Mansergh 1984). The species has also been reported from dry coastal heathlands and steep areas with naturally little vegetation cover (Green and Scarborough 1990; Jones et al. 2003). The ability of male animals to move over large distances can result in them being recorded in ‘non-typical’ habitats such as heathland, coastal dunes, farmland and outer urban residential areas bordering on forested land (Backhouse 2003).

Historically the spotted-tailed quoll was recorded well out onto the western slopes of the ranges in areas dominated by dry open forest and woodland (Alexander 1980). Broad scale clearing and fragmentation of this habitat for agricultural production has reduced the extent of these habitats, yet the spotted-tailed quoll is still patchily distributed in New South Wales as far west as the Warrumbungle Ranges (Maxwell et al 1996). Interestingly, strong spotted-tailed quoll populations inhabit the white box Eucalyptus albens- white cypress pine Callitris glaucephylla alliance that occurs throughout the Snowy River Valley in Kosciuszko and Snowy River National Parks of NSW and Victoria respectively (Mansergh 1984; this study). This vegetation type contains many components found in semi-arid lands west of the Divide (Pulsford et al 1993). Clearing for cropping and grazing throughout this part of the species’ range has likely led it
to be most commonly recorded currently along the ranges, escarpment and coastal strip where rainfall is higher and vegetation is taller and more closed.

The apparent catholic preference for habitat indicates that the spotted-tailed quoll is a habitat generalist with a preference for structural complexity. Within the landscape quolls are often linked with structural habitat features that provide a complexity of den, latrine, foraging and other opportunities for the individual and their prey (Alexander 1980; Watt 1993; Edgar and Belcher 1995; Belcher 1995, 2000b; Oakwood 2000). This includes areas containing structural features including a dense overstorey, abundant rock outcrops, large hollow bearing trees, rocky escarpments or fallen logs (Backhouse 2003). For example, the highest density of northern quolls *Dasyurus hallucatus* is found in rocky habitats (Oakwood 2000). Areas with a high density of mammalian prey are also utilised (Belcher 2000b; Backhouse 2003).

Based on limited radio-tracking studies, it has been suggested that within occupied areas spotted-tailed quolls may use drainage lines, gullies, flats, and escarpments for movement through the landscape, hunting and denning opportunities, and saddles for crossing between catchments (Belcher 2000b). It is also suggested that spotted-tailed quolls avoid mid-slopes, although why this might be so is not clearly elucidated (Belcher 2000b).

2.1.5 Threats

The causes of apparent decline in distribution and abundance of the spotted-tailed quoll have recently been reviewed at national level (Jones et al 2003; Long and Nelson 2004). The wide range of threats acting on the species at a range of spatial and temporal scales can be broadly categorised as:

*Removal and degradation of habitat*

Clearing of habitat for agricultural intensification and expansion, and for urban development is considered the greatest threat to the spotted-tailed quoll across its range (Long and Nelson 2004). In addition to the removal of habitat,
fragmentation of remaining areas may increase the magnitude of other threats such as persecution by humans, road mortality and predation or increased competition with domestic and introduced predators (Watt 1993; Jones et al. 2003). Habitat degradation, either through forestry practices or regular use of low-intensity burning is also likely to reduce the suitability of habitat for the species, particularly in relation to availability of den sites and prey, although these impacts are yet to be clearly quantified (Catling 1991; Belcher 2003);

*Impacts of introduced species*

The fact that quolls share forest and woodland habitats with larger carnivores, in particular dingoes *Canis lupus dingo* and wild dogs *Canis familiaris*, foxes *Vulpes vulpes* and cats *Felis catus*, raises the question of predatory or competitive interaction. Currently, most of the discussion surrounding this issue is speculative, with few reported instances of predation (Green and Scarborough 1990; Jones et al. 2003; Körtner et al. 2003) and only a few diet studies to suggest competition for prey resources (Belcher 1994; Molsher 1999). As such, research to quantify the threat of introduced predators is identified as a specific objective in recent national reviews of management for the species (Jones et al. 2003; Long and Nelson 2004).

*Direct human-induced mortality*

Interactions between spotted-tailed quolls and humans are unfortunately most often deleterious to the marsupial carnivore. Direct killing of quolls occurs largely as a result the species’ habit of raiding poultry houses (Fleay 1948; Green and Scarborough 1990; Burnett 1993; Watt 1993). There is much debate over the impact on spotted-tailed quolls of poison baiting programs for introduced predators, particularly dogs and foxes. Research into the susceptibility of the species to the poison sodium monofluoroacetate, or compound 1080 (McIlroy 1981), suggests that, theoretically at least, wild quolls are at risk from the majority of baiting programs undertaken in south-eastern Australia (Green and Scarborough 1990; Watt 1993; Belcher 1998; Belcher 2000b; DEH 2004). However, circumstantial evidence and theoretical
speculation is contradictory, with some sources suggesting significant impacts at the population level (Belcher 2000a, 2003; Glen and Dickman 2003b) while others report persistence and even high density populations in areas with a long history of poison baiting (Fleming 1996; Körtner et al. 2003). Experimentally, studies have focussed largely on the issue of potential impact through examination of uptake of non-toxic baits (Belcher 1998; Glen and Dickman 2003a; Murray and Poore 2004), with only three studies looking at the impact of poison fox and dog baits on spotted-tailed quolls in wild populations (Körtner et al. 2003; P. Cremasco, unpublished data; G. Körtner, unpublished data). These studies appear to indicate that the actual impact of poison baiting programs may not realise the theoretical impact although, obviously, far more work is required to clarify this contentious issue (Long and Nelson 2004).

Road mortality accounts for many spotted-tailed quolls in some areas (Green and Scarborough 1990; Jones and Rose 1996; Long and Nelson 2004). The large home ranges of spotted-tailed quolls, particularly males (Belcher and Darrant 2004; Claridge et al. 2005), make them susceptible in forested areas fragmented by roads, and their propensity to scavenge road-killed carcasses may increase this threat (Green and Scarborough 1990; Jones 2000; Jones et al. 2003; Long and Nelson 2004).

2.2 Latrine use by carnivores

2.2.1 Internationally

Olfactory communication between carnivores aids in the maintenance of complex social structures between individuals (Gorman and Trowbridge 1989). Scent marks are an effective form of communication at night or in dense vegetation, remaining active for long periods of time in the absence of the producer, a quality useful in solitary, large ranging carnivores (Gorman and Trowbridge 1989).

Latrines occur where faeces accumulates over time at discrete sites (Gorman and Trowbridge 1989). Repeated excretion of faeces and urine at specific,
prominent locations such as latrines aids distinction between simple functional excretion and communication through scent-marking (Kleiman 1966; Macdonald 1985). Although some studies have identified a latrine by the location of a single scat (e.g. Kruuk and Jarman 1995), presence of multiple scats of varying ages at a site is more likely to designate a latrine by providing evidence of repeated use over time, and use by multiple individuals (Kruuk 1978). For the purposes of this study the definition of a latrine has been adopted from Begg et al. (2003) from their detailed study of scent marking behaviour of the honey badger *Mellivora capensis*, as:

‘A common or communal defecation site containing signs of at least two independent visits’.

In a detailed study of scent-marking behaviour of honey badgers in southern Africa, Begg et al. (2003) described a range of scent-marking behaviours utilised at latrine sites. These included defecation, urination, anal dragging, squat marking, body rubbing, and scratching and rolling. Eurasian badgers *Meles meles* have been recorded using squat marking, defecation and digging and scuffing at latrines (Kruuk 1978; Stewart et al. 2002). Latrine use by the Sulawesi palm civet *Macrogalidia mosschenbroekii* and the Malay civet *Viverra tantalunga* has been reported in Indonesia, while African civets *Civettictus civetta* defecate at latrines, often referred to as ‘civeties’ (Wemmer and Watling 1986; Wemmer 2001).

Scent-mark at communal latrines by mustelids is thought to play a role in territorial maintenance and act as information sites for other members of the population (Kruuk 1978; Roper et al. 1993; Stewart et al. 2002; Begg et al. 2003). Scent-marking material, be it faeces, urine or other secretions, is a limited resource requiring investment of time and energy, and as such scent-marks will be distributed so as to increase their chances of discovery by the intended receiver (Gosling 1981; Gorman and Trowbridge 1989). The placement of marks on latrines at visually conspicuous, often elevated, traditionally-used landmarks and areas of frequent use and movement reduces the number of places to be searched and helps disperse their odour, which
suggests that strategic decisions are made about where marks are placed to maximise detection (Gorman and Trowbridge 1989; Begg et al. 2003). The majority of long-term latrines of the honey badger are beside or under trees, prominent visual landmarks in the Kalahari landscape, which are also used as focal sites for resting and foraging (Begg et al. 2003). Eurasian badger latrines are significantly closer to tree trunks and linear features (movement paths or channels) than random samples (Kruuk 1978; Stewart et al. 2002). Brown hyenas *Parahyena brunnea* place most latrines at base of conspicuous trees (Mills et al. 1980). European otters *Lutra lutra* deposit faeces at nose height on top of prominent objects, such as large rocks or tussocks of grass, forming distinct latrine mounds over time along movement trails and at junctions, ensuring regular encounters by other otters (Gorman and Trowbridge 1989). Latrines of river otter *Lontra canadensis* were found to be associated with the waters edge at raised sites (vertical banks, rock formations, beaver *Castor canadensis* bank dens) or at prominent features such as points of land (Newman and Griffin 1994; Swimley et al. 1998). Raccoon *Procyon lotor* latrines are most often found at the base of trees, in raised crotches of trees, and on large logs, stumps, rocks, tree limbs and other horizontally oriented structures (Page et al. 2001).

Not only does placement of latrines at these locations promote detection by the intended receiver, but the feature itself may assist in prolonging the effective working life of the scent mark. For honey badgers and brown hyenas the shade provided by trees also lessens scat desiccation and may prolong the odour value of scent-marks (Mills et al. 1980; Begg et al. 2003). Badger latrines are more likely to be associated with conifers than broadleaf trees, which may increase protection of scent-marks from erosion (Stewart et al. 2002).

Three main hypotheses are suggested to explain the scent-marking behaviours exhibited at latrines by solitary carnivores. Firstly, scent-matching may be used by males for the purpose of maintaining territorial or dominance hierarchies (Ralls 1971; Gosling 1982). Visiting a high proportion of latrines in an area provides an olfactory association between a dominant individual and the
predominant scent mark at latrines, or may signal mate quality to a resident female (Gosling 1982; Rich and Hurst 1999). Secondly, females may advertise reproductive status at latrines for the purpose of attracting mates (Gorman and Trowbridge 1989). Thirdly, use of latrines may assist in the maintenance of spatiotemporal separation of individuals that either have overlapping home ranges or who share territorial boundaries (Clapperton 1989; Begg et al. 2003).

Scent-marking behaviour by the honey badger, including use of latrines, supports the scent-matching hypothesis of male dominance hierarchies (Begg et al. 2003). Larger males can move further and produce more marking material than smaller males and adult males are far more likely to deposit scats at latrines than either females or juvenile males providing long-term signs of latrine use (Begg et al. 2003). Females may use latrines to actively sniff and assess status of males and match dominant scent to dominant male for mating (Begg et al. 2003). Females exhibited low rates of scent marking at latrines, so visitation was unlikely to be for oestrus advertisement, possibly to avoid attracting subordinate males (Begg et al. 2003). Latrine use by the honey badger showed no clear seasonal pattern of use, although peaks of activity were observed within and between latrines over time (Begg et al. 2003).

A peak in latrine use just prior to and during the breeding season is suggested as indicative of a reproductive advertisement function. This has been observed in the northern quoll and may assist males in locating females in oestrus (Oakwood 2002).

Analysis of spatial and temporal patterns of latrine use at the landscape level provides an avenue to investigate communication function. There appear to be two systems that may be employed, and both are used by Eurasian badgers – hinterland latrines defining a core of territory shared by the group, and boundary latrines that are shared by groups and delimit boundaries between neighbouring core group ranges (Roper et al. 1993). Similarly, brown hyenas have latrines at the centres of their territories as well as along borders shared with neighbouring groups (Mills et al. 1980), whereas spotted hyenas Crocuta crocuta defecate at latrines on borders of their group territories (Kruuk 1972). In solitary animals
similar strategies are employed. For example, latrine use by adult male honey坏gers has been defined as a hinterland marking strategy, with clustering oflatrines toward the centre of the home range at some distance from the home range boundary (Begg et al. 2003).

2.2.2 Australia

Reviews of communication and behaviour of dasyurid species (Croft 1982, 2003; Toftegaard and Bradley 2003) have tended to ignore or overlook the use and function of latrines as a key aspect of the biology and ecology of the quolls. This is somewhat surprising, as latrine use by carnivorous marsupials in Australia has been described for several species.

Repeated defecation at communal latrines, and indeed other scent-markingbehaviours less conspicuous to humans, has been reported for most of thelarger dasyurids. The use of latrines has been reported for 4 species: thespotted-tailed quoll (Belcher 1995; Kruuk and Jarman 1995; see section 1.2.3below), western quoll or chuditch *Dasyurus geoffroii* (Serena and Soderquist1989; Soderquist and Serena 1994), northern quoll (Oakwood 2002), andTasmanian devil *Sarcophilus laniarius* (Pemberton 1990). The only other largedasyurid extant in Australia, the eastern quoll *Dasyurus viverrinus* is not known to use latrines (Jones and Rose 2001). There is no information on latrine use orotherwise for the two other quolls found in New Guinea, the bronze quoll*Dasyurus spartacus* and the New Guinea quoll *Dasyurus albopunctatus*.

Latrine sites of the larger dasyurids appear to have associations with structuralfeatures of their habitats. Latrines of the western quoll have been recorded along trails and on logs fallen across rivers or lying on the forest floor (Serenaand Soderquist 1989). Studies of the northern quoll have revealed latrines onprominent locations such as on rock piles, boulders and termite mounds(Oakwood 2002). Tasmanian devils use a system of latrines located on paths orcreek crossings (Pemberton 1990).

Single scats are deposited in the landscape in addition to aggregations of scats
on latrines. Aggregations on well-developed latrines of the western quoll comprise 5-25 scats (Serena and Soderquist 1989), while latrines of the Tasmanian devil contain as many as 46 scats on each (Pemberton 1990). Latrines are used year round in all of these animals, however the rate of deposition of scats appears to vary between these species. Scats are deposited at an even rate throughout the year at latrines used by western quolls (Soderquist and Serena 1994), whereas latrine use by the northern quoll peaks during the mating season (Oakwood 2002). It is suggested that latrines and other scent marking behaviours act as signposts for male northern quolls seeking mates (Oakwood 2002).

The use of latrines in these species is likely to be part of a complex olfactory communication system as yet unexplained in the carnivorous marsupials (Serena and Soderquist 1989; Kruuk and Jarman 1995). In both the Tasmanian devil and the western quoll scats are deposited in places where animal movements are likely to be concentrated such as paths and river crossing points, ensuring maximum detectability by conspecifics (Serena and Soderquist 1989; Pemberton 1990). Cloacal dragging, resulting in deposition of clear liquid on the substratum, is another example of scent marking behaviour at latrines (Serena and Soderquist 1989). Information relating to territoriality, social rank, reproduction or resource utilisation are the likely scenarios for use of latrines by mammalian carnivores (Kruuk and Jarman 1995).

2.2.3 Latrine use by the spotted-tailed quoll

Among the larger carnivores of eastern Australia, native and introduced, the use of latrines by the spotted-tailed quoll appears to be a unique habit (Belcher 1995; Kruuk and Jarman 1995). Foxes and dogs, while using scent to mark their habitat, do not use latrines (Macdonald 1980). Latrine use by cats has been reported in one study (Molsher 1999), although this was considered a rare occurrence for the study and the two latrines located were assumed to be visited by a single adult female cat in each case, and therefore was not a communal defecation site. Latrines of the spotted-tailed quoll are specific sites
where groups of animals urinate and defecate over time, often resulting in bleaching of the substrate and accumulation of scats (Belcher 1995; Kruuk and Jarman 1995). Activity at latrines includes sniffing of scats, defecation, urination and rubbing the cloacal area on the substrate, usually rock (Belcher 1994; Kruuk and Jarman 1995; Claridge et al. 2004).

In the wild, scats of the spotted-tailed quoll are identifiable by a combination of size, shape, smell, composition and locality (Triggs 1996). They are often deposited on latrines, are twisted and cylindrical in shape, 3-10 cm in length, have a distinctive oily smell, contain hair and bones of prey, and may also contain hair ingested while grooming (Kruuk and Jarman 1995; Triggs 1996). Detection of grooming hairs through detailed analysis provides definitive identification, as difficulties in attributing single scats to the spotted-tailed quoll have been noted (Belcher 1995; Triggs 1996). Although it has been suggested that up to 40% of scats contain grooming hairs (Belcher 1995), most studies to date indicate that the figure is far lower, meaning that this method should not be overly relied on for identification (Alexander 1980; Boschma 1991; Belcher 1995).

For a species such as the spotted-tailed quoll that is difficult to study because of its highly cryptic nature, latrines provide valuable focal points for investigations into distribution, diet, habitat, population structure, and management (Alexander 1980; Belcher 1995, 2000b, 2003; Kruuk and Jarman 1995; Murray et al. 2000; Burnett 2001; Claridge et al. 2004). Latrines are found in a range of topographic locations and have been recorded on features including rock outcrops, cliffs, rocky riverine environments, tracks, roads and large logs (Alexander 1980; Boschma 1991; Belcher 1995, 2000b; Kruuk and Jarman 1995; Burnett 2001). Latrines tend to occur in prominent locations on flat, horizontal surfaces, usually on top of large boulders, on bedrock, and at both the top and base of cliffs (Belcher 1995; Kruuk and Jarman 1995). In these situations latrines are also visually conspicuous to humans, as vegetation such as algae and lichens is bleached and rubbed off rocks in patches, a result of frequent urination and cloacal dragging (Boschma 1991; Kruuk and Jarman.
1995). This bleaching can cover up to 2 m\(^2\) of the surface of the rock (Kruuk and Jarman 1995).

Populations of spotted-tailed quolls use latrines over long periods of time, with two studies describing use of individual latrines over a period of at least 3 years (Belcher 1995; Kruuk and Jarman 1995). Latrines are used year-round although some studies suggest a peak of usage in winter (Alexander 1980; Belcher 1994). The number of scats found on each latrine varies, both between and within sites (Alexander 1980; Belcher 1995; Kruuk and Jarman 1995). Where topographical features provide protection from the elements large accumulations may occur. In excess of 250 scats were collected over a two and a half year period from a single latrine protected from the prevailing weather by suitable aspect and an overhang (Belcher 1995). Smaller accumulations up to 15 scats have been recorded from exposed latrines (Alexander 1980), with a mean of 4 scats per latrine recorded in a study of 51 latrine sites (Kruuk and Jarman 1995). Where latrines are exposed to the elements, particularly in riverine habitats or even in hot and humid conditions, the possibility of scat loss from weather is high. Despite this the animals appear to persist in their use of a particular site as shown by the re-establishment of latrines in a rocky gorge within a month of being cleaned off by flooding (Kruuk and Jarman 1995).

In areas with high density populations of spotted-tailed quolls and numerous rock outcrops, cliff lines or rocky creek lines, latrines may also occur at high densities (Kruuk and Jarman 1995). One study recorded 51 latrines (including single scat locations) in rocky gorge country in the New England area of New South Wales, including 29 separate latrines over a 500 m section of rocky riparian habitat, with up to five latrines in a single 25 m section of gorge (Kruuk and Jarman 1995).

Interestingly, in Tasmania use of latrines by spotted-tailed quolls is not a feature of all populations. Latrine use has not been recorded in wetter areas such as Cradle Mountain National Park, but latrines are used by spotted-tailed quolls in drier, coastal habitats in the east of the State, such as Freycinet National Park.
Using trapping or remote photography, multiple spotted-tailed quolls have been recorded visiting a single latrine over time (Kruuk and Jarman 1995; Belcher 2003; Claridge et al. 2004.). This adds evidence to the conclusion that use of latrines by the spotted-tailed quoll appears to be an important aspect of the species’ social behaviour and a communication function is likely (Belcher 1994, 2000b; Kruuk and Jarman 1995). While no study has yet attempted to examine this communication function in detail, individual observations have been made that may point to communication through latrines by spotted-tailed quolls. For example, the lack of latrines in the vicinity of dens, has led to the suggesting that individual spotted-tailed quolls do not scent mark their dens (Watt 1993; Kruuk and Jarman 1995). It has also been suggested that spotted-tailed quoll latrines are not associated with territorial boundaries (Kruuk and Jarman 1995), although, in that particular study, no radio-tracking was undertaken to quantify home range. A further suggestion is that communication at latrines of spotted-tailed quoll relates to social status between individuals in overlapping home ranges, causing sub-dominant animals to avoid each other (Kruuk and Jarman 1995). In addition the deposition of urine at latrines may convey information about the receptivity of females and a ‘system’ of latrines could be used to inform the solitary suitors, although this hypothesis was not supported by the observation of a lack of seasonal peak in latrine use in concert with the annual reproductive cycle (Kruuk and Jarman 1995). While these observations are useful, closer study is required to reveal the real nature of this form of scent-marking behaviour.

2.3 Diet of the spotted tailed quoll.

The spotted-tailed quoll is a solitary, opportunistic predator of predominantly vertebrate prey (Settle 1978; Alexander 1980; Belcher 1995; Jones 1997). Few studies have targeted the diet of wild spotted-tailed quolls (Alexander 1980; Boschma 1991; Belcher 1995, 2000b; Jones and Barmuta 1998, Burnett 2001).
Previously, information was only available on food preferences of captive animals (Fleay 1932; Troughton 1954; Settle 1978) or more general descriptions of diet from small sample sizes (Settle 1978; Green and Scarborou h 1990; Kruuk and Jarman 1995).

Spotted-tailed quolls are active, individual hunters, killing by leaping onto prey and killing with a powerful crushing bite to the base of the skull or on top of the neck (Fleay 1932; Troughton 1954; Green and Scarborough 1990; Jones 1997). Skinks and other small prey are captured by pinning them with their front paws (Green and Scarborough 1990), while larger prey such as pademelons and small wallabies are leapt upon and grappled with, with bites delivered to the neck area (Green and Scarborou h 1990; Jones 1997).

Information on the diet of wild populations of the spotted-tailed quoll comes from analysis of scats collected either from live-trapped animals (Jones and Barmuta 1998; Belcher 2000b, Burnett 2001), or from scats collected at latrine sites (Alexander 1980; Boschma 1991; Belcher 1995; Kruuk and Jarman 1995; Burnett 2001). These two collection measures provide differing opportunities to interpret results. Collecting scats from latrines gives access to large samples of scats and a good overall picture of diet at the population level (e.g. Burnett 2001). Collecting from trapped animals yields less scats but allows comparative analysis of diet between age-sexes classes (Jones and Barmuta 1998; Burnett 2001). Belcher (1995) measured diameter of scats collected from latrines in an attempt to distinguish differences in diet between adult and juvenile spotted-tailed quolls, although the validity of this measure must be questioned due to lack of information on food consumption of wild animals and overlaps in body size and weight between juvenile males and adult females (Jones and Barmuta 1998; Burnett 2001; Belcher 2003).

Spotted-tailed quolls are primarily a predator of medium-sized mammals (500 – 5000 grams) (Edgar and Belcher 1995). When information is provided to the species level principal prey items in the diet include ringtail possum *Pseudocheirus peregrinus*, brushtail possums (common brushtail possum *Trichosurus vulpecula* and mountain brushtail possum *Trichosurus caninus*),
greater glider *Petauroides volans*, or rabbit *Oryctolagus cuniculus* (Alexander 1980; Belcher 1995, 2000b). Although this reliance on one or two medium-sized mammal species appears to be consistent across diet studies, different habitats provide different primary prey resources. In tall wet forests of the escarpment and ranges of southern NSW greater gliders occur at high densities and subsequently dominate diet of the spotted-tailed quoll (Belcher 2000b). In contrast, quolls inhabiting a mix of dry woodland, wet forest and open habitats in north-east Victoria have been found to rely on rabbits and brushtail possums (Belcher 1995). This ability to target the most abundant medium-sized mammals in a given area or habitat type highlights the adaptability of the spotted-tailed quoll. Large mammals, particularly the swamp wallaby *Wallabia bicolor*, also form a significant component of diet and in one study this species was the most frequently occurring prey item (Boschma 1991). While it is assumed that dietary items larger than small wallabies are scavenged (Jones et al. 2001) a significant proportion of diet is comprised of large mammals, including kangaroos *Macropus* spp., wallabies, wombats *Vombatus ursinus* and domestic stock (Alexander 1980; Boschma 1991; Belcher 1995, 2000b; Jones and Barmuta 1998).

Spotted-tailed quolls utilise a high diversity of mammalian prey (Jones et al. 2001). Mammals of all sizes are consumed with at least 20, and up to 29 mammals identified to species level from diet studies (Alexander 1980; Boschma 1991; Belcher 1995; Burnett 2001). Arboreal mammals are well represented with up to six arboreal species recorded in the diet from a single area (Alexander 1980, Belcher 1995). Spotted-tailed quolls have been shown to be significantly arboreal (Jones and Barmuta 2000) and are able to hunt for and catch arboreal prey during the day by climbing trees and entering hollows to search for food (Alexander 1980; Belcher 2000b). This strategy has been shown to be particularly important in areas with high dietary overlap with other carnivores (Belcher 1994; Jones and Barmuta 2000).

In addition to medium- and large-sized mammals, the diet of the spotted-tailed quoll also includes insects, crayfish, lizards, snakes, birds, poultry, small
mammals, frogs, fish, plant material and scavenged rubbish (Alexander 1980; Jones et al. 2001). Analysis of contribution to diet by biomass reveals that these items are of relatively low overall importance (Belcher 1995, Jones and Barmuta 1998). Plant material in scats has been assumed to be incidentally ingested (Jones et al. 2001).

Differences in diet have been observed between sexes, seasons and areas although no strong pattern is evident across studies. In Tasmania, male and female spotted-tailed quolls were shown to have significantly different diets in summer but not winter, but there were no differences within sexes according to season (Jones and Barmuta 1998). In summer males were most reliant on medium- and large-sized mammals, whereas females consumed mostly small mammals and birds (Jones and Barmuta 1998). This contrasts with findings from the southern tablelands of New South Wales where no difference was found between the diet of males and females, although it should be noted that no seasonal comparison was available from this study (Belcher 2000b). Differences between areas, i.e. from geographically separate latrine sites, have been demonstrated, but may be attributable to small sample sizes (Belcher 1995). Size range and diversity of prey is similar on the mainland and in Tasmania (Jones 1997).

2.4 Population biology of the spotted-tailed quoll

Information on the demographics, morphometrics, breeding success and sex ratios of wild populations is sparse (Belcher 2003; Körtner et al. 2004). Data from intensive, long-term field studies of populations of the spotted-tailed quoll can provide relatively reliable information on size, structure and dynamics of populations, as well as body size, breeding characteristics and longevity of individuals (Belcher 2003; Körtner et al. 2004). This type of information can also provide information of the impact of current management practices on spotted-tailed quoll populations, particularly where conservation management is required (Belcher 2003; Körtner et al. 2004).
2.4.1 Reproduction

Most information on the reproductive biology of the species comes from early observations of captive animals (Fleay 1940; Settle 1978). A recent detailed review of the species (Jones et al. 2001) summarises knowledge from these captive studies and provides correlation with observations of wild populations. These studies describe seasonal breeding, with mating and births occurring over the winter months of June to August (Fleay 1940; Settle 1978; Lee et al. 1982). Seasonal, rather than synchronous, breeding provides the opportunity for widely roaming males to mate with more than one female (Belcher and Darrant 2004). Timing of reproduction in winter is suggested as coinciding with peak food availability for females at the time of greatest food stress in late lactation, and the period of greatest food availability for juveniles when they become independent 18 weeks after birth in late spring (Belcher 1995; Jones et al. 2001).

Following a 21 day gestation period, litters of between 4-6 young (mean 5.38) are born in late July to mid-August (Fleay 1940; Settle 1978; Belcher 2003). Females have 6 teats in two curved rows within a pouch that opens anteriorly (Fleay 1940). At birth young measure 7 mm in length and grow steadily, enabling age of pouch young to be accurately estimated from measurement (Fleay 1940; Green and Scarborough 1990). Young are carried in the pouch, attached to the teat for about 8 weeks, after which time they may be left in the maternal den while the mother is hunting (Fleay 1940; Green and Scarborough 1990). At 18 weeks of age the young are fully independent (Edgar and Belcher 1995).

Levels of juvenile mortality in wild populations are poorly understood, with few studies of other than captive animals following litters through to weaning and beyond. In captivity juvenile survival is high, and weaning of complete litters is common (Brad Walker, Featherdale Wildlife Park, Sydney, personal communication 2002). Low juvenile: adult ratios observed in wild populations
may be a result of either low reproductive success despite high pouch litter size, or high juvenile mortality rates (Belcher 2003). It has been suggested from one study that the period between leaving young in den and weaning (8-18 weeks) resulted in mortality of 50% from 4 wild litters (Belcher 2003).

Total lifetime reproductive output is low (Jones et al. 2003). Females are sexually mature at 12 months of age and have been recorded breeding from one to four years old in wild populations (Fleay 1940; Belcher 2003). In small, fragmented or otherwise threatened populations this low lifetime fecundity may affect rates of population recovery and possibly result in more rapid decline (Jones et al. 2003).

2.4.2 Demography

Sex ratios

Reports of surveys and reviews of database records and museum specimens of the spotted-tailed quoll have often described a disproportionate number of male to female quolls (Fleay 1940; Mansergh 1984; Green and Scarborough 1990; Watt 1993; Belcher 2003; Körtner et al. 2004). Males are caught more frequently in traps and nearly all animals killed on the road or in chicken coops are male (Jones et al. 2001). This contrasts with the observed sexual parity of litters born in captivity and in the wild (Fleay 1940; Settle 1978; Burnett 2001). Conclusions based on these observations include that males numerically exceed females in wild populations, or that males of the species are far more trappable than females (Fleay 1940; Settle 1978; Green and Scarborough 1990).

In contrast, most targeted trapping undertaken over larger temporal and spatial scales show a decreased tendency for sex biases in populations (Jones and Barmuta 1998; Burnett 2001; Belcher 2003). As discussed below, male spotted-tailed quolls occupy large, overlapping home ranges and females are likely to be intrasexually territorial (Belcher and Darrant 2004; Claridge et al. 2005). Surveys undertaken at small scales are therefore likely to encounter
more males than females, and a ratio of 5:1 (M:F) has been suggested as normal in a female territory (Belcher 2003).

Age/sex classes

As described above, growth rates of spotted-tailed quolls in the pouch is relatively well understood from museum specimens and captively bred litters (Fleay 1940; Settle 1978; Green and Scarborough 1990). More recently, several longer term, larger-scale studies have been undertaken throughout the range of the species that have described the morphological characteristics of age classes of both sexes from field observations of trapped animals (Jones and Barmuta 1998; Burnett 2001; Belcher 2003; Körtner et al. 2004).

Marked sexual dimorphism is evident, with adult male weight double that of adult female weight (Jones 1997; Körtner et al. 2004). While smaller males have a gracile build similar to that of adult females, males are significantly heavier than females in all corresponding age classes (Green and Scarborough 1990; Jones and Barmuta 1998; Belcher 2003). Descriptions of the weight ranges for male and female spotted-tailed quolls vary considerably, particularly maximum weights. While males have been attributed maximum weights up to 7 kg and females 4 kg (Settle 1978; Edgar and Belcher 1995), these weights are markedly higher than those observed in most studies. Descriptions of males exceeding 5 kg are rare (Watt 1993; Green and Scarborough 1990) with mean adult weight reported as between 2.81 kg and 4.55 kg (Watt 1993; Belcher 2003; Körtner et al. 2004). A trend is evident in these studies that correlates increasing sample size with decreasing mean weight for males (Green and Scarborough 1990; Watt 1993; Jones 1997; Belcher 2003), indicating that at the population level males are likely to be smaller than some of the literature suggests. Adult female weights range from 1.2 kg to 2.5 kg, although a female of 3.0 kg has been reported (Green and Scarborough 1990). Mean weights for females range from 1.52 kg to 2.0 kg (Green and Scarborough 1990; Jones 1997; Belcher 2003; Körtner et al. 2004).

Age estimation of individual spotted-tailed quolls is taken from a combination of
date of capture, sex, body weight, shape, condition, tooth wear and tooth loss (Jones and Barmuta 1998; Belcher 2003; Körtner et al. 2004). In general, males are described as juvenile/sub-adult up to one year of age (maximum weight 1.2 – 1.6 kg) and adult thereafter, although they continue to grow. Males attain full weight at three years and may live up to five years old at which time body weight and condition has deteriorated, including increasingly broken and worn canine teeth (Belcher 2003; Körtner et al. 2004). Females similarly are considered juvenile/sub-adult up to one year old at which time they weigh between 0.7 and 1.0 kg. They may approach adult body weight at the end of the first year and reach maximum final adult weight at around 2 years, remaining stable up to a possible maximum age of five years (Jones and Barmuta 1998; Belcher 2003; Körtner et al. 2004).

Spatial organisation

Spotted-tailed quolls are principally solitary animals that hunt and den alone, although den sharing during mating has been observed in the breeding season (Watt 1993; Belcher and Darrant 2004). Studies to-date point to the use of latrines as focal points for communication, and home range configurations that partition the landscape for females, which in turn drives male distribution (Belcher 1994; Kruuk and Jarman 1995; Belcher and Darrant 2004; Claridge et al. 2005).

From the few radio-tracking studies completed it appears that females occupy exclusive territories throughout the year of between 250 and 500 hectares (Burnett 2001; Belcher 2003; Belcher and Darrant 2004; Claridge et al. 2005). Natal philopatry is suggested by the capture of juvenile and sub-adult females in adult female home ranges (Belcher and Darrant 2004). Overlap between home ranges of neighbouring females has been observed (up to 24% shared territory) and it has been suggested that this occurs between related females (Belcher and Darrant 2004).

Males have very large home ranges that overlap extensively both with other males and females (Belcher and Darrant 2004; Körtner et al. 2004; Claridge et
al. 2005). Home range estimates for males vary widely depending on the timing and duration of observation, and the method used to calculate area. Estimates range from 875 hectares for brief tracking studies (3-4 days) (Watt 1993), up to almost 6500 ha for longer-term studies (1-2 years) (Belcher and Darrant 2004). During the breeding season (May-August) males move back and forth between the territories of a number of females with overnight movements of >6 km recorded and longer-term movements of up to 30 km recorded (Belcher 2000b, 2003; Jones et al. 2003; Belcher and Darrant 2004; Claridge et al. 2005). This is likely to enable individual males to monitor the onset of oestrus of females within their territory (Belcher 2003).

The spatial and social organisation of the spotted-tailed quoll largely determines the number of individuals and sex ratios (Belcher 2003). The distribution of prey and mates may influence spatial organisation and may affect the sexes differently, with females depending on prey resources for rearing of young and males influenced by distribution of breeding females (Belcher and Darrant 2004). The defence of exclusive territories by females in order to secure food resources during the time of greatest nutritional stress limits the numbers of females that occur over a given area of suitable habitat (Belcher 2003). At any given location males would be expected to be captured more frequently due to their large overlapping home ranges and this is borne out in most studies (Fleay 1932; Settle 1978; Watt 1993; Belcher 2003). Belcher (2003) suggested a ratio of 5:1 (males: females) for any one site in a female’s territory. With home range size ratios of males and females being at least 3:1, and perhaps as high as 8:1 in some areas (Belcher and Darrant 2004), sexual parity in terms of numbers is easily achievable at the landscape level.

2.5 Effect of fire on fauna

Despite the fact that fire is a key ecological process in the Australian landscape, the level of understanding of the effect of fire on fauna in general is variously acknowledged as being poorly known, inadequate, limited, or fragmentary (Friend 1993; Bradstock et al. 1995; Williams and Gill 1995; Parr and Chown
While conservation agencies have the protection of biodiversity as one of their major goals, the dearth of information on the effect of fire on fauna limits the extent to which the use of fire as an ecosystem management tool is predictable such that any potentially undesirable outcomes (detrimental impacts on fauna) can be avoided (Williams and Gill 1995; Parr and Chown 2003). There are multiple objectives for the use of fire, including conservation, but most often fire is used to protect human life and for protection and enhancement of natural resources exploited or harvested by humans such as timber, water, or pastures (Catling 1991; Bradstock et al. 1995). Notably, European culture in Australia tends to emphasise the dangers of burning and the destructiveness of fire to its material possessions (Nicholson 1981). This contrasts vividly with the symbiotic relationship often suggested for the indigenous inhabitants, being that fire was maintained by aborigines and that aborigines were maintained by fire (Nicholson 1981). Increasingly, frequent low-intensity fires are being used in an effort to prevent the occurrence of uncontrolled wildfire under the assumption that wildfire is detrimental, not just to human life and property, but also to fauna, a belief that may be born from the fact that high-intensity wildfires kill many forest animals in their path and low intensity burns do not (Catling 1991). However, studies of the effects of fire on some species and their habitats indicate that in the long-term wildfires are not the bogey imagined and emphasise change to the fauna rather than destruction (Newsome et al. 1975; Fox 1982).

The remainder of this section summarises the available knowledge on the effect of fire, both wildfire and control burning, on fauna in Australia, with particular emphasis on carnivores and the mammalian prey most likely to be eaten by the spotted-tailed quoll.

2.5.1 Effect of fire intensity

Fire regimes affect many forest fauna, including rare and threatened species, arboreal (tree-dwelling) species, folivores, omnivores and insectivores (Williams and Gill 1995). Variation in fire frequency, season, intensity and the area of
forest burnt influences the availability and quality of habitat, and the responses of fauna will vary, perhaps significantly, depending on the timing (season) and the natural variability of habitat in the locality for the species of concern (Williams and Gill 1995). Studying the impact of fire on individuals is essential to establish mortality rates, refuge sites, and behavioural responses to fire (Sutherland and Dickman 1999).

The influence of wildfire in altering habitat structural complexity, and its consequent effect on fauna, is particularly noteworthy. Habitat structural response to wildfire has been studied in one long-term study from Nadgee Nature Reserve in coastal far-south NSW (Newsome et al. 1975; Coops and Catling 2000; Catling et al. 2001). The immediate effect of intense wildfire is the complete removal of ground cover and shrub cover, loss of hollow-bearing trees and logs, and removal or thinning of the canopy (Newsome et al. 1975; Inions et al. 1989; Coops and Catling 2000; Catling et al. 2001). In the longer-term however, high intensity fires increase structure and all features increase in cover over time, with canopy and shrub cover reaching a maximum approximately 12 years after the fire, providing suitable habitat for many animal species (Inions et al. 1989; Catling 1991; Catling et al. 2001). On the other hand, frequent low intensity fires appear to reduce forest structure, by reducing shrub cover (Catling 1991).

Evidence indicates that survivorship rates from fire by fauna is mainly a function of fire intensity (Suckling and Macfarlane 1984). Mortality of even highly mobile animals such as horses Equus caballus, kangaroos and wallabies can be substantial for high intensity wildfires, with charred carcasses providing dramatic evidence of immediate mortality (Heislers 1974; Newsome et al. 1975; Suckling and Macfarlane 1984; Walter 2003). Small and medium-sized terrestrial mammals and arboreal species may also suffer significant mortality in high-intensity fire events (Recher et al. 1974; Newsome et al. 1975; Russel et al. 2003). Charred remains of these mammals including Antechinus spp., ringtail and brushtail possums, and rabbits can be found in intensely burnt areas immediately after the passage of the fire (Heislers 1974; Newsome et al. 1975;
Despite this apparent carnage, monitoring of fauna following even extreme wildfire events has repeatedly demonstrated that representatives of all functional groups survive the immediate impact of fires (Heislers 1974; Newsome et al. 1975; Vernes 2000; Russell et al. 2003; Green and Sanecki in press). Some species or faunal groups do better than others. Burrowing mammals such as the wombat and rabbit may survive intense wildfire well, protected from the direct impact of the flame by well insulated earth (Newsome et al. 1975). Gullies and drainage lines can also serve as refuges during wildfire events for a range of species (Newsome et al. 1975; Lunney 1987).

Immediate mortality of animals is much reduced for fires of lesser intensity (Suckling and Macfarlane 1984; Thompson et al. 1989; Catling 1991; Vernes 2000). Perhaps the best study of behavioural response of animals to fire showed that direct mortality of woylie *Bettongia penicillata* and tammar wallaby *Macropus eugenii* during experimental burns was very low (Christensen 1980). This study appears to be the only study to monitor the response of individual animals to the threat of fire, in this case a moderate experimental burn. Radio-collared animals did not leave their home ranges, remaining in daytime resting places until the last minute when they left and moved in front of the flames until they found an unburnt patch and refuge under a log or other structure. If no suitable patches were located before the animal was forced to leave its home range, an animal would double back through the flames to the safety of burnt ground (Christensen 1980).

For individual animals that survive the immediate threat to life posed by fire of any sort, the world has changed in the post-fire environment and may include a new suite of threats. Considerable mortality can be experienced for animals in post-fire environments as a result of starvation and an increased likelihood of predation (Christensen 1980; Newsome et al. 1983; Suckling and Macfarlane 1984; Russell et al. 2003). High home range fidelity causes some species to remain in burnt areas, where they may be exposed to higher levels of predation (Christensen 1980; Thompson et al. 1989). In one example, 12 common
Ringtail possums were radio-tracked at the time of a wildfire near Sydney in 1994 (Russell et al. 2003). Seven possums were killed by the fire and the remaining five were depredated within 2 months by foxes and cats. It is interesting to note that an increased predation threat following fire is unlikely to be uniform across all mammal species, even those living in the same habitats and areas. Northern bettongs *Bettongia tropica* had complete survival from fire and negligible post-fire predation by dingoes in one study in northern Queensland, whereas red-legged pademelon *Thylogale stigmatica* appeared to suffer increased predation following the same fire (Vernes 2000).

Trends for many mammalian species following wildfire indicate immediate post-fire declines but regeneration subsequently to levels well beyond those prevailing pre-fire (Newsome et al. 1983; Catling 1991). Re-colonisation of intensely burnt areas is rapid for some mammal species but others may require periods of between 20 and 40 years for total recovery (Suckling and Macfarlane 1984). Within four years of one wildfire in central western Victoria, kangaroo and wallaby populations had returned to levels similar to those present pre-fire, whereas possum populations remained low (Heislers 1974). For some carnivores, fire-opened habitats may have increased the availability and vulnerability of prey (Newsome et al. 1983).

A range of behaviours may assist the long-term survival of animals living in areas affected by fire. Again, the work of Christensen (1980) is most informative, showing that persistence of both woylies and tammar wallabies was achieved by either partial reorganisation of home range, total relocation of home range, or surviving to reproduce on the burnt area. This lack of stereotypical response is undoubtedly of value to any population, particularly where the situation in each fire is different and the results vary enormously (Christensen 1980).

Long term studies show that individual wildfires may not realise the perceived threat to fauna, as new habitats are generated by high-intensity fires, which may be lost through the use of frequent cooler burns (Catling 1991). The results of monitoring response of vertebrate fauna populations following severe wildfire
at Nadgee Nature Reserve emphasise change to the fauna rather than destruction (Newsome et al. 1975). For example, response and recovery of small mammal populations is not uniform across species. Immediate declines in rodent populations may be followed by marsupials a year later and populations may remain low for several years (Recher et al. 1974; Newsome et al. 1975; Fox 1982; Newsome et al. 1983; Lunney et al. 1987). However, a successional recovery of small mammal populations follows an individual fire, with species entering regenerating habitats as their requirements for food and shelter are met (Fox 1982, 1990). In a study from Myall Lakes National Park in coastal New South Wales, species reached peak abundance in the following order after fire (years in brackets): house mouse *Mus musculus* (1), New Holland mouse *Psuedomys novaehollandiae* (1), common dunnart *Sminthopsis murina* (4), brown antechinus *Antechinus stuartii* (5), bush rat *Rattus fuscipes* (7) (Fox 1990).

There has been increasing concern about the impact of a combination of fire occurrences, or fire regime, on fauna. The fire regime best suited to the biota may differ widely from that best suited to fire protection (Gill 1981). Modelling of individual species’ likely responses to different fire regimes highlights the influence of a given regime on habitat structure (Catling 1991). Under a long-term fire regime of high intensity and low frequency it would be expected that native species would be reduced in abundance immediately after each intense fire but would recover quickly in the first few years as the understorey grew rapidly (Catling 1991). Introduced species would invade or increase in abundance for a short time while native species were scarce and the understorey open (Catling 1991). A range of responses is expected for mammalian species to different fire events and regimes (Table 2.2).
### Table 2.2: Expected responses to different fire regimes of carnivores and other mammian fauna most likely to be eaten by the spotted-tailed quoll. Species included based on occurrence in diet of spotted-tailed quoll in other studies (Alexander 1980, Boschma 1991, Belcher 1995) and likelihood of occurrence in the Byadbo Wilderness. Categorisation of response to low-intensity prescribed burns after Catling (1991). Categorisation of response to wildfire summarised from Recher et al. (1974), Newsome et al. (1975), Newsome et al. (1983), Lunney et al. (1987), Fox (1990), and Catling et al. (2001). * Introduced species.

#### 2.5.2 Fire, quolls and other carnivores

The impact of fire on wild populations of the spotted-tailed quoll, be it uncontrolled wildfire or low-intensity hazard reduction burning, is largely unknown. To date no detailed experimental or observational studies have been published. Fleay (1940), speculated that “following the widespread fires of 1939 numbers of spotted-tailed quolls have probably declined”, and it has been suggested that small and isolated populations of spotted-tailed quolls may be particularly vulnerable to stochastic events such as fire (Backhouse 2003; Belcher 2004; Burnett and Marsh 2004). These views appear to be based on

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<th>Frequent, low-intensity prescribed fire</th>
<th>Individual high-intensity wildfire</th>
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<td><strong>Disadvantaged</strong></td>
<td><strong>Advantaged</strong></td>
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<td>Short-term recovery (&lt;2 yrs)</td>
<td>Long-term recovery (&gt;2 yrs)</td>
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<td><em>D. maculatus</em></td>
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<td><em>P. peregrinus</em></td>
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<td><em>T. vulpecula</em></td>
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<td><em>H. chrysogaster</em></td>
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<td><em>O. anatinus</em></td>
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| *T. vulpecula*                         | *T. vulpecula*                      |
| *V. ursinus*                           | *T. caninus*                        |
| *M. rufogriseus*                       | *P. peregrinus*                     |
| *M. giganteus*                         | *P. breviceps*                      |
| *A. agilis*                            | *P. volans*                         |
| *R. fuscipes*                          | *C. nanus*                          |
| *W. bicolor*                           | *A. swainsonii*                     |
| *P. fumeus*                            | *A. pygmaeus*                       |
| *C. l. domesticus*                     | *P. australis*                      |
the assumption that spotted-tailed quolls will be adversely affected by wildfire.

The use of frequent low-intensity burns for property protection and wildfire suppression has been suggested as being detrimental to the spotted-tailed quoll due to simplification of forest structure and potential for burning-off to decrease availability of den sites, alter population dynamics, prey availability and subsequent fecundity of quoll populations (Catling 1991; Watt 1993). Recent reviews of threats to the species have acknowledged a need to understand the effects of fire regimes, including frequency, intensity and spatial patterns of burning on habitat structure, food resources and den sites of the spotted-tailed quoll (Backhouse 2003; Jones et al. 2003; Long and Nelson 2004).

Review of studies on other dasyurids in relation to fire provides some context for the present study. The impact of fire, both periodic intense fires and annual burning, on the northern quoll has been relatively well studied compared with the other larger marsupial carnivores in Australia (Begg et al. 1981; Oakwood 2000; Woinarski et al. 2004). The study of Begg et al. (1981) is perhaps most relevant to the current study as it monitored the effect of a single high-intensity fire (crown fire, spotting, whirlwinds) across several habitat types, the majority of which contained significant rocky elements. Flame heights reached 20 metres in parts and intensity was measured up to 17000 kWm\(^{-1}\), figures that relate to high-intensity late season burns in tropical forests. Northern quolls did not suffer from increased mortality immediately after the fire, nor did the numbers of animals known to be alive decrease over the subsequent year, a trend evident in three other small mammal populations being monitored. Furthermore, no differences in body weight were noted, and there was no measured change in habitat usage. The only discernable effects of the fire on the population of northern quolls was in the reproductive cycle, with a delay of approximately one month in the breeding season and a lower mean weaning rate, a factor offset by high female survival. Begg et al. (1981) concluded that northern quolls were less affected by the fire because of a wide habitat tolerance, broad diet and relatively high mobility.
Fire can also be detrimental to these smaller quoll species in much the same ways as for the majority of their prey. Alteration of fire regimes and consequent homogenisation of habitat may have played a role in the arid zone extinction of the western quoll (Johnson and Roff 1982), while extensive fires increase vulnerability of northern quolls to predators by removing vegetative cover and destroying hollow logs and trees that are used for shelter, possibly combined with increased predator abundance (Oakwood 2000; Jones et al. 2003). In this way, fire has been implicated in the broad scale decline of the northern quoll in savannah habitats through the removal of understorey vegetation (Oakwood 2000; Jones et al. 2003). It appears that the impact of fire on the northern quoll may not be uniform across its range as one recently published study suggested that the species appears to prefer or at least tolerate a moderate frequency of fire (Woinarski et al. 2004). In the only other study relating fire and quolls, the frequency of capture of eastern quoll decreased significantly over two trapping periods 2 and 6 years after a cool burn in a Tasmanian dry sclerophyll forest (Driessen et al. 1991).

Information on the effect of fire on larger carnivores in Australia is available from the long-term study of the impact of extensive wildfires at Nadgee Nature Reserve in far south-east New South Wales in 1972 (Newsome et al 1975; Newsome et al. 1983; Catling et al. 2001). Fire appeared to have no immediate impact on dingo populations, and numbers of dingoes peaked about 12 years after the fire in association with increased populations of larger macropods in more open habitat, until habitat complexity had been restored (Newsome et al. 1983; Catling et al. 2001). Dingoes changed their basic diet from small mammals before the fire to macropods afterwards (Newsome et al. 1975).

Declines in numbers of foxes and cats were observed following the same fire, most likely due to a decline in numbers of small mammals (Newsome et al. 1975). The response of foxes to wildfire did not appear to be related to either time since fire or habitat complexity, suggesting other variables as the major influence (Catling et al. 2001). Cats were in medium abundance before the fire and fell to low abundance immediately after (Catling et al. 2001). Cats
responded linearly to time since fire and increased faster in habitats of higher complexity over time, presumably because of increasing availability of small and medium-sized prey.

Dingo, fox and cat are considered likely to be advantaged by frequent low-intensity fire through increased accessibility of land and a reduction in refuge sites for their prey (Catling 1991). It is interesting to note that Catling (1991) has categorised two quoll species occurring in south-eastern Australia as being likely to be disadvantaged by this fire regime. While an increased vulnerability to predators may be a real threat for the small eastern quoll, the larger spotted-tailed quoll appears to be little affected by predation from dogs or foxes (Catling and Burt 1995; Jones et al. 2003). In a summary of studies on diet of wild canids in south eastern Australia, the spotted-tailed quoll occurred as a dietary item in only 2 of 16 studies on diet of wild dogs and 2 of 15 studies of fox diet at an overall mean of 0.1% occurrence in the diet of both predators (Mitchell 2003). On the other hand, one recent study of spotted-tailed quolls in northern New South Wales attributed the death of five individuals to predation by either dogs, foxes or other quolls (Körtner et al. 2004). Of course, impacts of these larger predators may be wider than predation alone, with competition for resources, killing a result of interspecies aggression, and temporal or spatial exclusion from habitat other possible impacts (Jones et al. 2003).
3 Study Area

3.1 Location

This study was undertaken within the Byadbo Wilderness Area of southern Kosciuszko National Park, south-eastern New South Wales, Australia. The Byadbo Wilderness covers an area of approximately 100,000 hectares and is bounded in the south by the Victorian border, the west by the Snowy River and in the north and east by privately owned, predominantly agricultural grazing lands (Figures 3.1 and 3.2).

The main focus of the work reported in this study was undertaken in the far north-west corner of Byadbo in the ‘Jacobs River study area’. This area is approximately 35 kilometres SSW of the town of Jindabyne along the Barry Way. The Jacobs River study area covers an area measuring approximately 5 x 7.5 kilometres (3750 hectares) (Fig 3.2). Elevation ranges from just below 300 m near the confluence of the Jacobs River and the Snowy River, up to 900 m at the Wallace Craigie Lookout in the north-east of the study area. It is centred on the lower reaches of the Jacobs (or Tongaroo) River and its major tributaries, Ingebirah Creek and Thatchers Mountain Creek. The study area also includes sections of the catchments to the immediate east and south, namely Bark Camp Creek and Feltons Creek respectively. The Jacobs River, Bark Camp Creek and Feltons Creek all flow directly into the Snowy River. In addition to the Jacobs River study area described above, this study included survey and examination of sites across the wider Byadbo Wilderness. Other areas which specific work was undertaken were Devils Hole (spotlighting, scat collection from latrines) and Paupong (spotlighting) (Figure 3.2).
Figure 3.1: Location of the Byadbo Wilderness Area, containing the Jacobs River study area, in Kosciuszko National Park, south-eastern New South Wales, Australia.
3.2 Climate and Geology

The climate of Kosciuszko National Park is principally governed by weather systems that move from west to east (DEC 2004). The climate of the lower Snowy River valley, and Byadbo as a whole, is dominated by the rain-shadow created by its proximity to the Great Dividing Range which rises directly to the west. The range captures most of the moisture-laden air from the prevalent westerly air stream resulting in a dramatic rain-shadow effect (DEC 2004). Mean annual rainfall is only 583 mm, with a slight peak in early summer (Costin 1954; Pulsford et al. 1993). Temperature ranges across the year illustrate the strongly seasonal climate, with mid-summer means of 24°C dropping to mid-winter means of 7°C (Costin 1954). Snow and severe frosts are rare occurrences in winter (Costin 1954).
The geology of the study area is dominated by Devonian granites, mostly granodiorite (Hancock 1972). This low fertility parent material produces coarse-grained, highly erodible soils including grey-brown podsolics, brown podsolics and colluvial brown earths (Costin 1954; Pulsford et al. 1993). The topography is characterised by step, well-drained slopes and extensive sheet erosion is apparent on the hot and dry north westerly aspect slopes (Costin 1954; Pulsford et al. 1993). One result is the occurrence of many rock outcrops ranging from boulder strewn slopes to massive, complex outcrops that are locally common throughout the Jacobs River study area and other sections of the Byadbo Wilderness.

### 3.3 Vegetation

The location of the lower Snowy River valley in the rain-shadow of the Great Dividing Range produces conditions favourable to a locally unique habitat more typical of the semi-arid slopes and plains to the west of the Great Divide (Pulsford et al. 1993). The habitat falls within the white box *Eucalyptus albens* – white cypress pine *Callitris glaucophylla* tall woodland alliance described by Costin (1954) that extends through the middle section of the Byadbo Wilderness along the Snowy River Valley and continues south into Alpine National Park across the Victorian border. This alliance includes several dry woodland associations that occur within the study area, described in greater detail below.

The deeply incised landscape of the Jacobs River study area lies 15 kilometres east of the Great Divide. This proximity and steepness of landscape provide sharp altitudinal and climatic gradients, in turn influenced by aspect, resulting in a locally diverse vegetation community (Pulsford et al. 1993). In the valley floors and lower slopes below about 650 metres, white cypress pine occurs in association with white box (Pulsford 1991). The composition and structure of this community in terms of both dominant canopy species and presence of shrubs in the understorey varies with changes in elevation and aspect, and several separate woodland associations types have been recognised (Costin 1954). In general white cypress pine dominates the lower elevation, warmer aspect slopes, while white box is more prevalent as
elevation increases and on cooler aspect slopes (Costin 1954). Understorey is largely absent from the hot aspect, lower elevation white cypress stands, while grasses (predominantly *Stipa* and *Poa* spp.) and a sparse shrub layer (*Cassinia longifolia, Bursaria spinosa*) occur in the understorey of cooler aspect slopes.

Above about 600 metres the vegetation community present in the Jacobs River area changes with increasing elevation (Costin 1954). The white box-white cypress pine community grades into a band of Yellow Box *Eucalyptus melliodora* open woodland with a sparse grassy and shrubby understorey, including *Exocarpus cupressiformis, Brachychiton populneus, Acacia implexa, Acacia melanoxylon, Xanthorrhoea australis, Bursaria spinosa, Cassinia longifolia, Chrysocephalum semipapposum, Senecio quadridentatus, Poa sieberiana, Poa meionectes, Chionochloa pallida* and *Danthonia linkii*. On the upper slopes and ridges of the study area, above about 800 m, mealy bundy *Eucalyptus goniocalyx* open forest with a grassy understorey appears. Above about 950 meters this community is replaced in turn by a tall mixed open forest community dominated by mountain gum *Eucalyptus dalrympleana*, broad-leaved peppermint *Eucalyptus dives*, candlebark *Eucalyptus rubida* and snow gum *Eucalyptus pauciflora* that extends north across the higher elevation tablelands away from the Snowy River valley.

### 3.4 Fauna

In contrast to the well studied alpine habitats that occur less than 30 kilometres to the west (see Newsome and Catling 1979; Newsome *et al.* 1983; Green and Osborne 1994), the low elevation woodlands of the Snowy River valley in the south-eastern section of Kosciuszko National Park are poorly surveyed in regards to fauna. Few targeted fauna surveys have been undertaken in the large expanse of the Byadbo Wilderness Area (see Reside 1997). That said, the white box-cypress pine alliance has long been recognised as rich in animal communities that include most of those species present in wet and dry forest vegetation (Costin 1954). Most of the fauna records represented in the Atlas of NSW Wildlife maintained by the NSW Department of Environment and Conservation come from incidental observation of park workers.
or travellers passing through the lower Snowy River valley along the Barry Way between Buchan in Victoria and Jindabyne in New South Wales. This study therefore provides a valuable opportunity to improve the understanding of the mammal fauna of this unique habitat through analysis of the prey utilised by one of the top order predators in the system, the spotted-tailed quoll. A list of those mammal species recorded on the Atlas of NSW Wildlife is included as Table 3.1.

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platypus</td>
<td>Ornithorhynchus anatinus</td>
</tr>
<tr>
<td>Echidna</td>
<td>Tachyglossus aculeatus</td>
</tr>
<tr>
<td>Brown antechinus</td>
<td>Antechinus stuartii</td>
</tr>
<tr>
<td>Spotted-tailed quoll</td>
<td>Dasyurus maculatus</td>
</tr>
<tr>
<td>Long-nosed bandicoot</td>
<td>Perameles nasuta</td>
</tr>
<tr>
<td>Wombat</td>
<td>Vombatus ursinus</td>
</tr>
<tr>
<td>Common ringtail possum</td>
<td>Pseudocheirus peregrinus</td>
</tr>
<tr>
<td>Mountain brushtail possum</td>
<td>Trichosurus caninus</td>
</tr>
<tr>
<td>Common brushtail possum</td>
<td>T. vulpecula</td>
</tr>
<tr>
<td>Eastern grey kangaroo</td>
<td>Macropus giganteus</td>
</tr>
<tr>
<td>Wallaroo</td>
<td>M. robustus</td>
</tr>
<tr>
<td>Red-necked wallaby</td>
<td>M. rufogriseus</td>
</tr>
<tr>
<td>Lesser long-eared bat</td>
<td>Nyctophilus geoffroyi</td>
</tr>
<tr>
<td>Eastern false pipistrelle</td>
<td>Falsistrellus tasmaniensis</td>
</tr>
<tr>
<td>Bush rat</td>
<td>Rattus fuscipes</td>
</tr>
<tr>
<td>Black rat</td>
<td>R. rattus</td>
</tr>
<tr>
<td>Brown hare</td>
<td>Lepus capensis</td>
</tr>
<tr>
<td>Rabbit</td>
<td>Oryctolagus cuniculus</td>
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<tr>
<td>Dingo, domestic dog</td>
<td>Canis lupus</td>
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<td>Equus caballus</td>
</tr>
<tr>
<td>Goat</td>
<td>Capra hircus</td>
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</tbody>
</table>

Table 3.1: Mammal species listed on the Atlas of New South Wales Wildlife to December 2004 recorded in the Byadbo Wilderness Area of Kosciuszko National Park. All records of brown antechinus A. stuartii are most likely to be the agile antechinus A. agilis (C. Dickman, USyd, pers. comm.).
3.5 Fire History

The vegetation of Kosciuszko National Park is a complex of vegetation communities that vary not only with altitude, aspect and rainfall, but also fire history, which is a natural and necessary component of these ecosystems (Banks 1989; Leaver 2004). Fire history across the many ecosystems and habitats of the Australian Alps National Parks, of which the Byadbo Wilderness Area is a unique part, has varied greatly both temporally and spatially (Walter 1997). Ecologists and park managers have a vital interest in forest fire histories as man has always used fire as a means of modifying the biota to his needs (Banks 1989).

Pre-European fire history is poorly understood (Nicholson 1981; Banks 1989). Of the little evidence available for eastern NSW it can be summarised that pre-European fire regimes were due to a complex mix of fires started by lightning and fires ignited by aborigines (Brown et al. 1998). Very little can be said about the timing, frequency or intensity of fires in the region, although there are suggestions that fires were less frequent and more intense in forests than woodland habitats, and that aborigines did not appear to burn much in the uplands and wetter forests (Brown et al. 1998).

There is a general pattern of marked increase in fire frequencies with the arrival of European pastoralists and prospectors, followed by a more recent decline with the ascendancy of the conservationist and recreationalist period (Gill 1981; Banks 1989). The fire history, and indeed history of disturbance, of the lower Snowy River valley in which this study was conducted appears to follow a similar pattern (Pulsford et al. 1992). Based on tree ring dating of cypress pines, increased fire frequency corresponded with the arrival of Europeans and their grazing animals in the 1840’s. Fire frequency from then up until 1900 was at about every 6 years (3-11 years), followed by declining frequency from 1910 and a further drop after 1940 (Pulsford et al. 1992).

The Australian Alps is conducive to periodic fire events that may on occasions coincide with ‘blow-up’ days, typically occurring toward the end of long, hot, dry summers (Banks 1989). For example, bushfires in January 1939 ravaged some 3
Chapter 3: Study Area

million hectares between Melbourne and Canberra, including a significant part of the Australian Alps (Banks 1989). Mapping of this, and all subsequent large fire events including the fires of the 2002-2003 summer relevant to this study, has been undertaken for much of Kosciuszko National Park, including the Byadbo Wilderness Area (Zylstra 2004; DEC, unpublished data). This shows that prior to the fires of 2002-2003 the Jacobs River study area had been completely burnt by the 1939 wildfires, and partially affected by fires in 1972-73. Since 1980, however, the only fires in the vicinity of the study area were six small, low-intensity controlled burns along the northern edge for the purpose of protection of neighbouring properties. Another large fire in the Byadbo Wilderness Area in 1987-88 was confined to the southern side of the Snowy River. As such, it can be safely assumed that the Jacobs River study area had been unburnt for 30 years prior to the January 2003 fire. The other areas in which survey was undertaken as part of this study, Devils Hole Creek and Paupong, have both remained unaffected by fire since 1939.

3.6 2003 fire

The fires of January and February 2003 variously affected over 1.5 million ha of land in New South Wales, Victoria, and the Australian Capital Territory (DEC 2004). The fires were started by multiple lightning strikes along the Great Dividing Range in early January 2003 and spread, eventually affecting 465 000 ha, or 67%, of Kosciuszko National Park (DEC 2004). While the area affected was extensive, the severity of the fire was patchy across Kosciuszko National Park (Mansergh et al. 2003).

The severity of the fires was mapped by the Department of Environment and Conservation (NSW) in 2003 on the basis of measuring the impact of the fire on the different vegetation types occurring across the park (Figure 3.3). Impact mapping utilised Landsat imagery, measured by assessing the change of a derived normalised burn ratio (NBR) between images taken pre-fire and post-fire (T. Barrett, DEC NSW, personal communication, 2003). Changes in the NBR are influenced by a decrease in above ground green biomass and vegetation cover, an increased char and consumption of fuels, increase in exposure of mineral soil and ash, a change to
lighter coloured soil and ash, and decreasing moisture content (T. Barrett, DEC NSW, personal communication, 2003).

It should be noted that the resulting fire impact maps are drafts, and do not necessarily infer the absolute intensity of the fire, as the measured impact in different vegetation types may relate to different fire intensities. For example, high fire intensity in the dry rain-shadow woodland of the Byadbo Wilderness may not result in as great a change in the NBR as the same fire in a tall, moist sub-alpine forest. However, within vegetation types a high impact can be correlated with high fire intensity (P. Zylstra, DEC NSW, personal communication 2004).

Five classes of fire impact were identified as a result of the fire impact mapping. These include:

- Very high impact – complete vegetation removal, including complete canopy removal where no leaves remain;
- High impact – total canopy scorch in which browned leaves remain attached;
- Moderate impact – partial canopy scorch, with the upper canopy remaining green;
- Low impact – canopy intact but the understorey burnt; and
- Very low impact – canopy intact and understorey unburnt or low impact (T. Barrett, DEC NSW, personal communication, 2003).
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Figure 3.3: Draft fire impact map of Byadbo Wilderness Area for the 2002-2003 fires. Deep red - very high impact, light red – high to moderate impact, light green – low impact, light blue – no impact. Fire impact map provided by Department of Environment and Conservation (NSW), 2003.

The fire in the Jacobs River study area resulted predominantly in very high impact, indicating that it was a fire of very high fire intensity. For most of the northern two-thirds of the study area, the fire completely removed the entire ground layer, mid storey and canopy vegetation, incinerating all logs and resulting in the loss of large numbers of hollow-bearing trees (Figure 3.4). Evidence of the death of large numbers of mammals was apparent, with carcasses of small mammals, possums, rabbits, wallabies, kangaroos, wombats and even horses found within the study area (Figure 3.5). Some smaller vegetation patches in the southern section of the study area were impacted less severely, to a moderate level, while some very small patches could be categorised as low impact.
Figure 3.4: Example of very high impact from January 2003 wildfire in the Jacobs River study area. Photo: J. Dawson.
Figure 3.5: One of eight horse carcasses located in the Jacobs River study area following the January 2003 wildfires. Photo: J. Dawson.
4 Use of latrines by the Spotted-tailed Quoll

The use of latrines by the spotted-tailed quoll, other dasyurids and members of the order Carnivora was reviewed in Chapter 2. As noted in that chapter, for a species that is difficult to study due to a highly cryptic nature, latrines provide valuable focal points for investigations into distribution, diet, habitat, population structure, behaviour and management (Alexander 1980; Belcher 1995, 2000b, 2004; Kruuk and Jarman 1995; Murray et al. 2000; Burnett 2001; Dawson et al. 2003, Claridge et al. 2004). This study initially aimed to describe latrines and identify factors that influence where they occur in the landscape to assist in the refinement of survey techniques and improve understanding of the ecology of the species. However, the severe wildfire that occurred in January 2003 provided another opportunity for this study to use latrines in ecological investigation - monitoring levels and patterns of latrine use by spotted-tailed quolls across the landscape to gain insight into the species response to disturbance.

4.1 Methods

The selection of a survey methodology was based upon meeting the major objectives of the study, which were:

i. identification of a suitable study population of spotted-tailed quolls; and

ii. the identification of a set of latrines to monitor activity for the duration of the study.

While the impact of the fire was great on the physical character of the Jacobs River study area it did not affect the selection or use of survey methodology in this regard.

4.1.1 Assessment of survey methods

The cryptic nature of the spotted-tailed quoll, characterised by its solitary habits,
large home ranges and preference for large areas of rugged timbered habitat, poses challenges for survey and research (Jones and Rose 1996). Difficulties in detecting the species have resulted in significant gaps in knowledge about distribution, abundance and conservation status, data that is required to prioritise management actions and measure recovery of the species (Long and Nelson 2004). Many survey methods have been used to detect the presence of the species or clarify distribution. These include community-based postal surveys or questionnaires surveys (Watt 1993; Jones and Rose 1996; Belcher 2000a; Lunney and Matthews 2001), soil plots or sand traps (Watt 1993; Catling and Burt 1997; Catling et al. 1997; Glen and Dickman 2003a), searches for sign (scats and tracks) (Alexander 1980; Watt 1993; Jones and Rose 1996; Reside 1997; Belcher 2000a; Dawson et al. 2003), hair-sampling devices (Watt 1993; Jones and Rose 1996; Belcher 2000a; Belcher 2000c; Nelson et al. 2001), spotlighting (Watt 1993), live-trapping (Watt 1993; Belcher 2000b; Burnett 2001; Nelson et al. 2001; Dawson et al. 2003; Körtner et al. 2003; Belcher and Darrant 2004; Körtner et al. 2004) and the use of remote photography (Glen and Dickman 2003a,b; Claridge et al. 2004; Tony Stubbs, DEC NSW, personal communication 2004). Of these techniques, the most suitable are considered to be trapping, hair-sampling devices, sand traps and searches for scats and tracks (Watt 1993; Jones and Rose 1996; SEFSTQWG 2003). To date, only one study has attempted to compare the effectiveness and efficiency of these field survey techniques with a conclusion that adequate survey requires a combination of techniques to be used (Watt 1993). The relative merits of these techniques for detection and provision of information on the spotted-tailed quoll are discussed below.

Hair-sampling devices

In the only direct comparative study on survey methods for the spotted-tailed quoll, hair-sampling devices were concluded to be effective in obtaining positive records and time-efficient (Watt 1993). They can be placed out in the field for extended periods, are cheap to construct and require minimal maintenance (Watt 1993). However, it should be noted that there are many different designs
of hair-sampling devices in use for wildlife survey work in Australia and that not all designs have equal catchability for all species (Mills et al. 2002). Also, analysis of hairs on tapes can be costly and identification of hair collected may be of varying reliability, depending on the amount of hair collected and experience of identifier, although this is not a problem with spotted-tailed quoll hair as it can be reliably identified (Watt 1993; Lobert et al. 2001). Furthermore, hair-sampling devices provide only minimal presence data and do not yield information that is useful for subsequent ecological studies (Watt 1993; Catling et al. 1997).

Scat and track searches

From the survey comparison work done in south-east Queensland by Watt (1993), searches for spotted-tailed quoll sign, conducted along walking tracks, bush tracks and creek beds, achieved a relatively high success rate, although were considered inferior due to time considerations. It is unclear from this report whether the ‘sign’ targeted in these surveys included scats, as the only positive record was of prints. Likewise, it was not stated whether searches targeted any structural features in the forest or landscape, such as rock outcrops or rocky riparian areas, known to be focal points for quoll latrines (Belcher 1995; Kruuk and Jarman 1995). Other researchers have pointed out that scat and track surveys can be rewarding although return per unit effort can be low, and are therefore best done in conjunction with other techniques (Watt 1993; Jones and Rose 1996). A key point is that the usefulness of scat searching depends on the physical characteristics of the site (Jones and Rose 1996). Based on the species known habit of using latrines in steep rocky areas, areas with rocky riverine corridors, forest tracks and even rubbish tips, searches can be targeted at areas where these features are prominent (Belcher 1995; Kruuk and Jarman 1995; Jones and Rose 1996; Reside 1997). Scat searching has proven successful in surveys when other methods, such as live-trapping and use of hair-sampling devices, have been unsuccessful or very low in success (Jones and Rose 1996; Belcher 2000a). Latrine sites, once located, provide very useful focal points for a range of ecological investigation, including targeted
trapping of multiple quolls for population assessment, and presence of concentrations of scats for detailed dietary studies (Belcher 1995; Kruuk and Jarman 1995).

*Spotlighting*

It has been suggested that spotlighting, while time consuming, may prove useful in surveys for spotted-tailed quolls if baits or lures are used to attract animals to an area (Watt 1993). In reality, too few individuals are seen when spotlighting (Jones and Rose 1996). While spotlighting is a standard technique for assessing arboreal mammals it is not considered a useful technique for surveying ground-dwelling mammals in forests because thick understorey makes observations difficult (Catling et al. 1997).

*Sand pads*

The use of sand pads (also referred to as sand or soil plots or traps) to track medium-sized and large vertebrate fauna has been widely used in southeastern Australia (Newsome et al. 1975; Newsome and Catling 1979; Newsome et al. 1983; Catling and Burt 1995, 1997; Catling et al. 1998, 2000). This method has been used to estimate the abundance of spotted-tailed quolls in eucalypt forests throughout eastern New South Wales (Catling and Burt 1995) and is considered particularly effective in recording species, particularly predators, that are rarely recorded by other methods (Catling et al. 1997). In one targeted survey for quolls, sand traps with bait in the centre were successfully used to record prints of animals investigating the bait, although traps were easily destroyed by rain, birds, dogs and other wildlife (Watt 1993). Time taken to set up sand traps in areas other than those with sandy substrates can be prohibitive (Jones and Rose 1996). Apart from one study that found quolls utilising roads as latrine sites in northern Queensland (Burnett 2001), there is little information about the propensity of quolls to use roads, tracks or trails for movement over the surrounding vegetation. As a result, it is not known if under sampling occurs by this method. Surveys by sand pads also require checking on a daily basis (Newsome and Catling 1979).
Chapter 4: Use of latrines by the spotted-tailed quoll

Cage trapping

The use of wire cage traps as a survey method to detect the presence of the spotted-tailed quoll has been widely used with variable results. As a targeted survey method on its own, cage trapping can be time-inefficient, trap placement is critical and very few animals may be caught (Watt 1993; Jones and Rose 1996), a finding in accord with comparative studies for ground-dwelling forest fauna as a whole (Catling et al. 1997). However, an advantage of using cage trapping is that it is the only technique that provides the opportunity to collect detailed biological or ecological data on quolls (Watt 1993). Cage trapping is most useful in intensive locally based studies as an adjunct to other methods (Catling et al. 1997). In the case of spotted-tailed quolls, trapping at latrine sites enables capture of multiple individuals (Belcher 1995; Kruuk and Jarman 1995). Cage trapping requires that cages are checked on a daily basis, and should only be undertaken by personnel skilled in handling spotted-tailed quolls. Additionally, not all individuals within a population may be trappable.

4.1.2 Selection of survey method

The selection of the survey method/s for this study reflected the objectives of the survey. Firstly, the method needed to be able to detect quolls in large, forested, rugged and remote areas with minimal human resources. Secondly, although simple detection of presence of quolls in an area was a consideration, the ability to follow up with targeted trapping was also necessary to assess population size at the local scale. And finally, a number of latrines were required to be located to provide a core of sites for monitoring and comparison over time.

A search for latrines was selected as the initial survey method for this study for obvious reasons. Targeted survey of areas with large complex rock outcrops, cliffs and rocky riverine corridors maximised the chances of locating an extant study population and identification of latrines for monitoring throughout the study. In addition, the location of latrines provided an avenue for broader
investigation into other aspects of the ecology of the species, such as diet (see Chapter 5) and population structure (see Chapter 6).

4.1.3 Site selection

At the commencement of the project in early 2002 the first objective was the location of a suitable study population. A three stage methodology was adopted to identify areas with features suitable for targeted scat surveys: desktop analysis, aerial reconnaissance and ground inspection. For desktop analysis topographic maps, wildlife databases, NPWS staff, local Rural Lands Protection Board staff and landholders were consulted to obtain an overview of potential areas. Sites of interest for further field inspection were deemed to be those that contained large complex rock outcrops, cliff lines, rocky terrain or rocky riverine gorges. Areas where wildlife databases or local knowledge indicated past sightings of quolls were also noted. Aerial reconnaissance, by helicopter, was then used to further refine specific sites of interest within each area. Again, areas with large, complex rock outcrops and rocky riverine corridors were targeted and marked on maps from the air, as well as being marked digitally using GPS. Follow-up ground inspection was then undertaken, concentrating on locating and inspecting sites of high potential. Most sites were visited, with access either by road, foot or helicopter, or a combination thereof. Particular attention was given to areas with the largest complex rock outcrops and long sections of rocky riverine corridor. Sites considered to have the highest potential to support latrines were marked using GPS for re-examination during the breeding season.

It quickly became apparent that the Jacobs River area of the Byadbo Wilderness would be the most suitable study site for this project. The Atlas of NSW Wildlife contained 7 records of the spotted-tailed quoll from the previous 20 years within 3 kilometres of the Barry Way. Reconnaissance surveys revealed that complex granite outcrops were locally common and that the major drainage systems of the area were typically rocky. Finally, scat searches in May 2002 revealed active quoll latrines on rock outcrops throughout the area.
4.1.4 Latrine searches in the Jacobs River study area

Intensive targeted searches for latrines of the spotted-tailed quoll were conducted throughout the Jacobs River study area within each of the three years of the study, commencing in late autumn and concluded by early spring. This period, from late April through to early September, coincides with the breeding period of the spotted-tailed quoll and is thought to be the time of peak latrine use (Alexander 1980; Belcher 1994). Over the three years of the study latrine searches in the Jacobs River study area occurred between 26 May – 5 September 2002, 29 April – 12 September 2003, and 10 May – 13 August 2004.

Sites identified during reconnaissance were again subject to intensive searches. Rock outcrops were searched by one to three persons, with particular attention paid to those sections of outcrop containing flat horizontal surfaces, overhangs or caves. Stretches of rocky riverine corridor were accessed by foot and inspected, with particular attention paid to large flat sections of bedrock in, or at the edge of, drainage features. These included ephemeral creeks and the permanently flowing Jacobs River. Narrow, ephemeral drainage features were able to be comprehensively surveyed by a single person. Wide, rocky sections of the faster flowing Jacobs River were searched either by pairs of people working along each bank, or alternatively, each bank of a given section was surveyed separately by a single observer.

During the 2002 survey season, vegetation obscured the presence of some rock outcrops within the study area, making identification of all outcrops difficult. In addition, infestations of weeds, particularly tall blackberry along drainage lines, precluded access to all sections of rocky riparian habitat. As such, outcrops were searched when encountered opportunistically during periods of trapping and radio-tracking (not reported in this study), resulting in extensive survey coverage. All accessible sections of rocky drainage line were surveyed and all visible and accessible rock outcrops were searched. In addition, continuous monitoring of roads and tracks, as well as logs and other possible latrine sites, was undertaken for the duration of the study.
On detection, the location of quoll latrines was marked using handheld GPS and details of the site recorded. Recorded information included general location in the landscape (riparian, lower slope, mid-slope, upper slope), specific location within feature (outcrop, stream or river course), and total number of scats present. All singly occurring scats were collected as they were not considered to constitute a latrine. Where multiple (>2) quoll scats were located clustered on a single feature this was designated as a latrine site.

Following surveys in 2002, the 61 latrines located during the year were designated as ‘core’ latrine sites for the remainder of the study, becoming the reference sites against which changes in activity in the two years post-fire were compared. The location of even a single scat at any of these sites in the two years following the fire was recorded as a positive indication of the latrine being active. This differs from the classification of single scats located in the study area in 2002, which were not deemed to represent a latrine as they did not meet the definition of repeated usage. Single scats located at previously unused sites in both 2003 and 2004 were not designated as ‘new’ latrines.

Due to the likely communication role that latrines play in the social ecology of the spotted-tailed quoll (Kruuk and Jarman 1995) not all scats on latrines were collected. When latrines were found prior to August, old scats (desiccated, partly decomposed, flattened mats of hair) were collected, while fresher scats (dry whole scat, moist smelly stools) were left in situ. This was to limit any potential interference of scat collection with possible olfactory communication between animals during the breeding season. Only when trapping indicated that all locatable females had bred, through the presence of pouch young, were all scats collected from latrines. Complete clearing of scats from latrines only occurred on or after 19 August 2002, 1 August 2003, and 9 August 2004.

Scats collected were placed in individual brown paper soil sample bags with fold down wire seal (78 x 144 mm or 100 x 210 mm; Min-Sam; Prospectors Supplies, Seven Hills, NSW). Details of date, collection location, and AMG (AGD 66) were recorded on each individual bag. At the end of each winter breeding season the number of scats on each latrine was quantified by
totalling the number of quoll scats collected or by taking the highest number of scats recorded on the latrine at any one visit. Scat degradation resulted in losses of scats from latrines during the course of the winter survey period and so estimates of activity are likely to be under-estimates. Losses are also likely to have occurred as a result of weather, primarily rain and wind, particularly as many latrines were located on prominent high points at the top of outcrops or on bedrock in the channel of ephemeral creeks.

Following the extensive wildfires of January 2003, all areas surveyed in 2002, including all latrines recorded, were revisited during the winters of 2003 and 2004. The exposure of substrate through the almost total removal of vegetative cover across the landscape revealed previously undiscovered outcrops and provided access to all sections of riparian corridor within the study area. For surveys conducted in the early part of the 2003 breeding season, late-April and early-May for example, scats located on latrines were determined to be deposited either pre-fire (baked onto rock, scorched, burned, black colour, very hard crust) or post-fire (as for 2002).

4.1.5 Analysis

**Latrine activity counts**

In 2002 intensive searches conducted throughout the Jacobs River study area resulted in the location of a set of core latrines that determined sites for monitoring of quoll activity for the remainder of the study. These core latrines were monitored for continued use in both 2003 and 2004 and the total number of latrines compared between years as an index of quoll activity in the study area. In addition, latrines were mapped with reference to likely population distribution and fire impact.

**Scat counts**

Total annual activity (gross total of scats on all latrines within the study area in each year) and the number of scats on each latrine was described and
compared between years. Two separate calculations were made to estimate the relative level of usage of latrines between years. Firstly, the mean number of scats per core latrine was compared between years. Secondly, the mean number of scats per active latrine (active core latrines plus ‘new’ latrines) was compared between years.

4.2 Results

4.2.1 Latrine activity pre-fire

Intensive searches conducted in 2002 located 61 active latrines that determined the core sites for comparison of latrine activity across the remainder of the study (Figure 4.1). These latrines were widely distributed throughout the study area. All latrines were on rock substrate. Latrines were found on and among the locally common complex granite rock outcrops throughout the topography, as well as on bedrock associated with riparian corridors (Table 4.1, Figure 4.1). Latrines on bedrock were positioned on large, flat, water-polished rock slabs in the channels of ephemeral creeks and along the edges of rocky sections of the fast-flowing Jacobs River. Latrines among the conspicuous granite rock outcrops typically occurred on top of boulders with flat, horizontal or gently sloping surfaces at the top or highest point of the outcrop, or on other rocks with similar characteristics among the outcrop.

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<td>-</td>
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<td>33</td>
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<td>61</td>
</tr>
</tbody>
</table>

Table 4.1: Topographic location and structure of core latrines in the Jacobs River study area.
4.2.2 Latrine use pre-fire

A total of 653 scats were recorded on the 61 core latrines in the Jacobs River study area in 2002. The number of scats on each latrine ranged from 2 to 57, with a mean of 10.7 scats per latrine (S.E. = 1.1). There was little difference in relative levels of usage between latrines in different landscape positions. Latrines that occurred on rock outcrops on the lower and mid-slopes had slightly more scats than those in riparian areas or outcrops positioned on mid-slopes, although there was no significant difference between the mean number of scats on latrines in different landscape positions (single factor Anova; F = 0.38, d.f. = 3, 57, P = 0.76) (Figure 4.2).
**Figure 4.1:** Location of core latrines and number of quoll scats collected in 2002 in Jacobs River study area. Graduated symbols represent scat counts for each latrine. For mapping clarity 6 latrines (to the south and east of the study area) are not represented.
Chapter 4: Use of latrines by the spotted-tailed quoll

Figure 4.2: Relative usage of latrines by spotted-tailed quolls in different landscape positions across the Jacobs River study area, 2002. Figure in brackets equals number of latrines. Error bars represent ± standard error of the mean.

4.2.3 Latrine activity post-fire

Continuity of activity on latrines varied between years. Twenty-two (36%) of the core latrines were active in all three years of the study. A further 26 (43%) core latrines were active in at least two of the years. Of these, 21 (34%) were active in 2002 and 2004 only, and 5 (8%) were only recorded as having scats in the first two years. Thirteen (21%) latrines were active in 2002 only and did not have scats during either of the 2 years following the fire. Therefore almost 80% of the 61 core latrines located at the commencement of the study were used in more than one year, indicating a high level of persistence of use, particularly in the face of disturbance to the habitat and population by severe wildfire.

In the winter breeding season of 2003, following the bushfire of January 2003, the number of active latrines decreased substantially, with repeat searches of core latrines revealing scats at 27 of 61 sites (44%) (Figure 4.3). In 2004, searches of the same 61 core latrines showed an increase in activity from the previous year, with 43 (70%) of these sites in use (Figure 4.4). In addition to recording activity on this set of core latrines, searches throughout the study
area located 8 previously undetected, or ‘new’, latrines in 2003 and 21 ‘new’ latrines in 2004. This brought the total numbers of active latrines located to 35 (57% of 2002 total) for the winter breeding season of 2003, and 64 (105% of 2002 total) for 2004. Overall, 90 active latrines of the spotted-tailed quoll were recorded in the Jacobs River study area.
Figure 4.3: Location of core latrines and new latrines, and number of quoll scats collected in 2003 in Jacobs River study area. Graduated symbols represent scat counts for each latrine. For mapping clarity 6 latrines (to the south and east of the study area) are not represented.
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Figure 4.4: Location of core latrines and new latrines, and number of quoll scats collected in 2004 in Jacobs River study area. Graduated symbols represent scat counts for each latrine. For mapping clarity 6 latrines (to the south and east of the study area) are not represented.
4.2.4 Latrine use – post-fire

Core latrines

Counts at the 61 core latrines in 2003 recorded 166 scats (range 0-23 scats, mean = 2.72, S.E. = 0.62), although only 27 of these latrines were active as indicated by the presence of at least one scat. In 2004, the same 61 core latrines revealed 359 scats when surveyed (range 0–35 scats, mean 5.89, S.E = 0.94) from 43 active latrines (Figure 4.5). This pattern of usage of core latrines over the course of the study shows a significant difference in the mean number of scats on these latrines between the years (single factor Anova: F=19.24, d.f.=2, 180, P<0.001).

![Figure 4.5: Comparison of rates of usage of the 61 core latrine sites in the Jacobs River study area. Error bars represent ± standard error of the mean.](image)

All active latrines

Total latrine usage for the Jacobs River study area was described by the total number of scats on all active latrines found in each of the three winter breeding seasons. Scat counts for the 61 core latrines located in 2002 are described above in section 4.2.2. In 2003, a total of 223 scats were found on 35 active latrines (mean = 6.37, S.E. = 0.92). Sixty-four active latrines were found in
2004 and 518 scats were counted (mean = 8.09, S.E = 0.86). There was a significant difference in the mean number of scats on all active latrines across the three years of the study (single factor Anova: F=4.56, d.f.=2, 158, P=0.01), with a large drop in the breeding season directly after the fire, followed by an increase in 2004 (Figure 4.6).

![Figure 4.6: Comparative rates of usage of all active latrines in the Jacobs River study area. Number of active latrines in brackets ( ). Error bars represent ± standard error of the mean.](image)

4.2.5 Changes in latrine use

Mapping of fire impact within the study area was overlaid on the pattern of latrine use in 2003 to look at potential spatial impacts of the fire (Figure 4.7). The largely uniform high intensity of the fire in the northern two-thirds of the study area coincides with a large number of latrines with no activity in 2003. This is particularly notable in the north-eastern section where a number of latrines were present in 2002 among outcrops south of Wallace Craigie lookout, and in the upper reaches and catchment of Ingebirah Creek. Conversely, a higher proportion of latrines either within or in proximity to patches where the fire was of lower impact remained active, particularly along the Jacobs River and the lower reaches of Ingebirah Creek. This difference is likely attributed to an absence of animals occupying the intensively burnt habitat rather than an
impact of the fire rendering these outcrops in some way unsuitable for use by resident animals, a hypothesis backed-up by the mapping of animal captures discussed in Chapter 6.

The numbers of quolls trapped in the study area was compared with the numbers of active latrines and their relative levels of usage in each of the three years of the study (Table 4.2). While it is difficult to draw firm conclusions, it may be suggested from the data that at lower population levels the number of latrines declines and rates of scat deposition on latrines decline. It must be noted, however, that this suggested relationship is based on a comparison across only three time intervals, and as such provides too few points to examine statistical correlations.

<table>
<thead>
<tr>
<th></th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
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<tbody>
<tr>
<td>Latrines</td>
<td>61</td>
<td>35</td>
<td>64</td>
</tr>
<tr>
<td>Scats on latrines</td>
<td>653</td>
<td>223</td>
<td>518</td>
</tr>
<tr>
<td>Quolls trapped</td>
<td>22</td>
<td>16</td>
<td>26</td>
</tr>
<tr>
<td>Latrines/quoll</td>
<td>2.77</td>
<td>2.19</td>
<td>2.46</td>
</tr>
<tr>
<td>Scats/quoll</td>
<td>29.7</td>
<td>13.9</td>
<td>19.9</td>
</tr>
</tbody>
</table>

Table 4.2: Relationship between quoll numbers and latrine activity and usage in the Jacobs River study area.
Figure 4.7: Fire impact and latrine usage in 2003. Graduated symbols represent scat counts for each latrine. Fire impact mapping provided by Department of Environment and Conservation (NSW), 2003.
4.3 Discussion

The location of 90 separate latrines of the spotted-tailed quoll throughout the three years of this study represents the largest aggregation of such sites recorded. The identification of over 60 latrines in both 2002 and 2004 exceeds the number of latrines found at other locations with high density quoll populations, such as rocky gorge habitat of the New England Tablelands of north-eastern NSW (Kruuk and Jarman 1995). In the only other published study relating to latrine use of the spotted-tailed quoll, scats were collected from only two latrines (Belcher 1995).

The latrines identified in this study occurred exclusively on rock substrate, being on or among the boulders of large rock outcrops or along riparian corridors across the study area. Latrines occurred across all topographic positions of the landscape where rock outcrops occurred. These findings confirm the strong association with rocky habitat for placement of latrines by the spotted-tailed quoll that has also been reported for other geographic areas and habitats (Alexander 1980, Belcher 1995, Kruuk and Jarman 1995, Murray et al. 2000). No latrines were found on large logs or roads as recorded in other studies (Burnett 2001) despite the presence and continuous monitoring of these features throughout the study.

It should be noted that the surveys carried out in this study for the identification of latrine sites were targeted in terms of both geographic features and seasonal timing to maximise success. Notwithstanding, not all parts of the landscape were sampled each year. For instance, vegetation present in 2002 (and subsequently removed by the fire) obscured the presence of a number of outcrops, while impenetrable thickets of blackberry prevented access to several sections of rocky creek line. Also, the advent of the fire prevented the use of systematic surveys to determine the use by quolls of rocky features in relation to availability, aspect and topography, one of the primary objectives of the project at commencement. Ironically, the complete removal of vegetation by the fire may have provided an opportunity to comprehensively map the distribution
of rock outcrops in the Jacobs River study area and other areas, facilitating comprehensive sampling for future work. The acquisition of high-definition aerial photography taken shortly after the fire by the Department of Environment and Conservation may make it possible to accurately map all rocky outcrops. With this information, systematic sampling of rock and non-rock sites within different landscape classes of topography and aspect across several years would provide a clearer indication of the factors dictating the placement of latrine sites.

The visitation of individual latrines by multiple spotted-tailed quolls in this study (see Chapter 6) has led to sizable accumulations of scats during the winter breeding season of three consecutive years, consistent with the finding of other studies (Belcher 1995; Burnett 2001). The highest number of scats collected from a single latrine in any one year was 57, collected in 2002 from a riparian latrine (‘El Primo’) in the lower reaches of Ingebirah Creek. Interestingly this latrine also ranked highest in terms of numbers of scats (35) in 2004 and third highest in 2003 (16), although greater numbers of scats have been recorded consistently over time for individual latrines in other studies (Belcher 1995). This suggests that all latrines are not equal in importance to the resident quoll population, or that latrines attract different levels of visitation and scat deposition for a variety of functions that are yet to be understood.

The pattern of latrine use across the three years of the study follows similar trends to that observed for the population of quolls in the study area, both in terms of spatial configuration and rates of activity (see Chapter 6). In areas where quolls had regularly been captured in 2002 and then were absent or in very low numbers following the fire, latrine use declined to negligible levels. This may indicate that a relationship exists between levels of latrine use and population size. More research is required to better understand the relationship between quoll density and scat deposition rate, both in this and other geographic areas and habitats. Monitoring of latrines may provide for relatively inexpensive and time efficient population assessment for quolls, a suggestion that has been raised in northern Queensland where latrine use is confined to
roads (Burnett 2001). Monitoring of latrines and scats deposition rates is also being developed and used for carnivore population assessment in other parts of the world. For example, numbers of latrines used by a social group of Eurasian badgers has been positively correlated with adult group size estimated from mark-recapture studies (Tuyttens et al. 2001). Systematic sampling and genetic typing of fresh faeces from badger latrines can provide data that can be used to estimate abundance accurately (Wilson et al. 2003). Latrine revisitation rates has been used as an index of habitat use in studies of the river otter (Newman and Griffin 1994), and scat deposition surveys have been shown to be effective at predicting density of populations of the swift fox Vulpes velox (Shauster et al. 2002). Indeed counts of scat density have been suggested as a means of monitoring relative density of foxes and badgers across large spatial scales in Britain, although the relationship with absolute density of these populations is yet to be validated (Sadlier et al. 2004; Webbon et al. 2004).

The placement of latrines on prominent rock outcrops and along riparian corridors provides further evidence that this system of latrines is used for communication by the resident population of spotted-tailed quolls, as has previously been suggested (Kruuk and Jarman 1995; Burnett 2001). Individual quolls use gullies and drainage lines when moving through the landscape and often select rock outcrops for dens (Belcher 2000b). The placement of scats along movement corridors and on latrines at visually conspicuous, elevated, and traditionally used landmarks reduces the number of places that quolls need to search and helps disperse odour, maximising detection as has been found in studies of other solitary carnivores (Gorman and Trowbridge 1989; Begg et al. 2003). Quoll scats remain ‘active’ for long periods of time on latrines, a quality useful for such a wide-ranging carnivore (Gorman and Trowbridge 1989). A similar system of latrines has also been observed for both the Tasmanian devil and western quoll, where scats are deposited in places where animal movements are likely to be concentrated such as paths and river crossing points, ensuring maximum detectability (Serena and Soderquist 1989; Pemberton 1990).
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The large numbers of scats found on latrines during the three winter breeding seasons of this study provides further evidence that at least part of the communicative function of latrines is to provide signals relating to reproduction, a theory previously suggested for the spotted-tailed quoll by other authors (Belcher 1994; Kruuk and Jarman 1995 Burnett 2001). Females may advertise reproductive status at latrines for the purpose of attracting mates (Gorman and Trowbridge 1989) as has been suggested for the northern quoll (Oakwood 2002). In addition, larger males may be using latrines for the purpose of scent-matching to maintain dominance hierarchies, providing information to a resident female to match dominant scent to dominant male for mating (Gosling 1982; Rich and Hurst 1999; Begg et al. 2003). Research currently underway aims to extract the DNA of quolls from scats, thereby identifying individual quolls and their latrine used habits and providing an additional avenue for more detailed understanding of the communication function of latrines (M. Ruibal, ANU, personal communication 2004).

A high degree of fidelity was observed in regard to use of latrines in this study, with almost 80% of the 61 core latrines monitored being active in at least two of the three years of the study. This finding supports observations of other authors who report consistent use of individual latrines over several years (Belcher 1995; Kruuk and Jarman 1995). This was particularly surprising in this study given the massive perturbation provided by the severe wildfire after the first survey season, although rapid re-establishment of latrines following flooding has previously been recorded in the gorge country of the New England tablelands (Kruuk and Jarman 1995). The findings of this study throw doubt on the suggestion that fire was responsible for the cessation of use of a latrine near Suggan Buggan in north-eastern Victoria, and that use of this latrine resumed only after the understorey had re-established (Belcher 2004). It appears clear that if a population of quolls is present in an area, even after a massive fire, then latrine use is likely to occur.
5 Diet of the spotted-tailed quoll and relationships to prey availability

5.1 Methods

While descriptions of captive spotted-tailed quolls killing a variety of prey have been published, killing of prey by wild spotted-tailed quolls has rarely been observed (Fleay 1932; Troughton 1954; Settle 1978; Green and Scarborough 1990). Collection and analysis of scats instead provides an alternate method for investigating the diet of this cryptic and rare species, particularly as other destructive sampling techniques, such as investigating stomach contents, are undesirable (Alexander 1980). In addition to being able to assess diet of the predatory spotted-tailed quoll, identification of mammalian hair from the collection and analysis of scats is an effective technique for compiling a species list of mammals in an area (Friend 1978; Lunney 1987; Catling et al. 1997).

5.1.1 Scat identification

Scats of the spotted-tailed quoll were identified in the field based on a combination of size, shape, smell, composition and locality (Triggs 1996). A detailed description of morphological characteristics is provided in Section 2.2.3 (p. 21), and photos of two typical examples of scats are provided (Figure 5.1). All scats collected from spotted-tailed quoll latrines were deemed to be quoll, regardless of whether or not they contained grooming hairs. Scats found opportunistically may not always be readily identifiable to species level (Belcher 1995). In such cases, and where positive identification of depositor was not possible, either in the field or from later analysis for grooming hairs, the scat was excluded from all further analyses.
Figure 5.1: Two typical spotted-tailed quoll scats from latrines in the Jacobs River study area. Photos: J. Dawson.

5.1.2 Scat collection

For the purposes of dietary analysis scats of the spotted-tailed quoll were collected from latrines and from live-trapped animals. Scats were collected from latrines from just prior to, during, and immediately post the winter breeding season (May-August) as this is the time of year that latrine use by the species peaks (Alexander 1980; Belcher 1994). Individual scats on latrines were defined as a single sample, while different scats were differentiated by distinct spatial separation on latrines, as well as by obvious differences in colour and age. All scat material collected from a trap following a capture (see Chapter 4 for trapping methods) was treated as one sample, although the number of scats produced per meal is unknown (Jones and Barmuta 1998). Scats collected from traps were placed in plastic zip lock bags and frozen on the day of collection, or were placed in brown paper soil sample envelopes (Min-Sam, Prospectors Supplies). All bags were labelled with the date, location, 13 digit grid reference (Australian Geodetic 66 datum) and identity of individual quoll where this information was known.

In addition to the extensive and intense searching for latrines that occurred in the Jacobs River study area, wider surveys for the species located several more latrines across the Byadbo Wilderness area. A latrine located along Devils Hole Creek, approximately 20 kilometres east of the Jacobs River, occurred in the
middle of a large (c. 5000 hectare) patch of rain-shadow woodland that remained completely free of fire over the summer of 2002/2003. The broad vegetation type of this site is comparable to the Jacobs River study area and hence contained a similar environment pre-fire. This latrine was visited again in 2003 and 2004, providing an approximation of an unburnt ‘control’ site against which changes in the diet in the intensely burnt Jacobs River study area could be compared. The interpretation of these results is limited however, given the possibility that differences in diet may occur between areas that are reasonably similar and relatively close (Newsome et al. 1983).

5.1.3 Prey identification from scats

All scats collected during the study were sent to Barbara Triggs, a noted hair and bone analyst, for identification of prey items (see Triggs 1996). Identification of mammalian prey items was to species level where possible and genus level where identification to species was unreliable. This latter category most often occurred with *Trichosurus* spp. (*T. vulpecula* or *T. caninus*) and *Rattus* spp. (*R. fuscipes* or *R. rattus*), groups in which distinction to species level has been shown to be intrinsically unreliable for even highly experienced practitioners (Lobert et al. 2001). Hair of rabbit and hare *Lepus capensis* in scats was occasionally described to species level, although the majority of identifications were ambiguous, leading to a lumping of these two prey items into a single prey group (lagomorphs) for dietary analysis. Where definitive identification from hairs was not possible, probable identification was provided and this was used in the analysis. Non-mammalian prey was grouped, respectively, as bird (feathers), reptile (scales), insect or plant (seeds). Multiple prey items in individual scats were listed where detected (up to 2), as was the presence of quoll grooming hairs. No attempt was made to determine age classes of prey items or estimate relative proportions of each prey type in each scat. Occasionally no hair was present in scats and only bone fragments were identified. This occurred mostly in scats obtained from live-captured animals that had been trapped on consecutive days, having consumed fresh chicken baits. In such cases these scats were excluded from later dietary analysis.
5.1.4 Dietary analysis

The relative importance of each dietary item in the diet of carnivores can be assessed using frequency of occurrence, relative weights of remains of prey types and estimates of percentage biomass ingested (Floyd et al. 1978; Corbett 1989). Frequency of occurrence and an estimation of biomass were both used to describe diet in this study. As no assessment was made of weight or percentage volume of prey remains in each scat during analysis, the relative weights method was not used. Furthermore, as no attempt was made to distinguish age classes of prey, all dietary items were assumed to be from adult prey, an assumption that affects calculations of biomass contribution to diet (Belcher 1995; Jones and Barmuta 1998).

The relative importance of each dietary item or group was first estimated on frequency of occurrence. This was calculated by dividing the number of occurrences of a particular prey item by the total number of scats analysed. Analysis of the frequency with which components occur in scats provides the most consistent method for comparison between studies (Putman 1984; Soderquist and Serena 1994). It was not uncommon for more than one prey item to be found in individual scats, resulting in a higher total number of occurrences than total number of scats. Thus, the sum of frequencies of occurrence gave a total greater than 100%. This method has been found to over-represent the proportion of smaller prey items compared with larger prey items due to the fact that smaller prey items have proportionally more indigestible remains than do larger prey (Floyd et al. 1978). Furthermore, this method does not enable the actual mass of the prey eaten to be determined (Alexander 1980; Belcher 1995).

Estimation of biomass is considered a better measure of diet composition than frequency of occurrence as it allows some assessment of the relative importance of each prey type (Corbett 1989; Jones and Barmuta 1998). Contribution of prey types by percentage biomass was calculated by multiplying the total number of occurrences of each prey item by the mean adult mass for that species, then dividing the resulting figure by the sum of the figures for all
prey species consumed (Belcher 1995; Strahan 1995; Jones and Barmuta 1998). In these calculations it was assumed that a single individual of a given prey type was in each scat. For larger prey a cap on mass of prey eaten from a single kill was required to account for the maximum amount of food able to be consumed at one sitting by a spotted-tailed quoll. This figure has been variously estimated in previous studies. For example, Jones and Barmuta (1998) estimated this figure at 0.4 kg for female and 0.7 kg for male spotted-tailed quolls, based on observed similar feeding habits of the smaller eastern quoll (23% of body weight). Alternatively, the western quoll, a species with a diet more similar to the spotted-tailed quoll than the eastern quoll in that it consumes a higher proportion of vertebrate prey, has been recorded eating up to 43% of body weight overnight in captivity (Soderquist and Serena 1993, 1994). Given that the actual mass eaten by wild animals may be higher that that of captive animals (McIlroy 1981), and that a captive female spotted-tailed quoll has been reported killing and eating an adult rabbit (Troughton 1954), 1.58 kg (an adult rabbit) has been adopted for use in this, and other studies for calculations involving larger prey items (Belcher 1995). Observations of remains of fresh kills by quolls of brushtail possums and rabbits during this study are in broad agreement with this figure. On one occasion a radio collar, previously fitted to a 3.2 kilogram male quoll, was recovered from the stomach cavity of a fresh brushtail possum carcass that had been killed 12 hours previously, the timing estimated from the commencement of a mortality switch fitted in the collar (J. Dawson, personal observation). The carcass was that of an adult brushtail possum (3-4 kg) and was approximately half eaten. Approximately 18 hours later, only hair and skull remained of the carcass, suggesting that the rest of the animal had been consumed at a second sitting, presumably by the same adult male quoll implicated in the kill.

For further comparison with other studies prey items were grouped into ecologically significant categories (eg. Newsome et al. 1983; Belcher 1995; Jones and Barmuta 1998). Mammalian prey was divided into three major prey groups based on size - large mammals > 5.0 kg (kangaroo, wallabies and wombat); medium sized mammals 0.5 – 5.0 kg (cat - water rat Hydromys
chrysogaster); and small mammals < 0.5 kg (black rat Rattus rattus and smaller prey). Birds, invertebrates, reptiles and plant material were grouped into a single category of ‘other’ given their low frequency of occurrence (Jones and Barmuta 1998).

5.1.5 Abundance indices for primary medium-sized prey

Estimates of abundance of primary medium-sized mammalian prey were derived for the study area over each of the three years. Plot based activity counts were used to assess the prevalence of rabbits/hares and bandicoots in the Jacobs River study area during the winter prior to the fire (2002, n=90) and in the two subsequent winters (2003, n=90 and 2004, n=86). Animal signs were located by searching the ground over circular plots of 10 m radius from a given random point. The occurrence of bandicoots was determined by recording the presence of their forage diggings that are left in the upper soil profile after searching for food. This is considered to be the most efficient way to survey for these animals (Claridge and Barry 2000). Bandicoot diggings were identified as those being distinctly conical in shape (Triggs 1996; Claridge and Barry 2000), and within the study area no other mammals that produce similar, potentially confusing signs (eg. potoroo) were present. All ‘bandicoot’ diggings were presumed to be those of the long-nosed bandicoot Perameles nasuta, as this was the only species of bandicoot known to be present in the Jacobs River study area (A. Claridge, DEC NSW, personal communication 2002). This technique was also adapted for use in assessing the presence of rabbits and hares, determined from the presence of distinctive scrapes, pellets and burrows. Scrapes were identified as shallow scratchings, rounded in shape and often with a small mound of soil at the base (Triggs 1996). Mounds were often accompanied by round pill-like scats, and accumulations of scats were also observed on rabbit hills or latrines (Triggs 1996).

Estimates of abundance of arboreal mammals were obtained using spotlight counts. Spotlighting was carried out in both unburnt and burnt rain-shadow woodland habitat in the Byadbo Wilderness area. Spotlight surveys were not carried out in the Jacobs River study area prior to the wildfire in January
2003. Estimates of abundance of possums in unburnt rain-shadow woodland habitat were instead obtained from spotlight surveys conducted in 2004 at alternate unburnt sites. These sites were selected based on mapping of 2003 fire distribution (NPWS unpublished data) and from discussions with NPWS staff in Jindabyne (P. O’Brien, P. Zylstra and R. Roach, DEC NSW, personal communications 2003). On this basis two areas within the Byadbo Wilderness were identified as having accessible unburnt rain-shadow woodland habitat: the area around the lower reaches of Paupong Creek and the catchment of Devils Hole Creek, approximately 15 km and 20 kilometres to the east of the Jacobs River study area respectively (see Fig 3.2).

Spotlight surveys in both burnt and unburnt habitat were conducted on moonless, still nights between June 2003 and June 2004. Surveys in the burnt habitat of the Jacobs River study area were undertaken over three nights in September 2003 and then again between May and June 2004. Surveys in unburnt habitat were conducted over three nights between April and June 2004. All surveys commenced at least 30 minutes after total darkness and were conducted throughout the study by a single observer (J. Dawson). Fifteen 500 m long transects were surveyed in both unburnt (2004) and burnt (2003 and 2004) vegetation using a handheld 50 W spotlight either on foot or from the back of a vehicle travelling <5 km/h. Transects were at least 500 m from the nearest fire edge and at least 500 m apart wherever possible to ensure that each transect was independent, being free of the effect of fire and to avoid overlap of transects with territories of individual possums (Kerle 1984). To obtain adequate coverage of available landscape classes, 5 transects each were surveyed along gullies, mid-slopes and ridges. Transects took between 15 and 25 minutes to complete depending on terrain. All vertebrates observed were recorded along with details of distance along the transect from the starting point and estimated distance from the transect line.

Visibility for spotlighting possums was highest in the Jacobs River study area in 2003, after the fire removed all leaves from trees and all ground-cover. In both the alternate unburnt sites and the Jacobs River study area in 2004, visibility for
detection of possums was lower because of the presence of healthy tree
crowns or dense epicormic growth respectively, and the presence of
understorey shrubs and grasses.

5.1.6 Statistical Analyses

Overall diet was examined using combined data of scats collected from latrines
and live-trapped animals. Analysis of variation in diet was assessed using $\chi^2$
tests based on count data. Significant differences for all statistical analyses
taken where $P < 0.05$. Differences in overall diet composition between years
was assessed by comparing counts of major prey groups (small mammals,
medium-sized mammals, large mammals, other). Further, differences in
occurrence of each major prey group across the study were assessed by
comparison of counts for these groups between years. Where sample sizes
were sufficient to enable use of $\chi^2$ tests, more detailed analysis was undertaken
to examine changes in diet through time at the species, or group of species,
level. This way, changes in composition of medium-sized mammal prey
(possum, lagomorphs, and bandicoot), Rattus spp. and swamp wallaby in diet
between years was assessed.

Differences in occurrence of food items in scats collected from live-trapped
animals was similarly analysed using $\chi^2$ tests. In this way data were analysed
to look for differences in diet between female and male quolls and quolls of
different sizes based on weights at first capture.

Data on prey abundance was assessed by two methods reflecting sampling
differences. Data on mean numbers of possums observed per transect was
compared across all years using two-way ANOVA, while differences between
individual years were analysed using a Students t-test. Differences in the
frequency of positive returns from prey plots for lagomorphs and bandicoots
were analysed using simple $\chi^2$ tests. Significant differences are highlighted in
the results section below along with noteworthy non-significant results.
5.2 Diet results

5.2.1 Scat collection

Over the three years of the study 1466 spotted-tailed quoll scats were collected from the Jacobs River study area and analysed for identification of prey items. In 2002 a total of 625 scats were collected, 495 from latrines, 60 incidentally collected while walking between latrines and during traverses of the study area, and 70 from live-trapped animals. In 2003, 269 quoll scats were collected; 191 scats were collected off latrines, 27 collected incidentally from throughout the study area, and 51 collected from live-trapped animals. In 2004, 572 scats were collected from the Jacobs River study area; 439 scats gathered from latrines, 76 scats collected incidentally, and 57 scats collected from live-trapped animals. One hundred and four scats were also collected from a single latrine in Devils Hole Creek, 20 kilometres east of the Jacobs River study area – 27 in 2002, 29 in 2003, and 48 in 2004.

5.2.2 Diet of the spotted-tailed quoll in the Jacobs River study area

Twenty-two species of mammal were recorded in the diet of the spotted-tailed quoll from the Jacobs River study area, representing the majority of all prey identified (98.5% occurrence) and contributing almost all of the biomass consumed (99.6%) (Table 5.1). Medium-sized mammals were the most important prey category at 74.4% occurrence. Over the three years of the study small mammals were the second most common prey group (15.8%), the majority of this being made up by *Rattus* sp., with most records of *Rattus* sp. were from 2002 prior to the fire. Large mammals were the next most common group by occurrence (8.3%), with swamp wallaby the major component. Other prey items (birds, reptiles, insect and plants) made up the balance (7.0% occurrence). Due in part to the broad range of prey items found in quoll scats, only 4 prey items or groups were represented at more than 5% by occurrence, and only 2 at more than 10%. Across three years of the study grooming hairs of spotted-tailed quolls were identified in 6.9% of scats.
Table 5.1: Food items identified in scats of the spotted-tailed quoll collected from the Jacobs River study area 2002-2004.
There was a highly significant difference in the composition of the diet by major prey category (small, medium and large mammal, other) across the years of the study ($\chi^2>30$, d.f.=6, P<0.001), indicating a shift in utilisation of food resources by quolls (Figure 5.2). This dietary shift was also apparent in significant differences in the frequency of occurrence of the four major prey categories between each of the years of the study: 2002 compared with 2003 ($\chi^2>30$, d.f.=3, P<0.001), and 2003 compared with 2004 ($\chi^2=10.82$, d.f.=3, P=0.001).

To examine where and when these shifts occurred, each of the major prey categories and, where sample sizes permit, individual prey species and groups, were further assessed below.

**Figure 5.2:** Composition of quoll diet in Jacobs River study area by major prey category, 2002-2004.

Some species considered rare in NSW, and others that may be considered unusual as dietary items of the spotted-tailed quoll were detected in scats. Two species listed as vulnerable on the NSW Threatened Species Conservation Act 1995 (TSC Act) were identified as prey remains in scats. Firstly, 6 quoll scats contained spotted-tailed quoll (vulnerable on the TSC Act) as a prey item, identified as distinct from being just a few grooming hairs by being wholly composed of matted quoll hair (B. Triggs, personal communication 2004).

Secondly, 4 scats contained hair of the eastern pygmy possum *Cercatetus nanus* (vulnerable on the TSC Act). The feral cat occurred as a prey item in
two scats, and other interesting prey included the largely aquatic platypus *Ornithorhynchus anatinus* and water rat.

5.2.3 Medium-sized mammals

In the diet of the spotted-tailed quoll examined over three winter breeding seasons from 2002 to 2004, medium-sized mammals were the most common prey category at 74.4% occurrence. When assessed by biomass the importance of medium-sized mammals to the overall diet of the spotted-tailed quoll in the Jacobs River study area increased to 87.2%. However, the contribution of medium-sized mammals to quoll diet varied significantly across the three years of the study ($\chi^2=14.47$, d.f.=2, $P<0.001$) with percentage occurrence increasing throughout the duration of the study (Figure 5.3). Interestingly, while quolls ate significantly more medium sized mammals in the first year of the study than in the last ($\chi^2=14.47$, d.f.=1, $P<0.001$), there was no significant difference between consecutive years.

The proportions of prey items that comprised the medium-sized mammal component of the diet of quolls in the Jacobs River study area, being mainly brushtail possum, lagomorphs (rabbits and hares) and long-nosed bandicoot, differed highly significantly across the three years of the study ($\chi^2>30$, d.f.=4, $P<0.001$). The contribution of brushtail possum to the medium-sized mammal component of quoll diet decreased while lagomorphs increased throughout the study (Figure 5.3).
Chapter 5: Diet of the spotted-tailed quoll

Figure 5.3: Percent occurrence and proportions of medium-sized mammal in quoll diet from the Jacobs River study area 2002-2004.

**Brushtail possum**

Brushtail possum (most likely the common brushtail possum) dominated the diet of quolls across the three years of the study. They were the most important prey item in all three years of the study by both frequency of occurrence and percentage biomass (Table 5.2). The frequency of occurrence of brushtail possum in diet of quolls was significantly different across the three seasons of scat collection \((\chi^2=27.01, \text{ d.f.}=1, P<0.001)\). Brushtail possum in the diet declined each year from 2002 through to 2004 (Figure 5.3), but the decline was not uniform. While quolls ate significantly more brushtail possums in 2002 than in 2003 \((\chi^2=10.48, \text{ d.f.}=1, P=0.001)\), there was no significant difference in the amount of brushtail possums eaten between 2003 and 2004 \((\chi^2=0.54, \text{ d.f.}=1, P=0.464)\).

**Lagomorphs**

Lagomorphs were the second most important prey resource for quolls in this study. The frequency of occurrence of lagomorphs taken by quolls was highly significantly different across the three years \((\chi^2>30, \text{ d.f.}=2, P<0.001)\). In 2002 lagomorphs were only the third most frequently occurring prey item, but
increased significantly between 2002 and 2003 ($\chi^2=23.08$, d.f.=1, $P<0.001$) and again between 2003 and 2004 ($\chi^2=15.98$, d.f.=1, $P<0.001$) to be ranked a very close second behind brushtail possum in 2004 (Figure 5.3; Table 5.2).

Long-nosed bandicoot

The only other medium-sized mammal to occur in more than 10 scats during the study, long-nosed bandicoot was the sixth most frequently occurring prey item from the Jacobs River area, accounting for a relatively small percentage of the diet of quolls (Figure 5.3, Table 5.2). As with the other medium sized-mammals described above, frequency of bandicoot in quoll scats was significantly different over the study period ($\chi^2=7.73$, d.f.=2, $P=0.021$). This difference was mainly due to a significant drop in occurrence from 2003 to 2004 ($\chi^2=7.12$, d.f.=1, $P=0.008$), as there was no significant difference in frequency of occurrence of bandicoot in quoll scats between 2002 and 2003 ($\chi^2=0.49$, d.f.=1, $P=0.482$).

<table>
<thead>
<tr>
<th></th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%O</td>
<td>%B</td>
</tr>
<tr>
<td><em>Trichosurus</em></td>
<td>spp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>spp.</em></td>
<td>334</td>
<td>53.4</td>
<td>68.9</td>
</tr>
<tr>
<td>Lagomorph</td>
<td>67</td>
<td>10.7</td>
<td>13.8</td>
</tr>
<tr>
<td>Bandicoot</td>
<td>28</td>
<td>4.5</td>
<td>3.57</td>
</tr>
</tbody>
</table>

**Table 5.2:** Composition of medium-sized mammals in quoll diet from Jacobs River study area. N - number of occurrences, %O - percent occurrence, %B - percent biomass.
5.2.4 Small mammals

Small mammals were the second most frequently occurring prey category in the diet of spotted-tailed quolls in the Jacobs River study area (15.8% occurrence) but contributed only 2.5% of the dietary biomass. The frequency of occurrence of small mammals in quoll diet differed significantly during the study ($\chi^2 > 30$, d.f.=2, P<0.001), declining from 2002 to 2004 (Figure 5.4). The difference in small mammal occurrence between the years separated by the fire, 2002 and 2003, was highly significant ($\chi^2 = 22.35$, d.f.=1, P<0.001), whereas the difference between 2003 and 2004 was not significant ($\chi^2 = 1.46$, d.f.=1, P=0.226).

Composition of the small mammal prey category, comprised of rats, *Antechinus* spp. and other small mammals, differed significantly between the years of the study ($\chi^2 = 10.22$, d.f.=4, P=0.037). This was mainly due to a large decrease in the occurrence of *Rattus* spp. from 2002 to 2003 following the fire (Figure 5.4), a result discussed further below.

![Figure 5.4: Percent occurrence and composition of small mammals in quoll diet from the Jacobs River study area 2002-2004.](image)

*Rats - black rat and bush rat*

*Rattus* spp. dominated the small mammal component of quoll diet in the Jacobs River study area, and interestingly it was the introduced black rat that was by far the most commonly eaten small mammal. In 2002, in the winter prior to the
fire, black rat was the second most frequently occurring prey item in quoll diet at 15.2% occurrence, compared with just 2.9% occurrence for the bush rat (Table 5.3). However, across the three years of the study the amount of black rat in scats differed significantly ($\chi^2 > 30$, d.f.=2, $P<0.001$), and as is evident in Figure 5.4, this was due to a significant reduction between 2002 and 2003 ($\chi^2 = 22.11$, d.f.=1, $P<0.001$).

<table>
<thead>
<tr>
<th></th>
<th>2002</th>
<th></th>
<th>%O</th>
<th>%B</th>
<th>2003</th>
<th></th>
<th>%O</th>
<th>%B</th>
<th>2004</th>
<th></th>
<th>%O</th>
<th>%B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black rat</td>
<td>95</td>
<td>15.2</td>
<td>3.48</td>
<td>11</td>
<td>4.1</td>
<td>0.8</td>
<td>27</td>
<td>4.7</td>
<td>1.0</td>
<td>7</td>
<td>1.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Bush rat</td>
<td>18</td>
<td>2.9</td>
<td>0.51</td>
<td>3</td>
<td>1.1</td>
<td>0.2</td>
<td>7</td>
<td>1.2</td>
<td>0.2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rattus sp.</td>
<td>5</td>
<td>0.8</td>
<td>0.16</td>
<td>1</td>
<td>0.4</td>
<td>0.1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 5.3: Composition of rat in quoll diet from Jacobs River study area 2002 – 2004. N - number of occurrences, %O - percent occurrence, %B - percent biomass.

5.2.5 Large mammals

Large mammals that occurred in the diet of the spotted-tailed quoll in this study included the swamp wallaby, eastern grey kangaroo, wombat and red-necked wallaby, although only a single scat contained hair of the red-necked wallaby. It is assumed that these prey items were scavenged and not hunted, although it is possible that quolls could prey on young-at-foot macropods. Combined for all years, large mammals were the third most frequent items in quoll scats with 8.3% occurrence, but the second most important category by biomass with a contribution of 9.9%. As with the other major prey categories, the frequency of occurrence of large mammal in the diet across the study was significantly different ($\chi^2 = 21.87$, d.f.=2, $P<0.001$). As shown in Figure 5.5, there was a significant increase in the occurrence of large mammals in scats in 2003 following the fire when compared with both 2002 ($\chi^2 = 19.56$, d.f.=1, $P<0.001$) and with 2004 ($\chi^2 = 12.83$, d.f.=1, $P<0.001$). This strongly suggests that
availability of large mammals increased in the period directly following the fire, and this is further supported by the fact that there was no significant difference in the frequency of large mammal in scats between 2002 and 2004 ($\chi^2=0.76$, d.f.=1, $P=0.382$). The increase in 2003 of large mammals in the diet resulted from increases of occurrence of the three composite species for this group, discussed below.

![Diagram](attachment:figure5.5.png)

**Figure 5.5:** Percent occurrence and composition of large mammals in quoll diet from the Jacobs River study area 2002-2004.

*Swamp wallaby*

Swamp wallaby was the fourth most common prey item in quoll diet for this study with an overall occurrence of 5.4% and importance of 6.48% by biomass (Table 5.4). While there was an increased frequency of occurrence in scats in 2003, there was no significant difference in swamp wallaby in the diet of quolls either across the whole study ($\chi^2=2.92$, d.f.=2, $P=0.232$) or between any of the three years: 2002 and 2003 ($\chi^2=2.84$, d.f.=1, $P=0.92$), 2003 and 2004 ($\chi^2=1.57$, d.f.=1, $P=0.21$).

*Eastern grey kangaroo*

Eastern grey kangaroo was a relatively minor component of quoll diet in this study with an overall frequency of occurrence in scats of 1.5% and a
contribution of just 1.8% by biomass. As shown in Figure 5.5 and Table 5.4, the number of scats containing kangaroo hair was greatest in 2003 following the fire.

**Wombat**

Wombat, like eastern grey kangaroo, was a minor dietary component of quolls in this study. As illustrated in Figure 5.5 and detailed in Table 5.4, frequency of occurrence peaked in 2003 following the fire, before returning to low levels again in 2004.

<table>
<thead>
<tr>
<th></th>
<th>2002</th>
<th></th>
<th></th>
<th>2003</th>
<th></th>
<th></th>
<th>2004</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%O</td>
<td>%B</td>
<td>N</td>
<td>%O</td>
<td>%B</td>
<td>N</td>
<td>%O</td>
</tr>
<tr>
<td>Swamp wallaby</td>
<td>29</td>
<td>4.6</td>
<td>6.0</td>
<td>20</td>
<td>7.4</td>
<td>8.5</td>
<td>30</td>
<td>5.2</td>
</tr>
<tr>
<td>Eastern grey</td>
<td>6</td>
<td>1.0</td>
<td>1.2</td>
<td>11</td>
<td>4.1</td>
<td>4.7</td>
<td>5</td>
<td>0.9</td>
</tr>
<tr>
<td>kangaroo</td>
<td>2</td>
<td>0.3</td>
<td>0.4</td>
<td>10</td>
<td>3.7</td>
<td>4.2</td>
<td>7</td>
<td>1.2</td>
</tr>
</tbody>
</table>

**Table 5.4:** Composition of large mammal in quoll diet from Jacobs River study area 2002 – 2004. N - number of occurrences, %O - percent occurrence, %B - percent biomass.

### 5.2.6 Non-mammalian prey

While the majority of food items of the spotted-tailed quoll in this study were mammalian, non-mammalian prey occurred in 7% of scats. These items, broadly listed as birds, insects, plants and reptiles, only contributed an estimated 0.4% of the biomass of prey consumed. As the collection of scats for dietary analysis occurred during the cooler months from late April to early September, the occurrence of reptiles and insects in the diet was expected to be low due to these groups relative inactivity at this time. No scats collected in 2003, following the fire, contained reptile scales or plant material.
Over the three years of the study the occurrence of non-mammalian prey in quoll scats was significantly different ($\chi^2=9.83$, d.f.=2, $P=0.007$) although there was no significant difference in occurrence between consecutive years. The frequency of occurrence of scats containing non-mammalian prey rose over the three years of the study to a peak of 9.6% in 2004, driven by an increase in frequency of bird and insect (Figure 5.6).

![Figure 5.6: Percent occurrence and composition of non-mammalian prey in quoll diet from the Jacobs River study area 2002-2004.](image)

**Figure 5.6:** Percent occurrence and composition of non-mammalian prey in quoll diet from the Jacobs River study area 2002-2004.

**Birds**

Although the overall contribution to quoll diet of non-mammalian prey was small, particularly by the measure of biomass, birds were the fifth most common prey item to be found in scats (Table 5.5). The occurrence of birds rose throughout the study but there was no significant difference in the occurrence of birds in the diet across or between the years.

<table>
<thead>
<tr>
<th></th>
<th>2002</th>
<th></th>
<th>2003</th>
<th></th>
<th>2004</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%O</td>
<td>%B</td>
<td>N</td>
<td>%O</td>
<td>%B</td>
</tr>
<tr>
<td>Bird</td>
<td>17</td>
<td>2.7</td>
<td>0.3</td>
<td>12</td>
<td>4.5</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>5.2</td>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 5.5:** Bird in quoll diet from Jacobs River study area 2002 – 2004. N - number of occurrences, %O - percent occurrence, %B - percent biomass.
5.2.7 Diet of the spotted-tailed quoll in the Devils Hole Creek area

Seven dietary items were identified from scats collected from the Devils Hole Creek latrine, compared with 26 from the more than 60 latrines in the Jacobs River area (Table 5.6). Medium-sized mammals comprised almost all of the prey items in each of the three years, including all of the prey for 2003 (Figure 5.7), and subsequently dominated overall diet of quolls utilising this latrine (93.3% occurrence, 98.3% biomass). Of the medium-sized mammals present in scats, brushtail possum occurred in 89 of the 104 (85.6%) scats collected, and rabbit/hare only 5 (4.8%). Bird (6 scats, 5.8%), platypus (2 scats, 1.9%) and long-nosed bandicoot, black rat and swamp wallaby (1 scat each) comprised the rest of the diet. There was no significant difference in the frequency of occurrence of medium sized mammals in the diet of quolls from this latrine across the years of the study ($\chi^2=5.03$, d.f.=2, P=0.08).

<table>
<thead>
<tr>
<th></th>
<th>All Years (104 scats)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>% occurrence</td>
<td>% biomass</td>
</tr>
<tr>
<td><strong>Small mammals</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R. rattus</td>
<td>1</td>
<td>1.0</td>
<td>0.2</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>1.0</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>Medium-sized mammals</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trichosurus sp.</td>
<td>89</td>
<td>85.6</td>
<td>91.1</td>
</tr>
<tr>
<td>Oryctolagus cuniculus/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lepus capensis</td>
<td>5</td>
<td>4.8</td>
<td>5.1</td>
</tr>
<tr>
<td>Perameles nasuta</td>
<td>1</td>
<td>1.0</td>
<td>0.6</td>
</tr>
<tr>
<td>Ornithorhynchus anatinus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>97</td>
<td>93.3</td>
<td>98.3</td>
</tr>
<tr>
<td><strong>Large mammals</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wallabia bicolor</td>
<td>1</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bird</td>
<td>6</td>
<td>5.8</td>
<td>0.5</td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
<td>5.8</td>
<td>0.5</td>
</tr>
<tr>
<td>D. maculatus (grooming)</td>
<td>4</td>
<td>3.8</td>
<td>-</td>
</tr>
</tbody>
</table>

**Table 5.6:** Food items identified in scats of the spotted-tailed quoll collected from the Devils Hole Creek latrine from 2002 to 2004.
5.2.8 Diet by sex

The diet of female and male quolls was compared through collection of scats from live-captured animals in the Jacobs River study area. In total, 177 scats were collected from traps, comprising 87 scats from female quolls and 90 scats from male quolls.

*Overall diet*

Nineteen prey species or food items were identified from these scats, including 16 mammals and three non-mammalian prey items (Table 5.7). Analysis of overall diet by prey category revealed no significant difference in composition of diet between females and males ($\chi^2=7.09$, d.f.=3, P=0.069). However, closer examination reveals slight differences with respect to consumption of some prey items. Medium-sized mammals occurred significantly more frequently in the diet of male quolls than of females ($\chi^2=4.96$, d.f.=1, P=0.026). While at the prey item level brushtail possum *Trichosurus* spp. and lagomorphs were the top two items for both females and males by both frequency of occurrence and percentage biomass, their relative contribution to the diet of the different sexes was significantly different ($\chi^2=7.55$, d.f.=1, P=0.006). Males ate possums...
significantly more frequently than females ($\chi^2=11.90$, d.f.=1, $P<0.001$). Conversely, females (21.8% occurrence, 29.9% biomass) preyed on a higher proportion of lagomorphs than males (12.2% occurrence, 15.3% biomass), although the result was not significant ($\chi^2=2.91$, d.f.=1, $P=0.088$).

<table>
<thead>
<tr>
<th></th>
<th>Female quolls (87 scats)</th>
<th>Male quolls (90 scats)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%O</td>
</tr>
<tr>
<td><strong>Small mammals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>R. rattus</em></td>
<td>7</td>
<td>8.0</td>
</tr>
<tr>
<td><em>Antechinus agilis</em></td>
<td>3</td>
<td>3.4</td>
</tr>
<tr>
<td><em>R. fuscipes</em></td>
<td>1</td>
<td>1.1</td>
</tr>
<tr>
<td><em>Mus musculus</em></td>
<td>2</td>
<td>2.3</td>
</tr>
<tr>
<td><em>Petaurus breviceps</em></td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td><em>Rattus</em> sp.</td>
<td>1</td>
<td>1.1</td>
</tr>
<tr>
<td><em>A. swainsonii</em></td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>14</td>
<td>16.1</td>
</tr>
<tr>
<td><strong>Medium-sized mammals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Trichosurus sp.</em></td>
<td>26</td>
<td>29.9</td>
</tr>
<tr>
<td><em>Oryctolagus cuniculus</em>/</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Lepus capensis</em></td>
<td>19</td>
<td>21.8</td>
</tr>
<tr>
<td><em>Pseudocheirus peregrinus</em></td>
<td>2</td>
<td>2.3</td>
</tr>
<tr>
<td><em>Perameles nasuta</em></td>
<td>2</td>
<td>2.3</td>
</tr>
<tr>
<td><em>Dasyurus maculatus</em></td>
<td>1</td>
<td>1.1</td>
</tr>
<tr>
<td><em>Petauroidea volans</em></td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>50</td>
<td>57.5</td>
</tr>
<tr>
<td><strong>Large mammals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Wallabia bicolor</em></td>
<td>9</td>
<td>10.3</td>
</tr>
<tr>
<td><em>Macropus giganteus</em></td>
<td>2</td>
<td>2.3</td>
</tr>
<tr>
<td><em>Vombatus ursinus</em></td>
<td>2</td>
<td>2.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>13</td>
<td>14.9</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Insect</em></td>
<td>6</td>
<td>6.9</td>
</tr>
<tr>
<td><em>Bird</em></td>
<td>5</td>
<td>5.7</td>
</tr>
<tr>
<td><em>Plant</em></td>
<td>3</td>
<td>3.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>14</td>
<td>16.1</td>
</tr>
<tr>
<td><em>D. maculatus</em> (grooming)</td>
<td>12</td>
<td>13.8</td>
</tr>
</tbody>
</table>

Table 5.7: Diet of spotted-tailed quolls trapped in the Jacobs River study area by sex. N - number of occurrences, %O - percentage occurrence, %B - percentage biomass.

5.2.9 Diet by size classes

The higher predation of medium-sized mammals, particularly brushtail possums, by males than females, when coupled with the extreme sexual
dimorphism of the species (Jones et al. 2001), raises the question as to whether this is solely a function of the larger size of males. That is, do larger quolls eat larger prey? To investigate this question diet was examined by size class of individual quolls. Quolls were classified as being small females (<1.5 kg), adult females (1.5 - 2.25 kg), small males (<2.5 kg) or adult males (2.5 – 3.8 kg) based on their weight at first capture in each of the three years (Jones and Barmuta 1998; Belcher 2003). If a higher predation rate of larger prey was associated with greater body weight, then presumably there would be a significant difference in the occurrence of medium-sized mammals, or at least brushtail possums, between the diet of small males and adult males.

Figure 5.8 illustrates the composition of diet by age-sex classes of quolls captured in this study. Rather than revealing any significant difference in the amount of medium-sized mammals in the diets of small and adult male quolls, the result shows a high similarity ($\chi^2=0.04$, d.f.=1, P=0.8). As shown with overall diet by sex, significant differences were found in frequency of occurrence of medium-sized mammals between males and females, a result that does not appear to be related to size differences in individual quolls. Small sample sizes for other prey categories prohibited further statistical analyses.

![Figure 5.8](image)

**Figure 5.8:** Composition of diet by age-sex class of quolls. SF - small female, AF - adult female, SM - small male, AM - adult male.
5.3 Pre- and post-fire prey abundance

Indices of abundance were obtained throughout the study for three of the most common medium-sized mammal species and groups present in the diet of the spotted-tailed quoll – brushtail possums, lagomorphs, and the long-nosed bandicoot.

5.3.1 Brushtail possums

Results of spotlighting surveys to assess the abundance of brushtail possums are presented in Tables 5.8 and 5.9, and Figure 5.9. No other arboreal mammal species were observed during these surveys. In the unburnt habitat possums were seen on all transects, with a mean of 3.5 possums per transect (53 total, range 1 – 12, S.E = 0.70). The highest number of possums observed on a single transect was along the flat, lower reaches of Devils Hole Creek near the confluence with the Snowy River. In the intensely burnt habitat of the Jacobs River study area, possums were observed on only 6 of 15 transects (14 total, mean = 0.9, S.E.= 0.36) in 2003, and on 10 of 15 transects (23 total, mean = 1.5, S.E = 0.44) in 2004. Significance of differences between the years was tested using a single-factor ANOVA and showed that the mean number of possums per transect was significantly different between transects in unburnt habitat and those undertaken in the Jacobs River study area in the two years post-fire (p = 0.0025).
Table 5.8: Results of spotlighting surveys in unburnt rain-shadow woodland habitat in the Byadbo Wilderness.

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Topographic position</th>
<th>Brushtail possums</th>
</tr>
</thead>
<tbody>
<tr>
<td>24/06/04</td>
<td>Paupong Fire Trail</td>
<td>Ridge</td>
<td>6</td>
</tr>
<tr>
<td>24/06/04</td>
<td>Paupong Fire Trail</td>
<td>Ridge</td>
<td>3</td>
</tr>
<tr>
<td>24/06/04</td>
<td>Devils Hole Fire Trail</td>
<td>Ridge</td>
<td>1</td>
</tr>
<tr>
<td>24/06/04</td>
<td>Devils Hole Fire Trail</td>
<td>Ridge</td>
<td>3</td>
</tr>
<tr>
<td>24/06/04</td>
<td>Devils Hole Fire Trail</td>
<td>Ridge</td>
<td>4</td>
</tr>
<tr>
<td>24/06/04</td>
<td>Wellsmores Fire Trail</td>
<td>Mid</td>
<td>2</td>
</tr>
<tr>
<td>24/04/04</td>
<td>Devils Hole</td>
<td>Mid</td>
<td>3</td>
</tr>
<tr>
<td>24/04/04</td>
<td>Devils Hole</td>
<td>Mid</td>
<td>2</td>
</tr>
<tr>
<td>24/04/04</td>
<td>Devils Hole</td>
<td>Mid</td>
<td>3</td>
</tr>
<tr>
<td>24/04/04</td>
<td>Devils Hole</td>
<td>Mid</td>
<td>5</td>
</tr>
<tr>
<td>23/04/04</td>
<td>Devils Hole</td>
<td>Gully</td>
<td>2</td>
</tr>
<tr>
<td>22/04/04</td>
<td>Devils Hole</td>
<td>Gully</td>
<td>3</td>
</tr>
<tr>
<td>22/04/04</td>
<td>Devils Hole</td>
<td>Gully</td>
<td>12</td>
</tr>
<tr>
<td>22/04/04</td>
<td>Devils Hole</td>
<td>Gully</td>
<td>3</td>
</tr>
<tr>
<td>22/04/04</td>
<td>Devils Hole</td>
<td>Gully</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>53</td>
</tr>
</tbody>
</table>
### Table 5.9: Results of spotlighting surveys in burnt rain-shadow woodland habitat of the Jacobs River study area for 2003 and 2004.

<table>
<thead>
<tr>
<th>Location</th>
<th>Topographic position</th>
<th>2003 brushtail possums</th>
<th>2004 brushtail possums</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barry Way</td>
<td>Ridge</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Barry Way</td>
<td>Ridge</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Jacobs stock route</td>
<td>Ridge</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Jacobs stock route</td>
<td>Ridge</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Jacobs stock route</td>
<td>Ridge</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>East Central Hill</td>
<td>Mid</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>West Central Hill</td>
<td>Mid</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Barry Way</td>
<td>Mid</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Mid Ingebirah Ck</td>
<td>Mid</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Sentry Box</td>
<td>Mid</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Bark Camp Ck</td>
<td>Gully</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Ingebirah Ck</td>
<td>Gully</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Thatchers Mountain Ck</td>
<td>Gully</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Thatchers Mountain Ck</td>
<td>Gully</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Thatchers Mountain Ck</td>
<td>Gully</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td></td>
<td>14</td>
<td>23</td>
</tr>
</tbody>
</table>
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5.3.2 Lagomorphs and bandicoots

Assessment of abundance of medium-sized terrestrial prey were obtained through identification of feeding signs and scats of rabbits and hares and the diggings of long-nosed bandicoots (Figure 5.10). In 2002, prior to the fires of January 2003, 90 plots were searched throughout the Jacobs River area. Sign of lagomorphs and of bandicoot were identified in 52.2% and 41.1% of these plots respectively. In the two winters following the fires, 2003 and 2004, 90 and 86 plots respectively were surveyed. Significantly fewer plots with sign of lagomorphs ($\chi^2>30$, d.f.=1, P<0.001) and of bandicoot ($\chi^2=23.08$, d.f.=1, P<0.001) were recorded in 2003 than in 2002. In contrast to this decline observed in the winter directly following the January 2003 fires, plots surveyed in 2004 showed significantly higher frequencies of diggings for both lagomorphs ($\chi^2=10.26$, d.f.=1, P<0.01) and bandicoots ($\chi^2=4.81$, d.f.=1, P<0.05) compared with the observed frequencies in 2003. However, the frequency of diggings in 2004 was still significantly lower than that observed in 2002 prior to the fire for both lagomorphs ($\chi^2=9.01$, d.f.=1, P<0.01) and bandicoots ($\chi^2=7.33$, d.f.=1,

Figure 5.9: Results of spotlight surveys for possums in unburnt and burnt rain-shadow woodland habitat. N = 15 transects for each sample, each transect 500 m in length. Unburnt surveys conducted at alternate sites in Byadbo Wilderness, 2003 and 2004 surveys conducted in the Jacobs River study area. Error bars represent ± standard error of the mean.
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P<0.01).

![Graph showing abundance of selected medium-sized terrestrial prey based on plots with sign, Jacobs River study area, 2002-2004.](image)

**Figure 5.10:** Abundance of selected medium-sized terrestrial prey based on plots with sign, Jacobs River study area, 2002-2004.

### 5.4 Discussion

In this study analysis of scats provided a detailed picture of the range of prey consumed by spotted-tailed quolls in a rain-shadow woodland habitat, quite different from environments where the diet of the species has previously been investigated. In addition, since scat collection was undertaken both before and after a major wildfire, it was possible to examine how this predatory carnivore shifted diet to cope with changes caused by the disturbance event. The ecological interpretation of these different sets of information is now discussed.

#### 5.4.1 Overall diet

Analysis of spotted-tailed quoll scats from the Jacobs River study area identified that the species was predominately a predator of mammalian prey. In total, 22 species of mammals were recorded, more than the number of species recorded in most other previous studies (Alexander 1980; Boschma 1991; Belcher 1995; 2000b), although the single study of diet of the smaller sub-species of spotted-tailed quolls in northern Queensland revealed 29 mammal species from
highland rainforest habitat (Burnett 2001). In addition, the current study sampled quoll scats over the breeding season during which time previous studies on diet of carnivores have shown that incidence of mammals peaks in south-eastern Australia (Brunner et al. 1975; Belcher 1995).

Medium-sized mammals dominated the winter diet of spotted-tailed quoll in this study, a finding in accord with most previous studies on the diet of the species (Alexander 1980; Belcher 1995, 2000b; Jones and Barmuta 1998). However, unlike other studies brushtail possum was the most important prey item for quolls on both a frequency of occurrence and biomass basis, with lagomorphs the second most important prey. In other studies, common ringtail possum was the most important prey item overall in a study from open sclerophyll forest, with brushtail possum, greater glider and rabbit the other medium-sized mammals present in decreasing order of occurrence (Alexander 1980). A study of spotted-tailed quoll diet undertaken in an area encompassing four distinctly different habitat types (wet forest, rain-shadow woodland, tableland tall open forest, agricultural pasture) revealed rabbit as the primary prey species, followed by brushtail possum and ringtail possum (Belcher 1995). Interestingly, Belcher (1995) found that brushtail possum occurred more frequently than rabbit in winter. Young rabbits would be in the population mainly in spring and summer, a fact that may explain the predominance of brushtail possum in winter diet in this study. Spotted-tailed quolls inhabiting tall wet forest of the Great Divide east of Canberra preyed most frequently on greater glider (Belcher 2000b). The only study to date on diet of the spotted-tailed quoll in which a medium-sized mammal was not the most frequently occurring prey item was that undertaken in rainforests of the Wet Tropics Area of north Queensland on the diet of the northern subspecies (Burnett 2001). While a small mammal, the fawn-footed melomys *Melomys cervinipes*, was the most commonly occurring prey item in scats, medium-sized mammals made the greatest overall contribution to diet. Therefore, this finding illustrates both a reliance on (or preference for) medium-sized mammals, particularly over winter, as well as the flexibility of the species to utilise whatever is likely the most abundant prey in this size range in the wide variety of habitats it occupies.
As recorded in other studies (Alexander 1980; Belcher 1995; Burnett 2001) small mammals were the second most frequently occurring prey item, ahead of large mammals assumed to be taken as carrion. Habitat plays a key role in determining diet, illustrated by studies from tablelands tall wet forest in southern New South Wales and rainforest in northern Queensland that found small mammals to be an insignificant dietary component and the most commonly occurring item respectively (Belcher 2000b; Burnett 2001). While it would have been preferable to have done small mammal trapping pre- and post-fire as part of the current study, the prevalence of the introduced black rat in the diet of quolls from the Jacobs River, particularly before the fire, indicates that this species was likely particularly abundant and may have been suppressing populations of native species found more commonly in diet in other areas, such as bush rat and Antechinus spp. (Alexander 1980; Belcher 1995). The contribution of small mammals to quoll diet at Jacobs River was minimal when considered by biomass, a finding similar to a study containing similar habitats (Belcher 1995), but low compared to another from wet forest habitat in Tasmania (Jones and Barmuta 1998).

Large mammals occurred relatively infrequently in quoll scats in this study but were the second most important item by biomass. The frequency of occurrence of large mammals was low compared with that observed in other studies (Alexander 1980; Boschma 1991; Belcher 1995, 2000b; Jones and Barmuta 1998). One of these studies found large mammals to be at their lowest occurrence in winter and highest in summer, 5.5 – 21.9 percent occurrence, respectively (Belcher 1995). This winter figure is comparable to the frequency of occurrence of large mammals in quoll scats collected during winter from the Jacobs River study area.

The contribution of non-mammalian prey to diet in this study was low when compared with other studies, particularly that of invertebrate prey. This finding can likely be attributed to the winter period of scat collection when reptile and insect activity is at its lowest. Seasonal ranges of frequency of occurrence have been reported as 13.6% (winter) to 30.5% (autumn) for invertebrates, and
0% (winter) to 8.4% (spring) for reptiles (Belcher 1995).

5.4.2 Diet by sex

The overall winter diet of female and male spotted-tailed quolls was not significantly different in this study. This finding concurs with two other studies comparing diet of quolls by sex (Jones and Barmuta 1998; Belcher 2000b). A study of spotted-tailed quolls at Cradle Mountain in Tasmania found that in summer males consumed primarily medium-sized and large mammals, while females preyed predominantly on small mammals and birds. However, the diets of males and females did not differ in winter (Jones and Barmuta 1998). Similarly, comparison of male and female diet assessed from scats obtained from animals trapped during the winter breeding season in Badja and Tallaganda State Forests in south-eastern NSW found no differences in diet between the sexes, either in the range of prey items consumed or in any specified prey category (Belcher 2000b).

While differences were not apparent in overall diet in this study, male quolls were found to eat significantly more medium-sized mammals, particularly brushtail possums, than female quolls. This finding initially suggests that the relationship between body size and prey size suggested for quolls by other studies (Belcher 1995; Jones and Barmuta 1998) may indeed be operating in the Jacobs River study area. However, the high similarities in frequency of occurrence of all prey items in the diets of small male quolls and the much larger adult males shows that, in this case at least, sex rather than body size is the decisive factor in determining what prey quolls eat. Small and large quolls, both male and female, are able to kill prey larger than themselves, and do so regularly.

5.4.3 Impact of fire on prey availability and diet.

The collection of spotted-tailed quoll scats from latrines and live-trapped animals spanning both before and after an intense, extensive wildfire provided an opportunity to look at the ecological response of the species and its prey.
in a dramatically altered habitat. Dietary response of the spotted-tailed quoll to fire, be it high-intensity wildfire or low intensity fuel reduction burning, has not previously been examined. Context for the current set of findings is provided by comparing studies on the impact of fire on other quoll species, on other carnivores in Australia, and the response to fire of the main prey species and groups from this study. To understand the switches in prey that occurred at Jacobs River as a result of the fire, each prey category has been discussed below with reference to the prey availability assessments made during the study, existing literature, or both.

Medium-sized mammals

The most important prey category for spotted-tailed quolls prior to the fire, medium-sized mammals increased by frequency of occurrence after the fire, being significantly more common in scats both years after the fire than the year before. Over the same time in nearby unburned habitat of the Devils Hole Creek, frequency of medium-sized mammals remained consistently high in quoll scats. In the only other study to look at differences in the diet of spotted-tailed quolls between years there was no difference in the number of scats containing hair from medium-sized mammals (Belcher 1995). These comparisons support the conclusion that the increase of medium-sized mammals in the diet of quolls in the Jacobs River study area was in response to the fire and the differential response of the composite prey species, discussed below.

Brushtail possums

In the year following the intense wildfires of January 2003 brushtail possums, suffered significant declines in abundance before increasing slightly in the second year post-fire. This is consistent with finding of other studies (Heislers1974; Newsome et al. 1975; Newsome and Catling 1979; Newsome et al. 1983), whereby the initial short-term decline can be attributed to direct mortality of individuals (Newsome et al. 1975; Russell et al. 2003), subsequent predation (Russell et al. 2003) and the destruction of large numbers of hollow bearing trees, which reduces denning opportunities (Newsome et al. 1975;
Inions et al. 1989). The decline in possum abundance is reflected in a highly significant drop in the frequency of occurrence of brushtail possum in quoll scats between 2002 and 2003. That brushtail possum still occurred in approximately 40% of quoll scats in 2003 and 2004 suggests either that quolls continued to preferentially hunt for possums in landscape elements such as drainage lines and gullies where fire may have been less intense and provided refuges for possums (Newsome et al. 1975; Lunney 1987), or that those possums which did survive the fire were more vulnerable to predation due to the loss of secure dens and habitat structure to provide cover from predators (Newsome et al. 1975).

*Lagomorphs*

Predation of rabbits and hares throughout the study shows an opposite pattern to that of brushtail possums, with an increase in relative importance in the diet following fire. From a relatively low level of occurrence in 2002 prior to the fire, quolls ate a significantly higher numbers of lagomorphs in the first year after fire than before the fire, and this trend continued in 2004 to the point where the occurrence of lagomorphs and possum remains in scats was comparable. Interestingly, the occurrence of lagomorph sign dropped significantly after the fire before increasing in the second year. Rabbits, being burrowers, are able to survive the immediate impacts of fire better than most native species. The reduced structural complexity and new vegetative growth in the post fire environment provide an ideal habitat for surviving rabbits and they have been recorded increasing in abundance to above pre-fire levels in the short-term (Newsome et al. 1975; Newsome and Catling 1979; Catling and Newsome 1981; Newsome et al. 1983; Leigh et al. 1987; Catling 1991). At the Jacobs River, the data indicates that there was increasingly heavy predation of lagomorphs in the first year after the fire despite the lower abundance indices, a situation recorded with dingoes following severe wildfire in Nadgee Nature Reserve in south-eastern New South Wales (Newsome et al. 1983). Then, as rabbits increased rapidly in abundance over the following twelve months in the favourable open habitat, quolls continued to take further advantage of this
readily available prey. This may be particularly fortuitous for the quolls as their principal prey, brushtail possum, was much slower to recover.

*Long-nosed bandicoot*

The patterns of abundance index versus occurrence of long-nosed bandicoot in quoll scats shows a different effect of fire than for possums and rabbits. While the broad pattern of abundance revealed by diggings follows a similar highly significant decline after fire with an increase in the second year after fire, the only significant difference evident in quoll diet was a decline in frequency of occurrence from 2003 to 2004. It has been noted from previous studies that populations of bandicoots drop substantially after severe wildfire and that recently burned habitats appear to be less favoured by bandicoots (Newsome and Catling 1979; Catling 1991; Claridge and Barry 2000). Also, diggings of bandicoots in post-fire habitats may indicate increased activity if not abundance (Newsome et al. 1975). Indices of abundance and occurrence of bandicoots in the diet of dingo following wildfire followed a similar pattern to that observed in this study (Newsome et al. 1983). The discrepancy between the frequency of occurrence of bandicoots in quoll scats and the activity index of bandicoot diggings on plots may be in part due to the reliance of bandicoots on cover. A significant positive relationship between abundance of bandicoots and habitat complexity has been found in habitat recovering from wildfire and bandicoots are considered to be disadvantaged by simplification of habitat resulting from fire (Catling 1991; Catling et al. 2001). Bandicoots that survived the fire were more susceptible to predation by quolls in the year after fire due to a complete lack of ground and understorey cover, and that as cover returned in the second year the incidence of predation dropped, reflecting reduced abundance. The simultaneous increase in occurrence of lagomorph in quoll diet may also indicate to a switch in prey to this more available resource.

*Small mammals*

The occurrence of small mammals in the diet of spotted-tailed quolls in the Jacobs River study area was highly significantly different across the study.
While no monitoring of abundance of small mammals was conducted during this study, reference to extensive literature from previous research on the effect of fire on populations of small mammals is useful in interpreting the pattern of predation by quolls in relation to the likely effects of fire on this prey category.

Prior to the fire black rat was the second most common item in quoll diet at the Jacobs River study area, and small mammals occurred in almost one-in-four scats. Wildfire has been shown to decimate populations of small mammals and populations of some species may remain low for several years (Recher et al. 1974; Newsome et al. 1975; Newsome and Catling 1979; Fox 1982, 1990; Lunney et al. 1987). In particular, most studies suggest that Rattus spp. are relatively slow to recolonise burned habitats and occupy a ‘late regeneration niche’ with a regeneration time of 3 to 5 years post-fire (Fox 1982; Catling and Newsome 1981; Catling 1991). It has been suggested that the introduced black rat, in contrast to native Rattus species, may be advantaged by habitat simplification resulting from frequent fire by invading unoccupied niches (Catling 1991; Sutherland and Dickman 1999). The highly significant decline in occurrence of black rats and small mammals in general in quoll diet following the fire is therefore very likely to be the result of a crash in small mammal populations after the severe wildfire. Remains of bush rats were present in quoll diet in both years after the fire, albeit in significantly lower numbers. After appearing in low numbers in the diet in 2002 the dusky antechinus Antechinus swainsonii, a species heavily reliant on dense ground cover, was absent from scats collected in 2003 and 2004. Previous post-fire research has shown that this species is very sensitive to fire, resulting in local extinction for up to 6 years (Newsome et al. 1975; Newsome and Catling 1979; Lunney et al. 1987; Catling 1991). Previous studies also point to the likelihood of an irruption of house mouse commencing anywhere from 1 to 3 years after the fire (Recher et al. 1974; Newsome et al. 1975; Fox 1982; Newsome et al. 1983; Catling 1986; Lunney et al. 1987). While frequency of occurrence of house mouse in quoll scats had regained pre-fire levels within two years, there was no evidence of a ‘population explosion’, in that the frequency of occurrence remained relatively low. Alternatively, quolls may not necessarily take advantage of an increase in
abundance of mice even in the event of an irruption.

Large mammals

The consumption of large mammals in the diet of the spotted-tailed quoll peaked significantly in the winter breeding season that followed the fire. Of the three large mammal species recorded in scats in all three years of the study the diet in 2002, all recorded their highest occurrence and biomass contribution in 2003 before declining to levels approximating pre-fire levels in 2004. The red-necked wallaby appeared in only a single scat in 2002 even though they were frequently observed throughout the study area in all years (J. Dawson, personal observation). It was assumed that the occurrence of large mammal in the diet of the spotted-tailed quoll in this study is a result of scavenging (Belcher 1995; Jones et al. 2001). In the weeks directly following the fire, kangaroo, wallaby and wombat carcasses were observed by the author, which would provide a potentially large resource of carrion. However, these animals killed by the fire were not available as food at the end of April 2003 when trapping and scat collection recommenced. While carcasses were observed, it is likely that wombats largely escaped the immediate effects of the fire in burrows (Newsome et al. 1975; Newsome and Catling 1979). However, impact of fire on large mammal populations does not cease when the flames have passed. Large mammals suffer increased predation from dingoes following severe wildfire, and animals may die of starvation when, as in this case, ground cover is completely removed for many months after the fire (Newsome et al. 1975; Newsome and Catling 1979; Newsome et al. 1983). Thus the data strongly suggests that quolls took advantage of an increased availability of large mammals as carrion in the winter following the fire.

Other (non-mammalian) prey

It is also interesting to note the effect that the fire had on the contribution of the ‘other’ food items – birds, insects, plants, and reptiles. Overall the contribution of this group increased throughout the study by both occurrence and
biomass contribution, although the contribution to biomass remained very low. While these rises are not large, they do suggest a shift toward alternative foods as a result of declines in abundance of key mammal prey items after the fire.

5.4.4 Limitations

The analysis and description of the diet of spotted-tailed quolls in the Jacobs River study area point to the fact that the spotted-tailed quoll has great flexibility in its use of available food resources when its habitat is severely disturbed by wildfire and prey populations are perturbed. However, the conclusions of this chapter must be taken in context of some of the limitations of the study. Firstly, the data used to describe diet is highly seasonal, resulting from collection of scats over the winter breeding season only. Doubtless, different patterns would emerge were scats to have been collected throughout the years pre- and post-fire. Secondly, the lack of monitoring of abundance of some prey groups, particularly small mammals, requires that conclusions are based solely on research previously undertaken.
Chapter 6: Population studies

As previously stated, the initial intention of this study was to examine patterns of latrine use among spotted-tailed quolls in a rain-shadow woodland environment. Following the major wildfires of January 2003, the nature and scope of the study altered to examining short-term impacts of this disturbance event on the local population. Fortuitously, live-trapping work conducted during the winter of 2002 provided a baseline estimate of numbers of animals pre-fire. Post-fire, it was then decided to continue this trapping work to make further population assessments. The observational nature of this component of the study, as opposed to a structured experimental approach, places some significant constraints on the interpretation of results. That said, it must be recognised that the use of replicates and ‘treatment’ and ‘control’ (i.e. burnt and unburnt) sites in the study of ecological effects of wildfire in general, and in particular the investigation of impact of wildfire on a solitary carnivore with a large home range, is likely to be logistically impossible (Whelan 1995). The main intention of this chapter, therefore, is to highlight observed changes in population numbers and structure among the local quoll population in subsequent years. Through comparison with prior studies on the spotted-tailed quoll and other relevant species, it is possible to draw some conclusions as to the impact and subsequent recovery from wildfire of the spotted-tailed quoll population in the Jacobs River study area.

6.1 Methods

6.1.1 Live-trapping

Live-trapping for the spotted-tailed quoll was undertaken in the Jacobs River study area during the winter breeding season (May – September) over three consecutive years from 2002 to 2004. Trapping was carried out over at least four weeks in each of the three years. In 2002 trapping occurred on 25 nights between 28 May and 20 September for a total of 1108 trap nights, with traps open for between 3 and 11 consecutive nights. In 2003, trapping was carried
out between 29 April and 7 August for a total of 26 nights and 1091 trap nights, with traps open for up to 13 consecutive nights. In 2004 trapping was undertaken between 10 May and 24 June for a total of 22 nights and 1140 trap nights. In all years, and throughout all trapping periods, traps at a specific site were closed if an individual quoll was recaptured for three consecutive nights to reduce the instance of multiple recaptures and avoid capture stress.

Up to 61 wire mesh, platform operated cage traps (30 x 30 x 60cm; Mascot Wire Works, Sydney) were used per night. These were covered with plastic sheeting and baited with raw chicken pieces hung from wire at the back of the trap. Traps were stabilised in situ using rocks and pieces of wood to minimise disturbance of traps by quolls before or after capture. All traps were checked early each morning and rebaited when required to maintain fresh baits.

Traps were set at between 17 and 24 trap sites each night during any given trapping session (Figure 6.1). A trap site was defined as a cluster of one to three traps set adjacent to a latrine or in a drainage line. Usually, one trap was placed within 5 m of the latrine, supplemented by 1-2 traps within 15 m placed among the rock outcrop in which the latrine occurred, or within 30 m if the latrine was situated in a riparian corridor. In addition to trapping around latrines, clusters of traps placed approximately 15 m apart were also placed in drainage lines and at confluences of creeks that occurred within the study area. Trap sites were kept consistent throughout the study, with minor movement and some supplementary trapping within and between years.

All captured quolls were visually assessed in the trap for overall condition before being transferred to soft, thick cotton handling bags. Overall body condition was described and included a record of individually identifying markings, scars, injuries or lesions. Date of capture, site information and grid reference (13 digit, Australian Geodetic Datum 1966 (AGD66)) were recorded on standard data sheets. On first capture quolls were marked by implantation of a passive integrated transponder (PIT) tag (Trovan Microchips Australia), sexed and weighed. Pouches of all female quolls captured were inspected, with condition of pouch and number of enlarged nipples or pouch young present
noted. Quolls were then released at point of capture. Any scats left in traps by captured quolls were collected and placed in bags marked with date, site and details of individual quoll (see Chapter 5).

Capture rates were expressed as a percentage, calculated as number of quoll captures divided by the number of trap nights, multiplied by 100. Population size was estimated as the number of individual quolls captured in each year. It should be noted that the population studied could not be clearly defined by any distinct geographic boundary since suitable habitat was contiguous over a much broader landscape than that sampled by the traps.

6.1.2 Age classification

Age classifications were assigned to individual spotted-tailed quolls on first capture. This classification was broadly based on descriptions of body weight and shape, and tooth wear and loss described from other studies (Jones and Barmuta 1998; Belcher 2003; Körtner et al. 2004), and adapted based on observations of known age individuals monitored during the course of the current study. As trapping was carried out between May and September, all captured quolls were nearing the end of their annual cycle in terms of age. First year females weighed between 0.9 kg and 1.3 kg, had minimal to no tooth loss or wear, and no pouch development (indicating that they had not previously had litters). Males up to one year old weighed between 1.2 kg and 1.8 kg, were of a slender build and had sharp teeth, particularly canines. Second year females weighed between 1.2 – 1.6 kg, had good teeth, with occasional wear or tip breakage of canines. Second year males weighed 1.6 – 2.8 kg, were of a more solid build and were starting to show some tooth wear. Third year or older females weighed 1.8 – 2.3 kg, had developed pouches and showed an increasing degree of tooth wear, commonly with at least one broken canine. Third year or older males weighed 2.1 – 3.8 kg, were of robust, solid build and usually had at least one canine tooth broken or missing. Quolls aged 4 and possibly 5 years old were trapped, however unless previous trapping was available to provide additional information they were categorised as being at least 3 years old (3+).
Chapter 6: Population studies

Figure 6.1: Location of trap sites within the Jacobs River study area 2002-2004.
Through the use of microchips individual quolls were able to be identified through consecutive years. When combined with estimates of the age of each individual a picture of overall demographic structure of the population was developed in each of the three years, providing insights into the relative importance of recruitment and immigration to maintenance of the study population.

6.2 Results

6.2.1 Capture information

Over the three years of the study, capture effort of 3339 trap nights resulted in the capture of 49 individual quolls (21 female: 28 male) on a total of 331 occasions. This represented an overall capture rate of 9.9%, or 1.5 new quolls per 100 trap nights. Quolls were captured on average 6.9 times each, with 13 individuals captured on only one occasion. When these 13 single captures are excluded, the remaining 36 individuals were captured on an average of 9.1 occasions, indicating that some quolls become accustomed to traps, which has been observed in other studies (Körtner et al. 2004).

Over the three years of the study captures of male and female quolls were almost equal, representing 48.6 % and 51.4 % of all captures respectively, although this varied significantly between years ($\chi^2=17.08$, d.f.=2, p<0.001). In 2002, males and females accounted for 58% and 42% of captures respectively, yet following the fire the proportions were significantly different, with 69% of captures being females and only 31% male ($\chi^2=14.61$, d.f.=1, p<0.001). This was mainly due to female capture bias in 2003 since the proportion of male to female captures was not significantly different between 2002 and 2004 ($\chi^2=0.004$, d.f.=1, p=0.947).

The number of quolls caught varied between years of the study (Figure 6.2). Prior to the fire in 2002, 22 quolls (9 female: 13 male) were caught a total of 127 times from 1108 trap nights. This represented an overall capture rate of 11.5%, with new animals being trapped at a rate of 2 per 100 trap nights. In 2003, in
the first breeding season after the January fires, 16 quolls (11 female: 5 male) were captured a total of 83 times from a total of 1091 trap nights. The overall capture rate declined to 7.6%, or 1.5 new animals per 100 trap nights. In 2004, the last winter breeding season sampled by this study, 25 quolls (9 female: 16 male) were captured on 121 occasions from 1140 trap nights, representing a capture rate of 10.6%. An additional micro-chipped female was captured in the study area in spring 2004 during separate research (Monica Ruibal, ANU, personal communication), bringing the number of quolls caught in the study area in that year to 26.

Figure 6.2: Number of female and male quolls captured in the Jacobs River study area, 2002-2004. Figures in brackets represent the number of trap nights.

The trappable population of quolls within the study area was effectively sampled in each of the three years. As can be seen in Figure 6.3, the incidence of unmarked (i.e. non- micro-chipped) quolls reached a plateau in 2002 and 2003 after approximately 750 trap nights of effort. In contrast, new animals continued to be captured toward the end of the trapping period in 2004, indicating that the number of quolls for that year may be an underestimate. This likelihood was confirmed by the additional spring capture described above. The number of quolls for the 2004 season had, however, already eclipsed that of the previous two years, indicating that even using conservative estimates the population had
recovered to a number that exceeded those observed pre-fire.

![Graph showing cumulative number of quolls captured compared with cumulative number of trap nights in Jacobs River study area, 2002-2004.]

**Figure 6.3:** Cumulative number of quolls captured compared with cumulative number of trap nights in Jacobs River study area, 2002-2004.

### 6.2.2 Distribution of captures.

#### 2002

The distribution of the quoll population across the Jacobs River study area was described by mapping the number of individual quolls captured at the various trap sites in each of the three years. In 2002, the 22 individual quolls were captured at 16 different sites throughout the study area, with only one trap site recording no captures (Figure 6.4). The number of individual quolls captured at each site ranged from zero to seven (mean = 3.2, S.E. = 0.47), with the majority of trap sites recording between three and four individuals (median = 3; Figure 6.5). The highest number of individual quolls recorded at a trap site was seven, for two sites in the northern section of the study area, named ‘Grass Tree’ (two female: five male) and ‘Upstairs’ (one female: six male). The number of total captures at each site varied from one to 16, with a mean of 7.5 captures per site (S.E. = 1.19). A maximum of two females was captured at any single site throughout the trapping period, compared with up to six different males.
**Figure 6.4:** Distribution and number of captures of individual spotted-tailed quolls at trap sites in the Jacobs River study area, 2002.
In the year following the fire, the distribution pattern of captures of quolls across the study area was notably different to that observed in 2002 (Figure 6.6). Of the 21 sites at which traps were set quolls were captured at 18, with three sites recording no captures. Between one and six quolls were captured at any given site (mean=1.8, S.E.=0.34), and significantly fewer individual quolls were captured per site compared with 2002 (Students T-test; t=2.46, d.f=37, p=0.019). Less than 2 quolls were caught at the majority of trap sites (median = 1; Figure 6.7). The number of captures at each site, including recaptures, ranged from 0 to 12 (mean = 4.0, S.E. = 0.75). Few quolls, relative to the numbers captured in 2002, were caught in the northern section of the study area over which the impact of the fire was uniformly very high. This was particularly notable for the trap sites in the north east of the study area where no more than two individuals were captured in an area in which up to seven individuals had been recorded in 2002. There was little difference from 2002 in the number of individual quolls trapped at sites in the southern-most section of the study area along the lower reaches of the Jacobs River, over which the impact of the fire was generally moderate to low. Interestingly, in 2003 four female quolls were captured at a single trap site, at the junction of the Jacobs River.
River and Thatchers Mountain Creek. In contrast, the maximum number of males recorded at a trap site was three, at a site named ‘El Primo’ in the lower reaches of Ingebirah Creek where, perhaps surprisingly, no females were captured.
Figure 6.6: Distribution and number of captures of individual spotted-tailed quolls at trap sites in the Jacobs River study area, 2003.
In the 2004 winter breeding season, 24 sites were trapped across the study area, 21 of which caught quolls (Figure 6.8). Between zero and seven individual quolls were captured at each site, with a mean of 3.0 (S.E = 0.39). The majority of sites recorded 2-3 individuals (median = 3; Figure 6.9). Seven quolls were captured at ‘Upstairs’, including a season-high of five males, the high success at this site similar to that in previous years. The highest number of females trapped at a site was three (plus three males) at ‘Double Gully’. Total captures at trap sites ranged from zero to 12 (mean = 5.0, S.E = 0.63). The distribution of quolls across the study area was more even than observed post-fire in 2003, with at least 2-3 quolls caught at sites in the north eastern section of the study area where only single individuals had been present in 2003. More quolls were also caught in the southern section compared to 2003, with up to 5 animals recorded from these sites, up from a maximum of three from 2003.
Figure 6.8: Distribution and number of captures of individual spotted-tailed quolls at trap sites in the Jacobs River study area, 2004.
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6.2.3 Population demographics

*Individual persistence*

The use of microchips for identification of individual quolls, and the classification of quolls into age/sex classes, allowed the persistence of individuals to be tracked from year to year and the structure of the population within and between years to be described and compared. There was a high rate of turnover in the population between years (Table 6.1). Of the 49 individuals captured and marked, 37 (75.5%) were captured in only one of the three years, although it must be noted that new animals caught in 2004 were unable to be subsequently recaptured following the conclusion of the study. Ten quolls (20.4%) were captured in 2 consecutive years, and only 2 quolls (4.1%) were present in the study area in all three years.

The turnover of the population, measured by the proportion of marked quolls recaptured in successive years, varied between the years. Of the 22 quolls captured prior to the fire in 2002, six (27%) were present in the study area in 2003, comprising 4 of 9 females (44%) and 2 of 13 males (15%). Nine of the 16 quolls captured in 2003 were recaptured in 2004, a persistence rate of 56%.

**Figure 6.9:** Number of trap sites at which between zero and seven individual quolls were captured in the Jacobs River study area, 2004.
This comprised 5 of 11 females (45%) and 4 of 5 males (80%) that had been trapped in 2003. Only one female and one male quoll were captured in all three years of the study. The female was likely a first year individual when captured in 2002 and was still in good condition at the end of trapping in 2004. She carried pouch young in all three breeding seasons. The male was estimated to be two years of age in 2002, and was losing weight and condition throughout the 2004 survey period, indicating that at four years old he was probably unlikely to last another year. The oldest female recorded was four years old, first captured as a three year old in 2002 and subsequently recaptured post-fire in 2003. This female’s weight had declined from 2.25 kg in 2002 to 1.85 kg in 2003, and she was the only one of the 6 quolls recaptured following the fire that had a reduced weight from the previous breeding season.

**Sex ratios**

Over the three years of trapping carried out in the Jacobs River study area more male quolls than female quolls were captured and marked (Table 6.2). Including individuals of all ages, 28 males and 21 females were trapped, a ratio of 1.33:1. The proportions of males and females present in the study area varied considerably between years. There were more males than females in both 2002 and 2004, however in the year directly following the fire more than twice the number of females than males were caught. This pattern was also apparent in the ratio of adult males to adult females, with an almost direct ratio reversal in 2003 compared with that observed in both 2002 and 2004. As the number of females captured remained stable in each of the three years, the changes in relative proportions of sexes present was due to the very low number of adult males, and indeed males overall, present in the study area in 2003. Whether this is due to a higher fire induced mortality of resident males, or perhaps a wider dispersal out of the study area due to the poor quality of the habitat post-fire is unclear. Potential reasons for this discrepancy are examined in the Discussion section at the end of this chapter.
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**Table 6.1:** Persistence of individual quolls between years in the Jacobs River study area, 2002-2004. Darkened cells indicate animal captured during relevant year.
### Table 6.2: Age and sex structure of the spotted-tailed quoll population in the Jacobs River study area, 2002-2004. Figures in brackets represent number of individuals in a given age group that were present in the study area in the previous winter breeding season.
Age structure

In 2002 there was a relatively even age distribution across the population, with similar numbers of first and second year females and males, but twice the number of males than females at least three years of age (Table 6.2). The presence of eight first year animals in the study area was the highest recorded of the three years. However, post-fire in 2003 the age structure of the population was markedly different; the most notable change was that only 3 adult males were captured, compared with the 9 from the previous year. A total of 6 adult females were trapped, yet there was only one female in the 3+ age category. In 2004, 18 months after the fire, the structure of the population had altered. While the age structure of the female component of the population was again relatively even, the numbers of adult males caught increased to 14, up from 3 in the previous winter.

The ratio of adult males to juvenile males was higher than that of adult females to juvenile females in all three years of the study (Table 6.2). When sexes were combined for comparison between years, the ratio of adults to juveniles was considerably greater in 2004 than in the previous two years. This pattern is apparent for both males and females, with the ratio being as large as 7:1 for adult males in 2004. It should be noted that the while the fire occurred in January 2003, any young present in the population in the winter of 2003 would have been independent at that time. Young born in the 2003 breeding season would have been raised in the post-fire environment when prey resources were reduced, potentially making it more difficult for females to find sufficient food to successfully raise and wean litters.

Recruitment and immigration

As shown in Figure 6.3, the trappable population of quolls within the study area was considered to be adequately sampled in each of the three years of the study. As such, the presence of previously undetected quolls in 2003 and 2004 can most likely be attributed to either recruitment in the population (first year animals from the previous years litter), or immigration (unmarked adult quolls).
A third, perhaps less unlikely explanation given the trappability of the species, is that these individuals were present in the population but not trapped. As discussed above, the number of first year quolls was highest in 2002 and lowest in 2004 (Table 6.2), indicating that there was a lower level of recruitment to the population after the fire. Interestingly, for a species in which there is evidence of natal philopatry (Firestone et al. 1999; Belcher and Darrant 2004, Claridge et al. 2005), two new adult females were trapped in the population in 2003 and 2004, indicating a degree of female immigration. The story for males is somewhat different, however. Only one new adult male was captured in the study area in 2003 following the fire, compared with the presence of 10 new adult males in the winter of 2004.

6.3 Discussion

In this study, live-trapping provided information about the size, demographic structure and distribution of a spotted-tailed quoll population over three years in a rain-shadow woodland habitat, quite different from habitats where the species has previously been investigated. In addition, since trapping was undertaken both before and after a major wildfire, it was possible to examine how the population survived and recovered following the severe disturbance. Interpretation of the results presented above is now discussed.

6.3.1 Population survival and recovery

The major finding arising from the live-trapping component of the study is the survival and short-term recovery of the quoll population in the Jacobs River study area after high-intensity wildfire affected almost the entire study area. Data on the population from the current study, including number of quolls caught and trap success rates, suggest a small, short-term decline in population size for the breeding season immediately post-fire, followed by a recovery to levels proximate with, and even exceeding, that observed pre-fire in the winter of the second year post-fire. This finding is consistent with studies on the impact of habitat disturbance on other carnivores in general in Australia, including other species of quoll. For example, a population of the northern
quoll did not suffer from increased mortality immediately after a high-intensity fire, nor did the numbers of animals known to be alive decrease over the subsequent year (Begg et al. 1981). Furthermore, no detectable differences in body weight were noted, and there was no measured change in habitat usage (Begg et al. 1981). High-intensity wildfire appeared to have no immediate impact on dingo populations at Nadgee Nature Reserve in south-east New South Wales (Newsome et al. 1983; Catling et al. 2001). While declines in numbers of foxes and cats were observed following the same fire, this most likely was associated with a decline in numbers of small mammals. The abundance of both introduced carnivores increased as habitat structure was restored, providing shelter for recovering prey populations (Newsome et al. 1975).

Overall, the size of the spotted-tailed population in the Jacobs River study area varied surprisingly little over the three years of the study, despite major perturbation to the site. Indeed, the few previous studies with data on the species that cover a similar time-frame have concluded that there is a high turnover in wild populations right across the range of the species and the habitats in which they are found (Burnett 2001; Körtner et al. 2004). The population sizes encountered in this study were relatively small and the differences between years are within the range observed in other wild populations that have not been severely perturbed. For example, the size of a population monitored for 26 months in northern New South Wales varied only slightly, ranging between 20 and 26 individuals known to be alive, despite apparent high mortality and short life span of individuals (Körtner et al. 2004). Similarly, a study in which trapping was undertaken over three consecutive breeding seasons in the Wet Tropics of northern Queensland recorded between 6 and 14 individuals on one trapping transect, yet the estimated the size of the wider spotted-tailed quoll population in the area remained stable at between 81 and 86 individuals in each of the three years (Burnett 2001). Against the background of inter-annual variation of these other studies, it is difficult to conclude that wildfire had any significant effect on the overall population size of spotted-tailed quolls in the current study.
Exactly how individual spotted-tailed quolls may have survived the immediate impact of such a severe fire is subject to speculation. However, studies on the effect of fire on fauna, including other members of the genus *Dasyurus*, provide some clues. The northern quoll is found across areas of northern Australia in which fire is an integral part of the landscape, with annual burning covering vast areas (Oakwood 2000). Several studies have found that populations of northern quolls that occur in rocky habitats are more secure from both the immediate and secondary impacts of fire than those in open lowland habitats (Begg *et al.* 1981; Oakwood 2000). In fact, there was no apparent immediate impact of fire on a population of northern quolls studied in rocky habitat, with logs, rocks and burrows providing sufficient protection (Begg *et al.* 1981).

The average capture success of spotted-tailed quolls at Jacobs River was 9.9%, a relatively high figure compared with other studies, suggesting a relatively high density population. The trapping methodology used in this study, which focused largely on identification of active latrine sites and subsequent targeted trap placement, is likely to have contributed to the high capture rate. Trapping at latrine sites of the species has previously been shown to result in the capture of multiple quolls over a period of just a few days (Belcher 1995; Kruuk and Jarman 1995). Trapping success when effort is not targeted at an ecological focal point for the species is often lower, and most commonly this is undertaken along roads that provide access to otherwise inaccessible, large forested areas with steep dissected terrain and dense vegetation (Watt 1993; Körtner *et al.* 2004). Trap success rates in such instances range from as little as 0.15% in what was presumably a low density population (Watt 1993), to 4% in an area with a known high density population (Körtner *et al.* 2004). The highest reported capture rate for the spotted-tailed quoll comes from northern Queensland, in which a trap success rate of 11% was achieved over three years by trapping along roads (Burnett 2001). Notably, roads also functioned as latrines in that latter population, providing the ecological focal point for the species at which to target trapping to achieve maximum success.
6.3.2 Population demographics

From a numeric point of view the overall population at Jacobs River did not appear to suffer significantly as a result of the fire. However, there were notable differences in population structure between the three years of the study. These differences include variations in sex ratios and age structure of the quoll population that persisted in the study area in the year following the fire compared with that observed pre-fire and the 2004 breeding season, 18 months following the disturbance.

Sex ratios

The fact that there was little difference in the overall numbers of male and female quolls captured during the course of this study belies the fluctuations in the proportional representation of the sexes between the years at Jacobs River. Even numbers of male and female spotted-tailed quolls has only been found in a single study of north Queensland populations (Burnett 2001), and is unusual in south-eastern Australia. In the current study, the trapping results for the breeding seasons immediately prior to the fire and 18 months post-fire are in accord with that found in most other studies (Watt 1993; Jones and Barmuta 1998; Belcher 2000b; Körtner et al. 2004), i.e. more males captured than females, in terms of both numbers of individual quolls and total number of captures. For example, in recently published research from northern New South Wales, males represented 74% of the 85 quolls trapped over three years (Körtner et al. 2004). Estimates from non-trapping studies (road kills, museum specimens, quolls killed in chicken coops) paint an even more male-biased picture, with ratios of 11 males per female suggested for Victoria and 3.5:1 for Tasmania (Mansergh 1984; Green and Scarborough 1990; Jones et al. 2001). Explanations for this bias include the fact that males have larger, overlapping home ranges, meaning more male home ranges will intersect with traps – i.e. males move further and are more likely to encounter traps (Belcher and Darrant 2004; Körtner et al. 2004; Claridge et al. 2005).
In the post-wildfire environment of the Jacobs River study area (winter 2003) a very different population structure was recorded, with female quolls outnumbering males by more than two to one. Numbers of females, both in terms of individuals and total captures, remained high between breeding seasons as has been observed in north Queensland spotted-tailed quoll populations due to replacement by new females (Burnett 2001). Females have been found to be more trappable than males at times of the year coinciding with lactation and a likely high energy requirement during rearing (Burnett 2001), but trapping was finalised in early August, prior to this period of highest food stress for females. As the difference was not due to an increase in the female population, the discrepancy in sex ratios between years lies with the fact that only five males turned up in the study area in 2003, compared with the 13 captured prior to the fire and 16 one-and-a-half years post-fire.

Two possible explanations may provide the answer to the case of the missing males. Firstly, it may be that there was a differential mortality between male and female spotted-tailed quolls as a direct result of the fire, leading to the low number of males present in the study area in 2003. This could potentially arise if males chose den or refuge sites that did not provide sufficient protection from the direct effects of fire, such as tree or log dens rather than sub-surface sites among rock outcrops or disused rabbit or wombat burrows. Unfortunately, there is no published information on den selection of the species, let alone differences between sexes. Based on radio tracking of quolls undertaken in the study area in 2002, it appeared that there was no shortage of sub-surface dens available (DEC, unpublished data). If differential mortality occurred between the sexes, the appearance of 10 new adult males in the study area in 2004 is hard to reconcile.

Secondly, spotted-tailed quolls are not evenly distributed in the landscape (Belcher and Darrant 2004). Males have very large home ranges and are capable of long distance movement, even over relatively short time frames, whereas females occupy smaller, exclusive home ranges throughout the year (Belcher and Darrant 2004, Körtner et al. 2004, Claridge et al. 2005). The fire at
the end of January 2003 dramatically altered the habitat within the study area and significantly reduced the availability of the quoll’s primary food resources, particularly brushtail possums (see Chapter 5, Newsome and Catling 1979; Russell et al. 2003). Females, by virtue of their innate home range fidelity (Belcher and Darrant 2004; Körtner et al. 2004), may have been obligated to remain in their territories, even following such a catastrophic event. Males, on the other hand, are non-territorial and demonstrate high mobility (Belcher and Darrant 2004; Körtner et al. 2004) and it is likely that they were able to move out of the study area once it became sub-optimal in terms of cover and prey resources. Eighteen months following the fire, once vegetative cover was becoming re-established and prey densities were increasing (see Chapter 5, Newsome et al. 1975; Newsome and Catling 1979), males were again attracted back into the study area for the breeding season by the continued presence of breeding-age females (Belcher and Darrant 2004).

Age structure and individual longevity

The short lifespan of spotted-tailed quolls has been reported previously (Belcher 2000b; Burnett 2001; Körtner et al. 2004). The maximum age estimated for both male and female spotted-tailed quolls in this study was 4 years old. This falls between the range of maximum ages for spotted-tailed quolls reported from other long-term (3+ years) studies. No individual over three years of age was reported from studies conducted in northern Queensland and northern New South Wales (Burnett 2001; Körtner et al. 2004), yet both male and female quolls were estimated to have attained five years old in Tallaganda State Forest in southern New South Wales (Belcher 2003).

The rate of turnover in the population of spotted-tailed quolls at Jacobs River was high between years, particularly between the two breeding seasons bisected by the fire. Only 27% of the quolls marked during the 2002 breeding season were recaptured after the fire in the 2003 breeding season, compared with 56% persistence from 2003 to 2004, but the relative contributions of mortality and emigration are not known. There is an apparent high turnover in all spotted-tailed quoll populations that is more similar to the latter of the two
figures above (Burnett 2001; Belcher 2003; Körtner et al. 2004). Yearly survival estimates in other spotted-tailed quoll populations have been estimated as 41% for a population as a whole (Körtner et al. 2004), and 56% and 34% for males and females respectively (Burnett 2001).

The number of females present varied little across the current study and the figures for female persistence between years (44% from 2002 to 2003; 45% from 2003 to 2004) are broadly similar to those stated above observed in other populations. Yet within the female population resident within the study area a degree of instability was apparent, potentially brought about by the dramatic disturbance of the fire. Numbers of females remained high between breeding seasons due to replacement by new females (Burnett 2001) but, in both 2003 and 2004, two new (unmarked) adult females were trapped in the study area. The high level of natal philopatry that has been reported from other studies suggests juvenile females stay close to their mother’s home range, and that adult females rarely leave an established home range (Firestone et al. 1999; Belcher and Darrant 2004; Körtner et al. 2004). This is supported by the fact that, in a three-year study in northern New South Wales, no new adult females were trapped after the first years census and all new females captured subsequently were less than one year old (Körtner et al. 2004). The contrast of immigration by adult females to an area, observed at Jacobs River, raises the possibility that neighbouring females were moving into areas of habitat that had become vacant following the severe wildfire event.

Male persistence between 2002 and 2003 was measured at only 15%, yet 80% (4 of 5) of male quolls that were present in 2003 turned up again in 2004. Both these figures vary widely from the suggested turnover for unperturbed populations (Burnett 2001), the first being very low and the second exceedingly high. High turnover of male populations is a characteristic observed in other studies where unmarked adult males were caught during each trapping period, indicating immigration by adult males and/or low trappability of resident males due to their large home ranges (Körtner et al. 2004). The male-biased dispersal pattern suggested from genetic study further supports the above observations.
(Firestone et al. 1999). The large discrepancy in the rate of turnover in the male population suggests that, rather than suffering high mortality, the more mobile adult males may have avoided the unsuitable or sub-optimal habitat that was present in the study area in 2003, before returning to the area the following year when conditions were more favourable, as discussed above.

The age structure of the population, as measured by the ratio of adults to juveniles, differed little in the first two years of the study despite the immense disturbance of the fire and apparent absence of adult males from the study area. Adult to juvenile ratios were low and relatively similar for the population in the winters of both 2002 and 2003, 36% and 44% juveniles respectively. While surveys in 2003 occurred after the fire, the juveniles present in the population would have been raised in habitat unaffected by fire and reached independence before fire event. These figures are only slightly lower than those observed in autumn surveys of spotted-tailed quoll populations in northern New South Wales, being 47% and 54% of two years (Körtner et al. 2004). While the small numbers of animals involved in each age class of each year make it difficult to draw firm conclusions, the data suggest that the fire may have impacted on breeding success from the 2003 breeding season and subsequent recruitment into the population for 2004. The number of juveniles in the population was lowest in 2004 and the contribution of juveniles to the overall population was less than 20%, with the age balance of both male and female populations their most heavily adult biased for the study. Young born during the 2003 winter breeding season would have weaned in the spring of 2003 at a time when the habitat structure was simplistic and prey populations low (see Chapter 5, Newsome et al. 1979; Lunney 1987; Catling et al. 2001). Fire has similarly been observed delaying breeding of the northern quoll (Begg et al. 1981). Another possibility lies in the increased threat of predation to juvenile quolls in more open habitat by introduced carnivores, as suggested for northern quolls in northern Australia (Oakwood 2000).
Chapter 7: General discussion

7 General discussion

The research described in this thesis provides insight into the immediate effects of wildfire on a population of the spotted-tailed quoll, a rare and poorly studied marsupial carnivore. The study was observational in nature, taking advantage of an otherwise unplanned event. In this regard it was fortuitous since other authors have recognised that the use of replicates and controls in the study of wildfire impacts on such species is likely to be logistically impossible (e.g. Whelan 1995). The attributes covered were dictated by the information available prior to the fire that would enable meaningful comparisons to be drawn from the post-fire environment, including survival and recovery of the population, descriptions of latrine use and analysis of diet. The results of this work will provide information to assist in the preparation of management strategies for the species, such as recovery plans, as well as information for land managers preparing management plans, including fire management plans, for habitats in which spotted-tailed quolls are found throughout their range. This chapter outlines the key findings of the research that are relevant to the biology and ecology of the spotted-tailed quoll, with particular reference to the species response to disturbance, and the broader body of knowledge of the effect of fire on fauna in south-eastern Australia. Finally, future research directions are outlined.

7.1 Population studies

7.1.1 Population size

Live-trapping and marking of individual animals using microchips (passive integrated transponders) were used to census the population of spotted-tailed quolls in the catchment of the Jacobs River in the Byadbo Wilderness Area of southern Kosciuszko National Park across three consecutive winter breeding seasons from 2002 to 2004. The existence of a large, high density population of the species in dry rain-shadow woodland habitat is noteworthy, since other authors have suggested that the species is most common in wet forest types of
the eastern escarpment, ranges and coastal lowlands (Jones and Rose 1996; Jones et al. 2001; Jones et al. 2003; Long and Nelson 2004).

A large-scale, high-intensity wildfire in the study area in January 2003 provided an opportunity to monitor the response of the population to this severe disturbance over two subsequent breeding seasons. Significantly, the wildfire did not result in the local extinction of the local population, a finding consistent with other studies on impact of wildfire on fauna, including other quoll species (Begg et al. 1981), eutherian carnivores (Newsome et al. 1975; Newsome and Catling 1983), and native terrestrial mammals (Newsome et al. 1975; Christensen 1980; Newsome and Catling 1983; Lunney 1987; Fox 1992, 1990; Vernes 2000).

The high turnover rate of individual animals observed in the study population between years was broadly consistent with that observed in unperturbed quoll populations (Burnett 2001; Körtner et al. 2004). However, there was evidence of a small, short-term decline in the number of quolls present in the study area in 2003, due to either mortality or emigration. This was followed by a recovery of the population within 18 months to levels proximate with, and even exceeding, those observed prior to the fire. It appears that immigration, rather than in situ recruitment, was largely responsible for the relatively rapid recovery of the population. The severity of the fire caused high mortality of fauna, with carcasses of small mammals, possums, rabbits, wombats, wallabies, kangaroos and horses found immediately following the fire, as has been observed following other wildfires (Heislers 1974; Recher et al. 1974; Newsome et al. 1975). However, the data suggest that there may have only been a short-term reduction in numbers of individual quolls in sections of the study area over which the intensity of the fire was uniformly severe.

7.1.2 Population structure

More male than female quolls were captured in the study area in both 2002 and 2004, a finding consistent with other population studies of the species in southeastern Australia (Jones and Barmuta 1998; Belcher 2003; Körtner et al.)
Post-fire in 2003, a notably reduced male population was outnumbered two-to-one by females. One possible explanation for this difference might have been that adult males temporarily vacated the sub-optimal habitat that resulted from the fire, because of their non-territorial nature and greater mobility, a theory consistent with findings on spatial organisation of males from other studies (Belcher and Darrant 2004; Körtner et al. 2004). Females, by contrast, remained resident in the highly disturbed habitat, perhaps obligated by reluctance to abandon established home ranges (Firestone et al. 1999; Burnett 2001; Belcher and Darrant 2004; Körtner et al. 2004). Also, the ratio of adults to juveniles in the population in 2004 was high compared with the other two years. This suggests that recruitment into the 2004 population of young produced in the 2003 breeding season was otherwise reduced because the fire rendered the habitat sub-optimal.

7.2 Diet

Scats collected from latrine sites and live-trapped individuals provided a large number of samples for analysis of winter diet of the spotted-tailed quoll in each of the three years of the study. Overall, the quoll population inhabiting the dry rain-shadow woodland of the Jacobs River study area was found to be very adaptable, preying primarily on medium-sized mammals, as has been found in most other studies of the diet of the species from other habitats (Alexander 1980; Belcher 1995; Jones and Barmuta 1998; Belcher 2000b). Brushtail possums were the most important single prey item by both frequency of occurrence and percentage biomass in all years, followed by lagomorphs, small mammals and large mammals, the latter most likely taken as carrion. These findings reinforce the predatory adaptability of the species, with preferential selection of different medium-sized mammalian prey in the wide variety of habitats in which spotted-tailed quolls occur (Belcher 1995, 2000b; Jones and Barmuta 1998; Burnett 2001). The overall diet of male and female quolls was not found to be significantly different, a finding that is also consistent with other studies (Jones and Barmuta 1998; Belcher 2000b).
Following the wildfire of January 2003, the quolls that remained in the study area shifted their diet in response to significant changes in prey availability. Brushtail possums, lagomorphs and bandicoots were significantly less abundant in the winter directly following the fire, as would have been expected from other studies (Newsome et al. 1975; Lunney 1987; Catling et al. 2001: Russell et al. 2003). There was a significant increase in abundance of lagomorphs, but not of possums, in the second winter after the fire, a trend also seen in other wildfire studies (Newsome et al 1975; Newsome and Catling 1983). Quolls adapted well to this altered availability, with a significantly higher frequency of occurrence of lagomorphs in quoll scats after the fire to the point where almost equal proportions of lagomorph and possum hair occurred in scats by the winter of 2004. Other fire-induced changes to the diet were evident, such as a significant drop in the occurrence of small mammals in scats directly following the fire. While no small mammal monitoring was undertaken on-site, other studies have previously identified short-term negative impact of fire on this faunal group (Recher et al. 1974; Newsome et al. 1975; Catling 1986; Lunney et al. 1987; Fox 1982). In addition, large mammals (kangaroos, wallabies and wombats) all reached their highest frequency of occurrence in scats in 2003 followed by a drop again in 2004 to pre-fire levels. This was most likely due to an increased availability of carrion for quolls in the year following the fire, as increased predation and starvation provided more carcasses on which quolls could scavenge (Newsome et al. 1975; Newsome and Catling 1983).

7.3 Latrine use

Surveys for latrine sites of the spotted-tailed quoll were found to be a successful survey technique, evidenced by the location of a suitable study population of the species in the Byadbo Wilderness Area of southern Kosciuszko National Park. There, quolls were found to use an extensive network of latrines: up to 64 active latrines was recorded across the study area in a single year. These were found throughout all parts of the topography among large, complex granite outcrops that were locally common in the study area, and also along rocky sections of riparian habitat. The choice of rocky substrates as preferred latrine sites by the
spotted-tailed quoll has been reported in other areas (Belcher 1995; Kruuk and Jarman 1995). While latrines have also been found around cliffs and on roads, tracks and large logs, a common feature of all sites appears to be the presence of a flat surface on which scats are deposited (Alexander 1980; Boschma 1991; Belcher 1995, 2000b; Kruuk and Jarman 1995; Burnett 2001).

High numbers of scats were found on latrines throughout the winter breeding season (May-August) of each of the three years, indicating that a peak in latrine use may be occurring at this time of the year, as suggested by other authors (Alexander 1980; Belcher 1994). After the fire lower numbers of latrines were in use in 2003, as well as lower levels of usage of individual latrines. This may be because of changes to the distribution of quolls in the landscape, changes to the age or sex structure of the quoll population, or physical disturbance of latrine sites by fire. Many latrines that had become inactive in 2003 following the fire were re-activated in the second breeding season following fire. The number of latrines used and the number of scats on latrines may have been linked to quoll population density in any given area. However, before monitoring of latrines can be used to monitor the status of quoll populations, the relationship with animal density needs to be validated. This would require a census of populations using equivalent trapping efforts at different sites with different densities of latrine use, as has been suggested for badgers (Tuyttens et al. 2001; Wilson et al. 2003) and foxes (Sadlier et al. 2004) in Britain.

7.4 Effect of fire on the spotted-tailed quoll and its mammalian prey

The need to understand the effects of fires, including frequency, intensity and spatial patterns, on habitat structure, food resources and den sites of the spotted-tailed quoll and other large dasyurids has been previously recognised (Jones et al. 2003; Long and Nelson 2004). Until the current study there was scant information about the effects of wildfire or prescribed burning on the species. As such it is useful now to review the concerns of previous authors in relation to fire, quolls and their prey in order to highlight what has been learnt from this study, and to identify those areas in which further research is still
required.

7.4.1 Wildfire

Previous authors have primarily expressed concern that wildfires remove vegetative cover, destroy hollow logs and trees that are used by spotted-tailed quolls for cover or refuge from predators, and lower prey abundances, supposedly to the detriment of resident quoll populations (Jones et al. 2003; Belcher 2004; Long and Nelson 2004). Suggested outcomes from such impacts range from local extinction of small and isolated populations (Backhouse 2003), to post-fire mortality, reduced fecundity and exacerbated interactions with introduced predators (Long and Nelson 2004) and cessation of latrine use until after vegetation structure re-establishes (Belcher 2004). These views no doubt arise from the fact that high-intensity wildfires kill many animals in their path and usually result in dramatic changes to structure of habitat (Newsome et al. 1975; Catling 1991; Coops and Catling 2000). Longer-term studies (Newsome et al. 1983; Catling et al. 2001) indicate that, contrary to this belief, wildfires may not be as destructive to fauna as that imagined. The findings of the current study and another on northern quolls in the Northern Territory (Begg et al. 1981), highlight that where populations are monitored before and after high-intensity fires these larger marsupial carnivores are relatively robust and local extinction does not occur. While it is likely that individual quolls were killed in the high-intensity fire at Jacobs River, there appears to have been little impact on the abundance of quolls in the relative short-term. Furthermore, the complete removal of vegetative cover and significant reductions in prey abundances immediately post-fire appear to have been changes to which the quolls rapidly adapted, ensuring a recovery of the population to exceed pre-fire levels within 18 months.

The presence of numerous complex rock outcrops and other sub-surface refuges throughout the study area are likely to have contributed to low levels of direct mortality from the fire. It should be noted however that in other areas and habitats where spotted-tailed quolls use logs, trees and other vegetation for
denning (Belcher 2000b; Körtner et al. 2004), and rocky refuge sites are uncommon, the impact of such intensive wildfire may be higher.

In addition, the near-absence of adult males from the study area in the breeding season directly following the fire may have assisted the survival of resident females. The ability of the larger males to move long distances to unburnt habitat may have reduced the pressure on the (limited) local food supply, until such time as the habitat and prey populations recovered sufficiently, after which the males returned. It should be noted, however, that there is some evidence for lower recruitment from the 2003 breeding season, indicating that resources may have been scarce for the resident females at the critical times for successful rearing of young.

The presence of a high population of rabbits prior to the fire may also have been a key to the rapid recovery of the quoll population following the fire. Rabbits have been shown to survive intense fire well and subsequently increase numbers rapidly following wildfire in response to a simplification of habitat structure and an abundance of regenerating vegetation (Newsome et al 1975; Newsome and Catling 1979). This response appears to have augmented the prey supply for the quoll population in the current study at a time when it was most needed, in a timeframe far quicker than most native prey are likely to respond (Catling 1991; Catling et al. 2001).

The suggestion that latrine use may be affected by wildfire (Belcher 2004) is supported by the findings of the current research, in the short-term at least. Less than half of the latrines in use in 2002 remained active in 2003, but many latrines were active again in the subsequent breeding season, well before vegetation structure re-established. Observations of several latrines becoming unused were made in this study that were likely related to physical disturbance of the latrine itself, such as fallen trees and shattered rock covering the rock where scats may have ordinarily been deposited. At Suggan Buggan in Victoria, to the south of my study area, (Belcher 2004) also previously noted a marked decline in scat deposition on a single latrine. He attributed this to the local extirpation of the quoll population as a result of 1080 poisoning.
programs for rabbits and foxes being conducted in the surrounding area (Belcher 2003). However, the area in which the latrine occurred was also burned by fire prior to the reported decline. It appears that at that site there may have been multiple factors affecting the quoll population, the relative impacts of which are not clearly understood.

7.4.2 Frequent, low-intensity fire

A change in fire regimes, or the perpetuation of a fire regime characterised by frequent low-intensity fires for the purpose of fuel reduction or post-logging burns, has been suggested as having the potential for similar deleterious effects on the spotted-tailed quoll, and other larger marsupial carnivores, as described above for wildfire (Catling 1991; Watt 1993; Oakwood 2000; Jones et al. 2003; Belcher 2004). These include the loss, degradation or structural simplification of habitat (Catling 1991; Jones et al. 2003; Belcher 2004), a decrease in the number of available den sites (Watt 1993; Belcher 2004), alteration of population dynamics (Watt 1993), and prey availability (Watt 1993; Jones et al. 2003). Most of the individual issues identified above are linked, to varying degrees, to the likely effects of simplification of forest habitat structure resulting from such a fire regime (Catling 1991). The current study provides information on the short-term response of spotted-tailed quolls to alterations by fire to some habitat features and prey resources similarly affected by a different fire regime.

Firstly, the presence of rock outcrops and other sub-surface refuges provide adequate den sites and cover for quolls. Rocky habitats, or at least habitats containing rock outcrops, appear to retain sufficient complexity to enable survival, short-term persistence, and perhaps even long-term persistence, given the example of northern quolls (Oakwood 2000). This, of course, will differ on a habitat by habitat basis, as spotted-tailed quolls often utilise logs and vegetation for dens in areas where rock is absent or scarce (Belcher 2000b; Körtner et al. 2004).

Secondly, the alteration of forest faunal composition suggested under such a long-term fire regime (Catling 1991) may not necessarily be detrimental to
the prey base of the spotted-tailed quoll. As has been shown in this and other studies (Alexander 1980; Belcher 1995, 2000b; Jones and Barmuta 1998; Burnett 2001), the spotted-tailed quoll is sufficiently adaptable in its prey selection to take advantage of the variable availability of mammals present. Should more introduced species be advantaged over time (such as rabbits, hares, black rats and the house mouse), while natives decline in abundance (brushtail possum, ringtail possum, bandicoots, antechinus) as has been suggested (Catling 1991), spotted-tailed quolls may be able to switch their diet accordingly.

7.5 Limitations

The observational nature of this study has already been recognised as a factor that limits the interpretation of the results presented here. The impact of wildfire on the survival and ecology of the resident quoll population has been inferred without the use of replicates or controls. The conclusions reached are instead based on differences in censuses carried out before and after the fire, allowing for the detection of a change in the population, but do not allow the separation of fire effects from temporal changes or site effects (Whelan 1995). That said, it has also been noted that the use of replicates and controls in the study of wildfire impacts is likely to be logistically impossible (Whelan 1995), and this is particularly so when the subject is also a threatened, solitary, wide-ranging carnivore. Also, it would have been ideal had a longer-term pre-fire data set been available to provide background on ‘normal’ population attributes and rates of turnover, against which the post-fire information could be more rigorously compared.

The data collected in this study is also highly seasonal in nature, and as such may not detect other effects impacting on the population in other seasons. It has, however, been collected during a critical time of year for the species, that of the winter breeding season. The findings of the study are likely to be specific to the area, habitat and fire event and, due to the wide geographic range and diversity of habitats in which the spotted-tailed quoll occurs, cannot be
extrapolated outside of the geographic region. Nevertheless, this study provides the first detailed information of the response of the spotted-tailed quoll to disturbance by fire of any sort. As such the findings are important in gaining an improved understanding of the species and the impact of landscape level change by fire on fauna in general.

7.6 Further research

7.6.1 Long-term monitoring

The short time frame for this study provides a snapshot of the survival and recovery of this population of spotted-tailed quolls in the Jacobs River area. As with vegetation, the observations from the current study represent the early stages of what is likely a longer-term succession in the response of the fauna of the area to this massive perturbation (Newsome et al. 1975; Catling and Newsome 1981; Fox 1982; Catling et al. 2001). Therefore, continued long-term monitoring of the study area, including the vegetative response and the response of, and interactions between, predators and prey populations, is required to understand changes in the ecosystem, brought about by wildfire, which will continue to occur over time (e.g. Newsome and Catling 1983; Catling et al. 2001). The continuation of quoll trapping in the Jacobs River study area can provide valuable information of the population size, structure and turnover that will assist in understanding not only the longer-term response of the species to wildfire, but also provide important background information on population dynamics to add to the relatively small amount currently available (e.g. Burnett 2001; Belcher 2003; Körtner et al. 2004). It would also be valuable to examine fate of juvenile animals over time, as the current study highlighted apparent low level of recruitment. This would require genetic testing of all animals in the population to see whether this continues to be the case.

The continued monitoring of the diet of quolls in the study area may reveal the timeframe over which diet becomes more like pre-fire situation. Long-term monitoring of prey populations, through spotlighting of established transects for arboreal prey and undertaking of ground-mammal activity plots, can also
provide valuable information on recovery of the principal prey species of the spotted-tailed quoll. This information would provide a valuable addition to the picture of faunal succession following wildfire in the Australian landscape (e.g. Catling et al. 2001).

7.6.2 Different fire regimes and habitats

The findings of this study provide a picture of the response of spotted-tailed quolls to a single-event, high-intensity, summer wildfire. As discussed in section 7.4.2 above, the effect of different fire regimes, in particular more frequent, low-intensity fires used widely in fire hazard reduction management, on the spotted-tailed quoll is likely to be very different and requires urgent attention (Jones et al. 2003; Long and Nelson 2004). To date the only information on such a regime has suggested that quolls are likely to be disadvantaged by the resulting simplification of habitat (Catling 1991). Experimental testing of such a hypothesis would be inherently difficult given the spatial scale required to obtain replicates and controls for an animal with home range sizes in the order of thousands of hectares. It may possible to examine the issue retrospectively by looking at habitat use by quolls of areas with different burning histories, at sites with similar climate and vegetation types. Coordination of researchers across the range of the species and long-term monitoring may be the only way for further trials on the response of the species of fire to be undertaken. In the meantime, all studies involving the live-trapping of quolls should utilise permanent identification techniques, such as micro-chipping, so that, in the event of a fire, the fate of the population can again be monitored. Ideally, the fate of individual radio-collared quolls could be tracked during fires of various intensity to provide information on movement and survival mechanisms.

7.6.3 Latrine-based survey and research

This study also highlights the effectiveness of the use of latrine searches as a survey methodology for the species. The development of a reliable detection
and survey methodology has been recognised as one of the key issues to address in the short-term for the conservation of the species (Backhouse 2003; Long and Nelson 2004). Latrine surveys have already been successful in confirming the occurrence of an extant quoll population in the Australian Capital Territory (ACT Government 2003), and have been used to clarify the distribution of the species throughout eastern Kosciuszko National Park (Dawson et al. 2003). Subsequent research should aim to develop a greater understanding of the attributes of latrines through investigation of factors that affect the selection of latrine sites by quolls at the landscape level, which will enable surveys to be more targeted and effective. To facilitate such understanding, several key research questions need to be addressed. Firstly, it is necessary to systematically determine whether rocky substrates are in fact preferred as latrines over other structures such as flat ground, tracks and trails, or fallen logs. This study would be a vital pre-requisite before any investigation of the spatial pattern of latrines at a landscape scale could be undertaken. Secondly, the issue of seasonal usage of latrine sites needs to be resolved by systematic searches of a set of latrines throughout the year. This information is necessary to increase success of the survey technique. Finally, the ability to spatially map areas of rocky substrate across broader geographic areas would enable investigation of the relationship between density of such structures and density of quoll populations. A widespread wildfire, such as the one affecting this study, provides an excellent opportunity to obtain a map of rocky habitat across the landscape, through the use of high resolution aerial photography or satellite imagery at a time when vegetation does not obscure mineral earth.

Currently, the effectiveness of latrine searches as a survey technique has been limited by the fact that low percentages (less than 10% from this study) of spotted-tailed quoll scats contain grooming hairs to enable definite positive identification. This uncertainty can be eliminated by recent advances in the gathering of genetic information from faeces to assist in the positive identification of spotted-tailed quoll scats, an issue driven by difficulties in the reliable identification of a variety of predators from scat morphological characteristics (e.g. Dalen et al. 2004). Additionally, genetic information from
scats could be used to unlock some of the secrets of the communication function of latrines in the social organisation of the spotted-tailed quoll. The use of remote photography may also be employed as an adjunct method in surveys and studies of communication and social functionality of latrines by the spotted-tailed quoll (e.g. Claridge et al. 2004). Such studies should focus on gathering information on differences in visitation of latrines by male and female quolls, the number of individual quolls utilising a latrine, temporal patterns of latrine use, the spatial configuration of latrines in relation to home ranges (particularly of females), and examination of other types of scent marking behaviour exhibited at latrines by both male and female quolls. The ability to accurately ascertain the number of individuals using any given latrine, or set of latrines, will also allow researchers undertaking trapping programs to assess whether there are individuals within the population that are not being captured.
8 References


Belcher, C.A. (2000a). The range, status and distribution of the spot-tailed quoll
(Dasyurus maculatus) in the Otway Ranges. Unpublished consultants report.


The Johnstone Centre Report No. 118. Charles Sturt University, Albury.


Claridge, A.W., Paull, D., Dawson, J., Mifsud, G., Murray, A.J., Poore R.N., and


DEH (2004). Listed advice - *Dasyurus maculatus maculatus* (spot-tailed quoll,
References


References


References


References

New South Wales.


Lunney, D. and Matthews, A. (2001). The contribution of the community to defining the distribution of a vulnerable species, the spotted-tailed quoll Dasyurus maculatus. Wildlife Research 28, 537-545.


Newman, D.G. and Griffin, C.R. (1994). Wetland use by river otters in...


References

*Mammalogy* 17, 133-136.


References


