Reducing wildlife predation by domestic cats: An approach based on the precautionary principle

This thesis is presented for the degree of Doctor of Philosophy

Murdoch University

Submitted by

Jacqueline Grayson

January 2016
Declaration

I declare that the information contained in this thesis is the result of my own research unless otherwise cited, and has as its main content work which has not previously been submitted for a degree at any university.

Jacqueline Grayson
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Abstract

Pet cats kill a range of suburban wildlife, including some native mammals, birds and lizards. The dense cat populations sustained in suburbs by people exacerbate the problem. However, there is sparse evidence of suppression of populations of any native species in suburbia as a result of cat predation and accurate estimates of predation rates are difficult. Such uncertainty as to whether or not cat predation poses a serious risk to remnant wildlife populations in suburbia is no reason for inaction until the question is resolved, because serious environmental impacts including species decline or local extinction could occur before definitive evidence is available. Therefore, it is appropriate to invoke the precautionary principle, which requires (i) detailed consultation to choose and implement precautionary measures to anticipate possible environmental damage, and (ii) concurrent research to reduce uncertainty as to the exact impact and whether precautionary measures should be continued or reduced. In this study I apply a precautionary approach to the question of whether or not predation by pet cats influences passerine species richness or community composition in suburban Perth, Western Australia. In keeping with the twin tenets of the precautionary principle the study involved an assessment of community attitudes and practices regarding the husbandry of pet cats and their impact on wildlife in general (consultation), and a detailed study of factors (including the density of pet cats) influencing passerine species richness or community composition across metropolitan Perth (reducing uncertainty).

To assess the attitudes and practices of the general public towards cat legislation and other issues relating to pet cats, I designed and issued a survey to 2,000 residents within the City of Melville, a local government municipality in Perth. The response rate was 63%. Respondents were questioned upon their knowledge of cat issues and their attitudes and practices toward sterilisation of pet cats; legislation regulating cat ownership and the putative impact cats have upon wildlife. Age, gender and cat-ownership status of respondents were investigated to determine if such factors influenced responses. Cat-owners, particularly women, knew more about cat issues. Non-owners were more supportive than cat-owners of the introduction of cat control measures and were more concerned about the possible impacts cats exert upon suburban
and remnant wildlife. Women, regardless of cat-ownership status, were more supportive of sterilisation, whereas men were more supportive of the introduction of cat control measures. Age was positively related to the implementation of control measures, with older respondents showing most support. Over 70% of respondents, both cat-owners and non-owners, supported the introduction of cat legislation that promoted sterilisation, restricted the number of cats per household and their roaming behaviour, and mandated licensing of pet cats. However, only a minority of cat-owners or non-owners supported the concept that local governments should enforce cat-free zones where ownership of pet cats was prohibited.

To find definitive evidence of the impact of cats upon suburban fauna, I utilised data collected by members of Birds Australia for the ‘Suburban Bird Survey’ that covered 57 sites throughout suburban Perth, extending onto the Darling Scarp. Using these data, I tested the influence of eight variables including cat density, dog density, housing density, age of suburb, distance to, and size of, nearest bushland less than or greater than 5 ha on passerine species richness, passerine species composition and the presence/absence of 15 selected passerines that were recorded in 20 to 80% of sites. Garden vegetation factors including structure and floristics were also tested in 18 of these sites.

Cat density was not a significant predictor of any of the dependent variables tested. Rather, community composition of passerines declined with increasing housing density and distance to nearest bushland, and increased with size of nearest bushland > 5 ha. These independent variables, particularly housing density, significantly affected small to medium size insectivores. There were no clear results that predicted the presence/absence of the 15 selected passerines, although housing density appeared to be the most likely predictor. Garden vegetation was not a significant predictor for the presence or absence of any of the 15 selected species, although gardens with low bird-pollinated plants were more likely to contain Yellow Rumped Thornbill, whereas gardens dominated by fruiting vegetation, tall, bird pollinated and deciduous vegetation were less likely to contain any of the 15 selected species.

Overall, the possible cat control measures supported by 70% or more of owners and non-owners would protect wildlife by reducing dumping of unwanted cats, limiting
Abstract
cat densities in suburbia and enabling identification of nuisance animals. Given this high level of community support, these measures should be implemented. However, they are not a panacea for wildlife conservation in the suburbs. While cat predation might be significant adjacent to remnant bushland or other areas of conservation significance, blaming cats for bird conservation issues in long-established suburbs may be a scapegoat for high residential densities, inappropriate landscaping at a range of scales or poor conservation of remnant bushland.
Acknowledgements

I have looked forward to writing this page for a very long time to thank all the people who have helped and supported me over this time. The two people at the top of the list are my partner in life, Richard Grayson and my supervisor, Dr Mike Calver. Richard has provided unshakeable faith, patience and support throughout this time. Mike has not only guided me academically, but he has been enormously supportive and patient throughout the duration of the thesis. Without either of these two people, the thesis would not have been completed.

I have met some great people over this time and these individuals, who without their help, much of the information in this thesis wouldn’t have been possible: Mark Garkaklis for mapping, Laurie Mitchell for his prowess with Excel, Thea Linke for her expertise and eagle eye in editing and formatting, Andrea Zappacosta (Department of Planning and Infrastructure), John Patterson (Department of Planning and Infrastructure), Irene Styles (Murdoch University), Alan Lymbery (Murdoch University), Tony Hodge (Murdoch University), Clive Nealon (Birds Australia, Western Australia), Belinda Cale for assistance with figures and Robert Hammond (dec.) for providing a Postgraduate Research Scholarship in the initial years.

I would like to acknowledge all of my friends and family that have also supported me through this journey, although a special mention needs to be made of my three children Andrew, Paul and Katie. Their support and understanding has been both remarkable and touching.
Overview of publications

Three chapters of this thesis have been published. While each paper has co-authors, I undertook the main role in each of the publications. The co-authors participated by assisting in statistical analysis, or, in the case of Grayson and Calver (2004), writing the final manuscript.


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Table 6.2  Studies of the effect of doomed surplus.

Table 6.3  Cat legislation throughout Australia as of 2015.

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Table A4.1  95% confidence set of best-ranked models (the models whose cumulative Akaike weight, $a_{wi} \leq 0.50$) examining relationships between environmental variables and the species richness of birds found in suburban gardens in Perth.

Table A4.2  Parameter weights and estimates examining relationships between environmental variables and the species richness of birds found in suburban gardens in Perth.
1. **The domestic pet cat**

The domestic cat has been introduced to every continent except Antarctica (but feral populations have established on sub-Antarctic islands (Ryan *et al.* 2009). The global population is estimated at 600 million and the domestic cat is the only felid not listed by global conservation bodies as endangered or threatened (O’Brien *et al.* 2008). While cats are valued companion animals, their predatory habits as both pets and feral animals raise concerns about their potential impact on wildlife and biodiversity conservation (Metsers *et al.* 2010, Lepczyk *et al.* 2013, Frank *et al.* 2014).

In this introductory chapter to a thesis covering the impacts of pet cats on passerine birds in suburban Perth, Australia, I place the topic in context by reviewing the history, spread and biology of the domestic cat, with particular reference to studies of the interactions of pet cats with wildlife. I also review the impacts of urbanisation on wildlife as an important alternative hypothesis to explain declines in urban wildlife. Penultimately, I introduce literature about the different groups of birds found in cities because the relationship between pet cats and birds is at the core of the thesis. The introduction concludes with an outline of my principal aims and a plan for the rest of the thesis, which approaches the central research question of the impacts of pet cats on passerine birds using the framework of the precautionary principle.

**1.1 History of the domestic cat**

Domestic cats are derived from *Felis sylvestris*, a polytypic species with at least 5 subspecies. Behavioural, physical and genetic evidence indicates that today’s domestic cat *Felis catus* is most likely to be a descendent from the African wildcat *F. sylvestris lybica* (Driscoll *et al.* 2007).

The desire to keep pets, particularly by women, precedes agriculture. Archaeological and genomic evidence suggests that domestication first occurred approximately 10,000 years ago at multiple locations in the Fertile Crescent region (Driscoll *et al.* 2007, O’Brien *et al.* 2008), probably after an indefinite period when cats existed as a human commensal (Driscoll *et al.* 2007). With the onset of agriculture, more wild cats would be attracted to human habitation by the presence of rodents.
Serpell (2000) speculated that dens of kittens were numerous and, while some litters were eaten, others were taken home and tamed. By c. 1,000 BC, cats were highly revered in Egypt and it was illegal to harm them (Kelsey-Wood 1989, Serpell 2000). As a mark of respect to the cat, upon its death, cat-owners shaved off their eyebrows (Lawrence 2003). The cat was often mummified and, if the owner could afford it, entombed in a specific large underground repository (Serpell 2000).

1.1.1 Global spread

Cats spread slowly from Egypt because it was illegal to export them and special agents were employed to ‘buy and repatriate’ cats (Serpell 2000). Romans introduced cats to Europe after recognising their ability to control vermin. Traders extended the distribution to the Middle East and Far East China circa fourth century AD (Kelsey-Wood 1989, Serpell 2000). However, in the Middle Ages, superstition about witches and cats caused cats to be condemned and persecuted as agents of the devil. Cats were often tortured en masse throughout modern Europe between the 17th to 19th centuries. ‘Practices varied, but ingredients were the same; bonfire, cats, and an aura of hilarious witch-hunting’ (Lawrence 2003, p 627). Nevertheless, the practice of keeping cats on ships saw them distributed widely throughout the world during the 18th and 19th centuries (Gaynor 2000, Abbott 2002, Lehmann et al. 2006). It was not until the 19th century that cats were re-accepted into the community and were bred for show purposes with the first cat show in 1871 in London (Kelsey-Wood 1989, Serpell 2000). The change in perception of cats, and their acceptance into society, has been gradual. It is particularly notable in America since the 1950s, evidenced by cat-ownership increasing in popularity over dog-ownership (Lawrence 2003).

1.1.2 Arrival in Australia

The time of arrival of the domestic cat to mainland Australia is in debate. There are three main theories. The first postulates that ships’ cats (Kelsey-Wood 1989) colonised coastal areas after shipwreck. The second possibility is that cats were traded by Malays to coastal Aboriginal communities (Gaynor 2000). However, historical research by Abbott (2002) found few references to cats aboard ships coming to
Australia prior to 1788. He supports the third theory that cats arrived with the early settlers at various points around the continent, radiating from their sites of introduction. By *circa* 1890, the cat had colonised much of the Australian continent (Abbott 2002). Comparisons of DNA from feral cat populations within Australia identified seven distinct populations, tracing back to feral/stray European cat populations still found at the dockyards of Europe (Spencer *et al.* 2015).

Rabbits (*Oryctolagus cuniculus*) were released into Sydney with the first fleet in 1788, spreading into Queensland by 1886. By 1900, rabbits had crossed the border into the Northern Territory and Western Australia (Lapidge *et al.* 2009). Many cats were released in the 1880s to combat rabbit plagues, including the release of 200 cats on the south coast of Western Australia in 1899 (Gaynor 2000). Between 1918 – 1921 it became illegal to kill feral cats because of their perceived abilities to control the rabbit plague (Abbott 2002), but it was quickly realised that cats were reaching plague proportions themselves and further releases were abandoned. Later, a bounty was placed on cats in an effort to control them (Abbott 2002).

### 1.1.3 Genetic changes associated with domestication

McFarland (2006) defines domestication as:

> “The process by which humans have structurally, physiologically and behaviourally modified certain species of animals by maintaining them in, or near, human habitations, and by selective breeding. Domestication is designed to suit human objectives, which may relate to economic performance, such as docility, efficient maternal care, high fertility, longevity, efficient food conversion, and increased production of materials such as wool, milk, or meat. Other objectives include ornamentation, as is the case with some fish, birds, and dogs, or entertainment, as is the case with fighting cocks, dogs, and bulls”.

Intentional breeding for specific characteristics is recent with the domestic cat and, in contrast to the domestic dog, the cat is ‘genetically resistant to extreme modification’ (Serpell 2000). Hence, many domestic cats are physically and behaviourally similar to their wild ancestor (O'Farrell & Neville 1994), to the point that
it is difficult to determine the difference between the native wild cats and feral domestic cat (Kitchener et al. 2005, Johnson et al. 2006, Driscoll et al. 2007, O’Brien et al. 2008). This is an important conservation issue in countries where domestic cats are hybridising with their wild relatives, ultimately resulting in declining populations and loss of biodiversity (O’Connor 2007, Oliveira et al. 2008a, b, Randi 2008). The domestic cat is also responsible for passing feline diseases to wild cats (Daniels et al. 1999).

1.2 Relationships of cats with humans

Today, domestic cats exist in one of three phases, with the relationship with humans the key consideration:

*The pet cat* “This is a pet or house cat living in close connection with a household where all its ecological requirements are intentionally provided by humans” (Moodie 1995, also used by Dickman 1996, and Baker et al. 2010).

*The stray cat or semi feral* “…relies only partly on humans for provision of its ecological requirements” (Moodie 1995, also used by Dickman 1996, and Baker et al. 2010).

*The feral cat* “…a free-living cat which has minimal or no reliance on humans, and which survives and reproduces in self-perpetuating populations” (Moodie 1995, also used by Dickman 1996, and Baker et al. 2010).

Cats in all of these classifications interact with wildlife, but the pet cat category is the subject of this thesis.

1.2.1 Benefits of cats as pets

Pet ownership is commonly viewed as providing many health benefits to the owner such as decreasing the incidence of heart attack and stroke and lowering blood pressure (Anderson et al. 1992). However, controversy is emerging regarding these
health benefits, both mental and physical. In a study of 2,528 Australian pet owners aged 40 to 44 years and 60 to 64 years, Parslow & Jorm (2003), and Parslow et al. (2003) found that pet ownership did not decrease the likelihood of cardiovascular disease. Instead, the pet owners in the survey displayed characteristics that were more likely to increase the risk of cardiovascular disease. They showed no decrease in the number of visits to their general practitioner and had a higher use of pain relief medication. Worse still, the pet owners in the 60 to 64 years group displayed higher levels of psychosis (Parslow et al. 2003), a result confirmed in a follow-up study (Parslow et al. 2005). Winefield et al. (2008), studying a sample of 314 older adults living in residential communities, also found that neither pet ownership nor the degree of attachment to a pet explained variation in a subject’s health or well-being. Furthermore, Parker et al. (2010) reported that, from 424 subjects recovering from cardiovascular disease, pet owners were more likely to suffer cardiac morbidity or be readmitted to hospital with acute coronary syndrome. This applied to cat owners far more than to dog owners.

Conversely, a study utilising two groups of married couples, one being pet owners and the other group non-pet owners, found that, on the whole, the pet owners had lower baseline levels for heart rate and blood pressure. When exposed to mental arithmetic and cold pressor tests, they showed smaller increases in saliva cortisol and recovered faster than those without pets. Furthermore, pet owners also displayed lower reactivity and recovered quicker when the pet was in the room during the test (Allen et al. 2002). Further evidence is emerging from attachment based research, utilising both animal research and neuroscience, recording the positive effects of primarily dogs, and secondarily cats, on the physical and psychological wellbeing of people in all stages of life (Sable 2013). In a study involving 81 newly bereaved women, some commented that after the initial loss of a partner social support was available, but wasn’t sustained; however, pets in their lives were a constant support (Sable 2013).

May (2007) argues that the human-animal bond is difficult to measure quantitatively. According to May, to truly gauge the effect of companion animals on the health and wellbeing of individuals, a hybrid test that incorporates both qualitative and
Chapter I

quantitative methodology is required. A Western Australian study using such approaches upheld beliefs in the benefits of pet ownership. Non-pet owners were twice as likely to feel lonely compared to pet owners. Furthermore, pets were associated positively with social interactions and encouraged exchanges between neighbours. Pet owners were more likely to be actively involved within their community, and have higher perceptions of neighbourhood friendliness and sense of community (Wood et al. 2007). Overall, while tangible benefits of pet ownership may be controversial, there is no doubting the intensity of many people’s attachment to their pets.

1.3 Impacts of pet cats on wildlife

While diverse organisations in many countries encourage owners to neuter cats and confine them to their owners’ properties in an effort to prevent nuisance, protect wildlife and improve cat welfare by reducing the chance of fighting, spread of disease, abuse from humans, exposure to the elements and road accidents (American Bird Conservancy 2011a), significant numbers of owners do not comply (Grayson et al. 2002, Rochlitz 2004). Consequently, pet cats, both neutered and entire, often roam unrestricted and interact with local wildlife. Such interactions may have deleterious impacts on wildlife through predation (e.g.: Australia: Barratt 1998, US: Kays & DeWan 2004, UK: Baker et al. 2008, New Zealand: van Heezik et al. 2010, and Switzerland: Tschanz et al. 2011). The mere presence of cats may lead to behavioural changes in wildlife (Bonnington et al. 2013), so-called ‘non-consumptive effects’ (Anson et al. 2013). Pet cats also transmit disease (Daniels et al. 1999, American Bird Conservancy 2011b) and hybridise with wild felids (Kitchener et al. 2005).

1.3.1 Predator/prey relationships

Natural predator/prey relationships are complex and affected by factors such as: seasonality (Kays & DeWan 2004), vegetative cover (Arthur et al. 2004, Morris & Gilroy 2008, Shaw et al. 2008), patch size (Crooks & Soulé 1999, Salo et al. 2007), supplemental feeding (Reddiex et al. 2006), latitude (Evans et al. 2005), spatial variation (Krebs 1994) and immigration of both prey and predator (Krebs 1994, Crooks & Soulé 1999, Shaw et al. 2008). There may even be non-lethal effects, where the mere
presence of the predator is enough to affect the foraging and/or breeding behaviour of the prey (Beckerman et al. 2007). Four hypotheses regarding predator/prey relationships are particularly relevant to the impacts of pet cats on suburban wildlife: doomed surplus, hyperpredation, non-lethal effects and mesopredator release.

Early predator/prey studies indicated that natural predators did not impact prey populations, but depredated a ‘doomed surplus’ - prey that were weak or old and would have died anyway (Errington 1956). Predation of doomed surplus prey does occur, but in stable systems predator/prey populations may be self-regulating via predator induced breeding suppression, where prey animals breed only when predator pressure has eased (Ruxton & Lima 1997). Nevertheless, there is mounting evidence that at least some coevolved predators do control prey numbers and that at least some alien predators definitely control native prey populations (the meta-analysis of Salo et al. 2007 and references therein). A common point in many studies is that habitat and refuge are the keys for protection and survival of prey, either in a coevolved or alien predator/prey relationship (Salo et al. 2007).

In contrast, detrimental effects on numbers of some prey species are expected under the hyperpredation hypothesis. In this case, a top order predator is maintained at high levels by an abundant supply of a prey species well-adapted to high predation pressure. Native prey are often poorly adapted to exotic predators, and these populations are often depleted by the abundant predator (Jones & Coman 1981, Courchamp et al. 1999a, Short et al. 2002, Salo et al. 2007). Pet, semi-feral and feral domestic cat populations are not regulated by the abundance of native prey because they are supplemented by introduced prey such as rats, mice, rabbits or feeding by humans (Reddiex & Forsyth 2006). In such situations, cats place a constant stress on native prey populations, preventing their recovery (Risbey el al. 2000) Risbey, 2000. Predation by pet cats Felis catus (Mammalia: Felidae) in suburbia may be analogous to hyperpredation, with feeding by humans replacing the introduced prey species in the model and maintaining cats at much higher populations than would otherwise be supported, leading to very high predation pressures on wildlife. Even if higher predation does not eventuate, the mere presence of high densities of predators may reduce the
reproductive success of prey species because of increased time and effort in nest defence (Beckerman et al. 2007, Anson et al. 2013, Bonnington et al. 2013).

A further possibility is that cats may actually protect some native species. In many situations, the domestic cat is a top order predator and depredates urban mesopredators such as House Mice *Mus musculus*, Black Rats *Rattus rattus* or Norway Rats *Rattus norvegicus*. For example, in Barratt’s (1998) study of predation by pet cats in suburban Canberra, Australia, 6.8 of the mean 10.2 prey caught by each cat were introduced mammals. House mice comprised 75% of the introduced prey and 56% of all recorded prey. Thus if pet cats are removed or suppressed in Australian suburbs through containment or continue to decline in popularity as a pet (a trend observed by REARK 1994, Perry 1999, Chaseling 2001, McGreevy et al. 2002), then rodent populations may increase and intensify predation on bird eggs and nestlings. This is a phenomenon noted in response to control of feral cat populations, especially on islands (Courchamp et al. 1999b, Crooks & Soulé 1999).

1.3.2 Pet cats as predators

The cat is a highly developed hunter. Both its visual and auditory senses are extremely well developed (Fitzgerald & Turner 2000). The domestic cat is considered to be a ‘generalist resident predator, exploiting a wide range of prey, and able to switch readily from one prey to another’ (Fitzgerald & Turner 2000, p153). Liberg (1982) found that free-roaming house cats in Sweden preferred to hunt and eat prey, but when prey were scarce, relied more upon food supplied by people.

Cats employ two hunting strategies: a mobile one that involves walking between two hunting areas until a prey is observed, and also a ‘stationary, sit and wait’ approach. The prey type may determine which strategy is employed. Cats hunting for birds usually stalk, then wait and pounce. Cats often give up trying to catch birds because the bird often flies away during the waiting phase of the hunt, without realising it was at risk of predation (Fitzgerald & Turner 2000). However, this method is usually successful for catching small, burrowing mammals. Cats do become specialised at hunting favourite prey. For example, the Stephen’s Island Wren in New Zealand was possibly hunted to
extinction within a year by the lighthouse keeper’s cat and feral cats on the island (Oliver 1955, cited in Dickman 1996). Liberg (1982) reported that female cats with kittens and supplemented with food by people, spent more time hunting prey that were easier to catch and had less calorific value. This suggests that these cats were catching rodents for practice rather than for their main food (Liberg 1982).

There are 8.5 million owned cats (19% households) in Great Britain (The European Pet Food Industry Federation 2012), 2.35 million (23% of households) in Australia (ACAC 2014), 89.8 million (25% households) in all of Europe (The European Pet Food Industry Federation 2012) and 74.1 million pet cats (30.4% households) in the US (American Veterinary Medical Association 2014). Cat densities are positively correlated with human population densities, being higher in urban areas and decreasing along the urban/rural gradient (Churcher & Lawton 1987, Lepczyk et al. 2003, Sims et al. 2008). These cat populations, maintained at such high levels by humans, could conceivably exert considerable pressure on wildlife populations through occasional predation. However, does cat predation cause declines in wildlife populations, or are cats a convenient scapegoat for complex wildlife management problems (e.g. see the list of anthropogenic factors causing songbird mortality in Erickson et al. 2005)? Descriptive studies of prey taken by pet cats, estimations of predation rates, correlation studies between cat densities and prey presence or abundance, and experiments monitoring the response of prey populations to manipulations in cat numbers all contribute to answering this question. However, there are significant methodological issues.

As established by field studies on the impacts of predation by feral cats, the strongest possible evidence for or against direct impacts of cat predation on wildlife comes from manipulative experiments that demonstrate population responses to changes in cat density or the intensity of cat predation (Risbey et al. 2000, Frank et al. 2014). However, they are logistically difficult to implement, so researchers often resort to drawing inferences from studies of diets, estimations of predation rates and searching for correlations between cat densities and the abundance or presence/absence of prey.
species. Experiments are even more logistically difficult in suburbia, so reliance on the logistically easier but logically weaker non-experimental methods predominate.

Data on the prey taken by pet cats have commonly been collected by: owners recording prey bought home by their cat over a length of time (e.g. Churcher & Lawton 1987, Barratt 1998, van Heezik et al. 2010), telephone surveys (REARK 1994a, b), or scat analysis (Liberg 1984), observed catches via radio tracking (Kays & DeWan 2004) and collar mounted cameras (Loyd et al. 2013). All have potential biases. Survey participants may not want to label their cats as hunters and could understate prey caught (Lepczyk et al. 2003, van Heezik et al. 2010), not admit to their cat catching rare or endangered prey (Baker et al. 2005, van Heezik et al. 2010), or alternatively brag and overstate captures (Loyd et al. 2013). Furthermore, the type of cat recruited for the study may also create bias, such as a study with a majority of accomplished hunters (Gordon et al. 2010, Loyd et al. 2013) and the length of time owners are asked to record prey captured may be too short to be representative or so long that loss of motivation leads to poor data collection (Gordon et al. 2010). Seasonal variation of prey availability also complicates comparison of predation studies. For example, Barratt (1998) found that owners who kept records of prey brought home over 12 months recorded 50% smaller catches than owners estimating prey caught.

Kays & DeWan (2004) radio-tracked pet cats and observed kills, estimating that kill rates were more than three times higher than the number of prey bought home. This agrees closely with the conclusion of (Loyd et al. 2013), based on video recordings from collar-mounted cameras, that only 23% of prey are brought home, 49% are left at the site of capture and 28% of prey are consumed. Finally, no method considers the prey that escape, but die later from shock or injury. Loyd et al. (2013) reported that 49% of prey are left at the site where caught, but did not state the condition the animals were in when they were left.

The mere presence of a cat, albeit in the form of a mannequin, reduced feeding rates to nestlings for up to 90 minutes after the cat model was removed (Bonnington et al. 2013). Feeding rates or amounts did not increase after the mannequin was removed. This could reduce the growth rates of nestlings by up to 40% (Schwagmeyer & Mock
Further, the presence of a cat nearby to breeding birds increased the likelihood of the nest being predated by a third party (Anson et al. 2013, Bonnington et al. 2013).

1.3.2.1 Prey taken by pet cats

Despite the methodological issues, a wide range of international studies confirm that pet cats are opportunistic predators that mainly predate small mammals (Sweden: Liberg 1984, Australia: Barratt 1998, New Zealand: Gillies & Clout 2003, Flux 2007, UK: Baker et al. 2008), with birds as a second preference (UK: Churcher & Lawton 1987, Australia: Barratt 1998, New Zealand: Gillies & Clout 2003) (see also the similar conclusions reached in the early review by Pearre & Maass 1998). Exceptions include an Israeli study (Brickner-Braun et al. 2007) and a New Zealand study (van Heezik et al. 2010), where birds were the preferred prey (but see Gordon et al. 2010) and reptiles were the preferred prey in Georgia, US (Loyd et al. 2013). However, Dickman (2009) cites multiple examples of individual cats demonstrating specialist hunting, highlighting the difficulty in generalising the impact of cats upon prey species.

Studies report a large range of mean prey items caught and, because the methodologies of arriving at the final number of prey caught per cat differ, it is impractical to compare the studies directly. Some researchers only include known hunters in the final number of cats whereas others include all cats, whether they are successful hunters or not. For example, Loyd et al. (2013) report that of the 55 cats in their study, 24 cats were recorded as either stalking and/or chasing prey but only 16 cats were recorded as successfully catching prey. Between these 16 cats, most caught 1 to 2 prey per week, but a small number of cats were far more successful hunters, catching 4 to 5 prey per week. Other variables between studies include climate, prey availability, opportunity to hunt, level of ownership and presence of predators.

1.3.2.2 Cat attributes associated with hunting success

Throughout the various studies, differing cat attributes contribute to hunting success. Younger cats are more successful hunters (Woods et al. 2003, van Heezik 2010, Loyd et al. 2013). More specifically, Woods et al. (2003) found that older or less healthy cats caught fewer birds and herpetofauna but similar numbers of mammals compared to
younger, healthier cats. No significant difference was found between hunting ability and sex (Woods et al. 2003), breed, or when (or whether) the cat was desexed (Barratt 1998).

Local proximity factors may explain some of this variation, although some studies give contradictory results and it is difficult to generalise. On an urban to rural gradient in the United Kingdom, female cats on the outer rural aspects caught more prey than female cats mid-way and in the inner-urban area (Churcher & Lawton 1987). In contrast, in North America Lepczyk et al. (2003) found that cat predation rates did not decline over the urban-rural gradient. In New Zealand, Gillies & Clout (2003) found that rural cats bought home more rodents than urban cats, whereas the urban cats caught more invertebrates. However, the disparity between invertebrates caught by urban and rural cats was explained by a few individuals catching many invertebrates. Prey numbers recorded by Israeli urban and rural cat-owners were similar, even though the species of mammals available differed over the urban/rural gradient (Brickner-Braun et al. 2007). Lastly, several studies found predation of native avifauna is greatest at the forest/urban interface (Barratt 1998, Crooks & Soulé 1999, Gillies & Clout 2003), whereas recorded prey numbers bought back by cats in van Heezik et al.’s (2010) study were not significantly different with regard to cats housed at various distances to bush fragments.

1.3.2.3 Impacts on prey populations

Demonstrating that cats prey on wildlife is not sufficient evidence to conclude that wildlife populations are endangered (Bomford et al. 1995). Given the logistic and ethical difficulties of experimental manipulations of predator numbers in suburbia, most studies examined relationships between cat densities and the abundance or species richness of susceptible prey. Examples show the potential and limitations of such approaches.

Crooks & Soulé (1999) studied in detail 28 sage-scrub fragments in urbanised environments near San Diego in southern California. On the basis of the incidence of cat ownership in the area and the proportion of owners allowing their cats outdoor
access, they concluded that even a modestly sized 20 ha fragment could be encircled by up to 35 hunting cats. Each of these cats would, on averages based on survey data completed by owners, catch 24 rodents, 15 birds and 17 lizards each year. Most would be native species. Given the projected population densities of birds in these fragments, Crooks & Soulé (1999) concluded that this level of predation for birds was unsustainable and that local extinctions would result. The study had the strength of being built upon detailed knowledge of cat densities and predatory habits in a limited area, as well as a solid understanding of the population dynamics of the prey.

In the city of Dunedin, New Zealand, van Heezik et al. (2010) estimated the impact of cat predation on long-term population persistence of a range of native and introduced urban bird species, allowing for data on catch rates in different habitat types, the level of cat ownership and hunting activity measured by prey brought home. City-wide, the estimated mortality caused by cats exceeded or was close to the lower confidence levels for populations of six species. Modelling of three of these (the blackbird *Turdis merula* (exotic), the fantail *Rhipidura fuliginosa* (native) and the silvereye *Zosterops lateralis*) found that in the long-term (50 or 100 years persistence) they were likely to be extirpated by cat predation. Their on-going presence suggests that the city was a population sink drawing on individuals migrating from the outskirts. Even with a 50% reduction in predation, the blackbird *Turdis merula* would still have a high likelihood of extinction within 50 years. The third species, the fantail *Rhipidura fuliginosa*, was only predicted to survive if cat predation ceased.

In a final example from Australia, Dufty (1994) used population demographic data to determine the proportion of mortality attributable to cat predation for a population of the eastern barred bandicoot, *Perameles gunnii*, near Hamilton, Victoria. Mark recapture studies indicated that the major causes of mortality were road kills (63%), cat predation (17.8%) and disease (8.1%). It is thus possible to model the consequences of a reduction in mortality from cat predation for future population size and age structure and demonstrate that cat predation is a constraint, although in a less car-conscious society the larger mortality from road kill would be examined.
As a generalisation, data on predation rates appear to be most useful when placed in the context of prey demography. This allows prediction of probabilities of persistence of prey species over given periods (van Heezik *et al.* 2010).

1.3.2.4 *Anti-predation devices*

Several studies investigated the effectiveness of collar-mounted warning devices in reducing the incidence of predation (Table 1.1). Some studies were observational and compared the incidence of prey capture between cats with and without devices during surveys of predation while other authors used manipulative experiments to better control variables and test the effect of deterrent devices. A key ingredient in some of these studies is the use of cross-over designs in which each cat is monitored for a period with and without a device, so each animal is its own control (Ruxton *et al.* 2002, Calver *et al.* 2007, Calver & Thomas 2011 and references therein).

Overall, collar worn anti-predation devices significantly reduced the total number of prey caught by cats (Ruxton *et al.* 2002, Nelson *et al.* 2005, Calver *et al.* 2007, Gordon *et al.* 2010, Calver & Thomas 2011, Hall *et al.* 2015, Willson *et al.* 2015, Table 1.1). Only the observational studies such as Paton (1991) and Barratt (1997b) failed to show effectiveness of collar mounted devices (bells) (Table 1.1).

The various anti-predation devices can be considered on a case by case basis as they operate in different ways. For example, in areas where the conservation of birds is of great importance such as in New Zealand or suburban areas where there are no native mammals, devices such as BirdsBeSafe™ (BBS) may be preferable. They provide a colourful warning of a cat's presence, protecting birds and herpetofauna with good colour vision (Hall *et al.* 2015). For the protection of mammals in particular, cats wearing devices such as the Liberator™ (Calver & Thomas 2011) have been shown to catch 30% less mammals (Table 1.1). The Cat Alert, CatBib and bells attached the collar have also been shown to be effective in reducing prey captures (Table 1.1).

Although anti-predation devices reduce the amount of prey caught, they do have limitations and reliance on them does not resolve the issue of the sub-lethal impact cats have upon their prey (Bonnington *et al.* 2013), nor the limitation of effectiveness in
reduced lighting for devices such as BBS. Further, encouraging widespread owner compliance for the use of these devices could be difficult.

1.3.3 Roaming behaviour and activity patterns of pet cats

1.3.3.1 Activity patterns

The ancestors of the modern domestic cat were nocturnal hunters, whereas today’s domestic cat seems much more variable. The activity pattern observed in a given situation could be related to prey availability or adapting to life with humans (Sterman et al. 1965, cited in Fitzgerald & Turner (2000)).

Examples of varied activity patterns by pet cats throughout a daily cycle occur across a range of international studies. For example, in suburban Canberra, Australia, Barratt (1997b) found that the type of prey caught depends upon the activity pattern of the prey. More birds were caught in the morning, reptiles in the afternoon and mammals and frogs in the evening. Panaman (1981) established that female British free ranging farm cats slept all night, but were active from dawn to dusk. However, Thomas et al. (2014) found that pet cats ranged further at night and, interestingly, showed no reduction of activity between the seasons. In Japan, Izawa (1982) observed increases in activity of the study cats corresponding to the return of fishing boats, which inadvertently provide fish waste for food. Unsurprisingly, pet cats contained throughout the night predate different prey to unconfined cats. For example, in the United Kingdom Woods et al. (2003) found that cats kept inside at night brought home less mammals but more herpetofauna. The number of birds caught was not affected. A comparison between owned and semi-feral cats in Illinois, US, showed semi-feral cats to be generally more active, particularly at night, whereas the activity periods of owned cats appeared to coincide with that of their owners (Horn et al. 2011).
<table>
<thead>
<tr>
<th>Type of deterrent</th>
<th>Country of Study/Reference</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bells (Observational)</td>
<td>UK (Woods et al. 2003)</td>
<td>Less mammals caught, but birds and herpetofauna not affected.</td>
</tr>
<tr>
<td>Bell (Manipulative)</td>
<td>UK (Ruxton et al. 2002)</td>
<td>Significant reduction of total prey caught per cat (48% less). Not specific toward any prey type.</td>
</tr>
<tr>
<td>BirdsBeSafe (Manipulative)</td>
<td>US (Willson et al. 2015)</td>
<td>Significant reduction in birds caught over two seasons, but particularly in the spring. Significant reduction in mammals caught in one of two seasons.</td>
</tr>
<tr>
<td>Bell and CatAlert™ (Manipulative)</td>
<td>UK (Nelson et al. 2005)</td>
<td>Significant difference when wearing either bell or CatAlert™. Bells significantly reduced total prey caught by 31% (mammals: 34% and birds 42%). CatAlert™ significantly reduced total prey by 42% (mammals: 38% and birds 51%).</td>
</tr>
<tr>
<td>Liberator™ collar mounted</td>
<td>NZ (Gillies &amp; Cutler 2001)</td>
<td>Significant reduction of invertebrates caught but not vertebrates.</td>
</tr>
<tr>
<td>electronic device</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bell (Manipulative)</td>
<td>NZ (Gordon et al. 2010)</td>
<td>Significant reduction in total prey caught by 53%. Significant reductions in mice caught (63%) and birds (50%) and rats (54% not significant).</td>
</tr>
<tr>
<td>Liberator™ collar mounted</td>
<td>Australia (Calver &amp; Thomas 2011)</td>
<td>Significantly reduced capture rates of the total number of prey caught by 50%.</td>
</tr>
<tr>
<td>electronic device (Manipulative)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CatBib™ (Manipulative)</td>
<td>Australia (Calver et al. 2007)</td>
<td>Significant reductions in prey captured for: birds (67%) and mammals (32.7%) but not significantly for herpetofauna (44%).</td>
</tr>
<tr>
<td>Birdsbesafe (Manipulative)</td>
<td>Australia (Hall et al. 2015)</td>
<td>Hall et al. (2015) found significant reductions in prey captured (54%) that have good colour vision. Rainbow and red BBS were more effective in reducing capture rates of birds (Willson et al. 2015).</td>
</tr>
</tbody>
</table>
Laboratory studies show that cats do not function well in cold weather, but cope well in heat (Kelsey-Wood 1989). Hence, in areas where seasonality is minimal, such as Australia (Jones & Coman 1981, Risbey et al. 1999, Read & Bowen 2001, Moseby et al. 2009), California (Crooks & Soulé 1999), Israel (Brickner-Braun et al. 2007), pet cats are unrestricted by weather and hunt all year. In regions with harsh winters, activities of pet cats are more limited (George 1974, Churcher & Lawton 1987, Kays & DeWan 2004, Horn et al. 2011). Reproduction also affects hunting times: females with kittens have shorter hunting times, and may opt to hunt prey that is easier to catch (Liberg 1982).

1.3.3.2 Roaming behaviour

Most studies of roaming behaviour in cats concern feral animals and interpretation of the studies is complicated by variations in the radio-tracking methodologies used, the definition of ‘feral cat’ and sample sizes that are often small. Generally, male feral cats have the largest home ranges (6.2 km$^2$), while pet cats (both male and female) have much smaller home ranges, around 0.02 km$^2$ (Table 1.2). Male home ranges of feral cats are generally significantly larger than those of female feral cats, but the differences are generally not significant between male and female semi-feral and pet cats. For feral, semi-feral and pet cats the degree of overlap and home range size may be determined by kinship and spatial distribution of other cats (Jones & Coman 1982, Barratt 1997a, Metsers et al. 2010, Wierzbowska et al. 2012), food sources, habitat and predators (Jones & Coman 1982, Crooks & Soulé 1999, Kays & DeWan 2004, Brickner-Braun et al. 2007, Wierzbowska et al. 2012). For pet cats specifically, Barratt (1997a) concluded that home range was constrained by the presence of other pet cats and that, in the absence of competition, cats would probably range over larger areas.
Table 1.2 Examples of studies of the home ranges of feral, semi-feral and pet cats

<table>
<thead>
<tr>
<th>Ownership status of cat</th>
<th>Country and author of Study</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feral</td>
<td>Australia (Jones &amp; Coman 1982)</td>
<td>Male 6.2 km(^2) <em>versus</em> female 1.7 km(^2)</td>
</tr>
<tr>
<td></td>
<td>Galapagos Islands (Konecny 1987)</td>
<td>3.04 km(^2) for males and 0.82 km(^2) for females</td>
</tr>
<tr>
<td></td>
<td>Hawaii (Smucker 2000)</td>
<td>5.74 km(^2) for males and 2.23 km(^2) for females</td>
</tr>
<tr>
<td>Semi-feral</td>
<td>New Zealand (Langham 1991)</td>
<td>No significant difference between male and female, but female home range larger than male home range (female: 2.19 km(^2) <em>versus</em> male: 1.34 km(^2))</td>
</tr>
<tr>
<td></td>
<td>UK (Page <em>et al.</em> 1992)</td>
<td>No significant difference between male and female, 1.5 km(^2) (± 1.7 km(^2)) for males and 1.0 km(^2) (± 0.7 km(^2)) for females.</td>
</tr>
<tr>
<td></td>
<td>US (Guttilla &amp; Stapp 2010)</td>
<td>Significant differences between male and females: male: 2.5km(^2) (+/-0.5km(^2)) v female: 0.9 km(^2) (± 0.1 km(^2)). No significant differences between entire <em>versus</em> desexed semi feral cats.</td>
</tr>
<tr>
<td></td>
<td>US (Horn <em>et al.</em> 2011)</td>
<td>No significant difference between male and female, but a significant difference between semi feral and owned cats: (semi-feral:15.7 km(^2) 5.69 km(^2) for males and females, respectively <em>versus</em> owned cats: 0.02 km(^2); 0.19 km(^2) for males and females, respectively).</td>
</tr>
<tr>
<td>Pet (entire)</td>
<td>Poland (Wierzbowska <em>et al.</em> 2012)</td>
<td>Significant differences between entire male and entire female cats (median 0.53 km(^2) <em>versus</em> 0.13 km(^2) for males and females respectively). NB, these cats are more representative of semi-feral cats.</td>
</tr>
<tr>
<td>Pet (desexed)</td>
<td>US (Kays &amp; DeWan 2004)</td>
<td>9/11 cats were sterilised. Mean home range of 0.024 km(^2), ranging between 0.0003 km(^2) and 0.013 km(^2).</td>
</tr>
<tr>
<td>Ownership status of cat</td>
<td>Country and author of Study</td>
<td>Findings</td>
</tr>
<tr>
<td>-------------------------</td>
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</tr>
<tr>
<td>Pet (desexed) cont’d</td>
<td>NZ (van Heezik et al. 2010)</td>
<td>They had a mean home range of 0.03 km², but a median home range of 0.02 km² (ranging from 0.0048 km² to 0.28 km²). There was no significant difference in the home ranges between male and female cats, or between night and day home ranges. The distance from the cat’s home to bush fragments did not significantly alter the home range sizes for these cats. However, the proximity to green areas and home ranges were significant for cats living on the outskirts of town, with home ranges of cats living closer to green areas being significantly larger than cats in suburbs, or next to small areas of remnant bushland.</td>
</tr>
<tr>
<td>Australia (Barratt 1997a)</td>
<td>Male and female cats had similar home ranges (0.08 km² and 0.07 km², respectively), but nocturnal home ranges were significantly larger than diurnal home ranges. Cats from the same residence shared home ranges.</td>
<td></td>
</tr>
<tr>
<td>Australia (Meek 2003)</td>
<td>13/15 were desexed. No significant difference between male and female rural home ranges (0.042 and 0.024 km², respectively), which were comparatively small to Barratt’s (1997a) suburban cats.</td>
<td></td>
</tr>
<tr>
<td>Australia (Lilith et al. 2006)</td>
<td>Significant difference between suburban and rural environments (suburban: ranged between 0.001 km² – 0.064 km² versus rural: ranged from 0.0007 km² – 0.0286 km²).</td>
<td></td>
</tr>
<tr>
<td>Pet (whether entire or desexed not indicated)</td>
<td>NZ (Wood et al. 2016)</td>
<td>Cats were at home &gt; 90% of the time, with home ranges of 0.05 – 16.6 ha (minimum convex polygon)</td>
</tr>
</tbody>
</table>
1.3.4 Pet cats as vectors of disease

Domestic cats (feral, stray and pet) are also vectors of pathogens, including \textit{Toxoplasma gondii} (Dabritz \textit{et al.} 2006, Eymann \textit{et al.} 2006) and \textit{Sarcocystis neurona} (Stanek \textit{et al.} 2003). Toxoplasmosis, caused by the protozoan parasite \textit{T. gondii}, has the highest profile.

\textit{Toxoplasma gondii} has a complex life cycle involving sexual and asexual stages, but the sexual stage only occurs within felids and the asexual stages within intermediate hosts (Hill \textit{et al.} 2005). If a predator other than a cat eats an infected animal, it too becomes infected with cysts. However, if a cat eats an infected animal the parasite establishes in the cat’s intestinal lining, reproduces sexually and completes the life cycle (Hill & Dubey 2002).

In intermediate hosts where rapid proliferation of the parasite has occurred, cell changes are often accompanied by behavioural changes and loss of coordination because of damage to muscles or the nervous system. \textit{T. gondii} alters behaviour in rats, making them more susceptible to predation by cats, the definitive host. Toxoplasmosis is a common cause of death in both captive and free ranging marsupials that are in contact with the domestic cat (Hartley 2006, Basso \textit{et al.} 2007). Marsupials are considered to be among the most susceptible of species to \textit{T. gondii}. While antibodies to \textit{T. gondii} are present in many populations, only immunocompromised animals show symptoms and succumb (Basso \textit{et al.} 2007). Confinement of pet cats can contain infection in urban areas.

1.4 Introduced species and suburban birds: a complex interaction

\textit{Pests are often viewed as having consistently strong and negative effects on biodiversity values..., especially if they have been introduced from elsewhere. However, pests do not necessarily have just negative impacts, and there is evidence that in some situations their effects can be beneficial. The positive effects of pests arise when they become deeply embedded in ecological communities and are involved in webs of direct interactions with other species} (Dickman 2007).
The popular environmental focus on cats in the suburbs is predation on wildlife. While this is well documented, there are few cases of predation by cats threatening wildlife populations. In Australia, the case of the Lyrebird *Menura novaehollandiae* (Pergl 1994) and the Eastern Barred Bandicoot *Perameles gunnii* (Dufty 1994) are important examples. More often, cats kill mainly abundant exotic species such as Common Mynah *Acridotheres tristis*, Common Starling *Sturnus vulgaris*, house mouse *Mus musculus*, and black *Rattus rattus* and Norway rats *Rattus norvegicus* (Barratt 1997b). These are all potential predators or competitors of native birds (e.g. Mathews et al. 1999, Parsons et al. 2006). Thus cats may protect some native species by controlling competitors or mesopredators of these species (Dickman 2007). Furthermore, a focus on cat predation may detract from other threats to wildlife in the suburbs such as high housing densities, road traffic, garden design or poor conservation of native vegetation (Erickson et al. 2005, e.g. Evans et al. 2005, Daniels & Kirkpatrick 2006, van Heezik et al. 2008, Luck et al. 2009). Therefore it is appropriate to balance the discussion on the possible impacts of pet cats with coverage of other possible deleterious impacts of urbanisation.

### 1.5 Urbanisation

Urbanisation, “the anthropogenic conversion of natural ecosystems into human dominated ecosystems” (Gering & Blair 1999), has increased rapidly over the last 60 years. As a comparison, in 1950, 29% of the world’s population lived in urban areas, whereas in 2010, 50% of the population was in urban areas (United Nations 2010). Over the same period in Australia, urban dwellers rose from 77 to 89% of the population (United Nations 2010). By 2050, the proportions of the world and Australian populations in urban areas are expected to continue to increase to 69% and 94% respectively (United Nations 2010). General effects of urbanisation include: habitat loss, fragmentation and isolation, introduction of alien plants and animals, homogenisation of species composition (both flora
and fauna), disruption of hydrological processes, disruption of nutrient cycling and energy flow and introduction of non-native fauna and flora (Alberti 2005).

Although urban areas occupy less than 6% of the earth’s surface, the resources human populations require can render urban areas ‘sinks’ for some native species (Alberti 2005) and ecological traps (Schlaepfer et al. 2002), where wildlife mortality often exceeds reproduction for many species. Prime sites for urbanisation are coastal and tropical areas, where biodiversity is often high (Alberti 2005, Daniels & Kirkpatrick 2006), leading to the conclusion that: “Urbanisation is arguably the most damaging, persistent and rapidly expanding form of anthropogenic pressure” (Garden et al. 2006). The more extensive the disturbance, the greater is the disparity between the fauna community in the urban area and that of faunal communities in remnant native vegetation (Chace & Walsh 2006, Blair & Johnson 2008). Research is not only centered upon the negative impact urbanisation has upon indigenous flora and fauna, but the process as a whole, including the importance of interaction between people and wildlife, no matter if it is introduced or indigenous (Jones & Wiencke 2000, Recher 2010).

1.5.1 Urbanisation and native birds

A healthy ecosystem is one that has sufficient resilience to cope with environmental stresses and is thereby able to sustain healthy communities (O'Laughlin et al. 1994, Vora 1997). Birds are often used as indicators of ecosystem health (Morris & Gilroy 2008) because they are readily observable and large sample sizes can be collected, allowing for analyses with high statistical power. Results from research projects are also more likely to be accepted by the general public if birds are the focus (White et al. 2005), although others argue for invertebrate indicators because invertebrates respond more rapidly to ecosystem processes (e.g. Christie et al. 2004).

Research into urbanisation is increasing, not only from an academic perspective, but from the grass roots or ‘citizen science’ level (Garden Birds Survey in Canberra, British Trust for Ornithology’s Garden Bird Feeding Survey/Garden Bird Watch, North American
Project Feeder Watch are but a few). Indeed, ecological studies of birds are regarded as one of the major successes of citizen science (Dickinson et al. 2012). Most research is in areas where the urbanisation process has been occurring longer, such as the northern hemisphere, although research in the Southern Hemisphere is increasing (Jones 2002, Recher 2004, Grayson et al. 2007, Catterall et al. 2010, Major & Parsons 2010, Stagoll et al. 2010, van Heezik et al. 2010).

1.5.2 Fragmentation and refuges

Urbanisation has had a large impact upon avifauna in terms of decreased quality of refuges and reduced carrying capacity (Lima 1998). As well as the obvious loss of habitat to clearing, weed invasion may significantly alter the characteristics of remnant patches (Recher & Serventy 1991). As patch sizes diminish to small islands, home ranges are reduced, increasing population density (Ditchkoff et al. 2006). Smaller patches also have a higher ratio of edge to core habitat, increasing ingress by predators from the surrounding urban matrix, with predation rates being often highest in the first 50m in from the edge of the patch (Krebs 1994, Barratt 1998, Crooks & Soulé 1999, Kays & DeWan 2004, Morris & Gilroy 2008, Shaw et al. 2008). Connectivity between patches is also important as migration between isolated patches is lessened or eliminated, reducing the genetic fitness/diversity in the population (Krebs 1994). The likelihood of an isolated population becoming locally extinct is greater, because island populations cannot be replenished if decimated by predation or disease (Parsons et al. 2003, Crooks et al. 2004, White et al. 2005). Other factors, such as roads, pollution in the form of noise, light and chemicals and the presence of people also have a large impact on species richness and diversity in urban areas (Blumstein 2014) and contribute to the selection of species that are adaptable and can exploit this environment.

1.5.3 Traffic

Roads and car traffic have more impact upon the abundance and species richness of nectarivores than the presence or absence of street trees (Young et al. 2007). Aside from
the obvious collisions between fauna and vehicles (Ramp et al. 2006), roads create barriers between refuges, increase edge effects and provide easy access for introduced predators dispersing along road verges. Furthermore, the noise from traffic impedes predator avoidance communication (Forman et al. 2003, Recher 2004) and affects the structure of begging calls of nestlings (Leonard & Horn 2008). The impairment of aural communication may also affect the abundance and distribution of avifauna within neighbouring populations (Bayne et al. 2008), excluding larger bodied birds with low frequency calls in the presence of low frequency noise such as in urban and industrial areas and favouring smaller birds with higher pitched frequency (Francis et al. 2011). Further, birds may also vocalise at night when it is quieter (Fuller et al. 2007), annoying residents.

1.5.4 Light

Artificial light in urban areas and diffuse light penetrating surrounding remnant vegetation can have various effects on birds including mate selection, timing of breeding, egg laying, moulting, and ultimately affecting their general fitness (Kempenaers et al. 2010). Depending upon the species, artificial light can impede or enhance their life history. For example, species that naturally vocalise early in the morning begin even earlier with artificial light (Kempenaers et al. 2010). Migratory birds can become disorientated with artificial light and suffer from exhaustion, dying or becoming more susceptible to predation (Spoelstra & Visser 2013). Interactions between species are altered. Insects attracted to street lights are no longer available to diurnal predators. Conversely, species that adapt to flying in poorly lit conditions, such as Great Tits *Parus major* increase the food supply to their chicks (Titulaer et al. 2012). Spoelstra & Visser (2013) call for much needed research into this field, investigating the long term effects of fitness at the species and community levels.

1.5.5 Pollution

Organophosphates, first used in WWII as nerve gas, are now the most common class of pesticide used in city gardens. Although they have a shorter half-life than their
predecessor, organochlorines, organophosphates and the related carbamates are potentially highly toxic to non-target wildlife and can be absorbed via the skin, the respiratory tract or the digestive tract. Organophosphates inhibit the enzyme acetylcholinesterase, which is essential for the functioning of the central and peripheral nervous systems. Further, exposure at a sub-lethal level reduces the animal’s ability to thermoregulate, forage and reproduce (Grue et al. 1997). Decarie et al.’s (1993) US study of the impacts of organophosphate insecticides on the American robin Turdus migratorius in suburbia did not find any ill effects of these pesticides, although Grue et al. (1997) believe that biases in sampling procedures may be the reason for not finding any ill effects. After a comprehensive literature review, Mitra et al. (2011) concluded that, although the risk of lethal doses to wildlife could be managed, sublethal doses could affect nervous system activity in a wide range of species with consequences for both individuals and populations.

Lead is a heavy metal and is neither excreted nor biodegraded. It concentrates through food chains, ultimately reaching high levels in top order predator where it affects reproduction, immunity and ultimately survival (Ditchkoff et al. 2006). Ditchkoff et al. (2006) notes several effects of lead pollution on birds in cities, including behavioural (increased aggressiveness and impaired ability to fly, land and walk) and physiological (anaemia, brain damage and emaciation) responses. Further, effects of heavy metals on Great Tits showed their song repertoire to be less frequent and reduced in length, ultimately affecting reproduction (Gorissen et al. 2005). Although lead is no longer used in insecticides, household paints, petrol, or fishing sinkers, significant amounts are still found in soil from previous use. Ground foraging birds are more at risk of ingesting contaminated sources such as insects and earthworms, which have high levels of lead per unit body weight (Butt 2008, Roodbergen et al. 2008). Many areas within the urban environment appear to provide opportunities for colonisation for passerines, but may actually act as a sink or environmental trap (Schlaepfer et al. 2002) because of unforeseen effects such as lead poisoning (Roux & Marra 2007). For example in Esperance, Western Australia, Gulson et al. (2012) examined liver samples of birds found dead in the town and concluded
the deaths were caused by acute toxic levels of lead, the source of which was lead carbonate that was exported from the Esperance port.

1.6 Recorded avifaunal changes over time and the urbanising gradient

Bird species richness most often decreases along the gradient from periurban to urban, sometimes with a peak in species richness where urban impact is intermediate between the two points (Strohbach et al. 2014). In the US, recorded changes in community composition include increases in seed eaters (Emlen 1974, Walcott 1974) and decreases in foliage gleaners and ground nesting species (Emlen 1974, DeGraaf & Wentworth 1981), with insectivorous migrants and breeding birds now being transitory (Walcott 1974). Australian studies found these changes too, as well as decreases in the occurrence and population sizes of small species plus increases in occurrence or population size of large species (Recher 2004, Catterall et al. 2010, Major & Parsons 2010).

In Sydney, Australia, Major & Parsons (2010) compared museum records to contemporary observations and showed that 80% of the species in the historical group weighed less than 50 g, whereas in the contemporary group there were less than 50% in this weight range. Of the 10 most common historical species, none are present in the current top 10 list, with insectivores more likely to become scarce. In the greater Brisbane area of Australia for over 15 years, changes in the abundance of suburban species were greater than in forest sites (Catterall et al. 2010). The majority of the suburban species were large bodied (≥ 60 g) and belonged to a variety of feeding guilds, whereas the forest species were predominately small bodied (< 60 g) birds that foraged for either nectar or insects near foliage (Catterall et al. 2010). In contrast, the urban bird fauna of the Northern Hemisphere comprises mainly small bodied and exotic birds (Garden et al. 2006).

Major & Parsons (2010) suggest that the decline in numbers of Australian insectivores and honeyeaters is due to the reduction in food resources as native plantings are replaced with exotic shrubbery which is also poor in providing refuge for those species requiring it. Further, the presence of large colonial honeyeaters is also linked with the
demise of smaller species, either because the larger birds aggressively exclude the smaller
birds, and/or because the habitat is more suitable for the larger bird and less so for smaller
species (Major & Parsons 2010).

The proportions of anthropogenic structures, hard surfaces such as roads and paving
and vegetation coverage, can be ordered on a gradient between periurban and urban areas
Clergeau et al. (2001), Blair & Johnson (2008), Evans et al. (2009), and van Heezik &
Adams (2014) have recorded gradual changes in the avian community composition and
diversity along the periurban to urban gradient, with communities becoming more
homogeneous nearer to city centres. However, in study sites experiencing marked
seasonality, diversity indices can be higher in urban than periurban areas due to
anthropogenic support of food and shelter (Clergeau et al. 1998).

Bird species can be grouped depending upon their response to anthropogenic
disturbance. Factors such as the individual’s flight initiation distance, degree of sensitivity
and habituation, requirement of complex structured vegetation are some of the main factors
that determine the presence or absence of birds throughout the urban gradient.

1.6.1 Suburban Species

Synanthropic species (wild species living near people and benefiting from them) (Johnston
2001) tend to be opportunistic generalists (Mennechez & Clergeau 2001) and include many
exotic species (e.g. Recher 2010). They utilise: anthropogenic structures for nesting
(Marzluff 2001), expansive lawn areas for feeding (Mennechez & Clergeau 2001), and
scavenge in refuse areas (Møller 2008). They reproduce rapidly, are often multibrooded
(Batten 1972) and take advantage of the longer growing season of urban areas (Møller
2008). There is evidence in some North American and European synanthropic birds of
rapid evolution (Diamond 1986), including: higher fecundity (Johnston 2001), acquiring
new behaviours and/or changes in behaviour (Diamond 1986) and physiological changes
(Møller 2008). For example, in Europe tits *Parus* spp. and starlings *Sturnus vulgaris* now
provision nestlings with easily obtainable anthropogenic food, even though it is usually lower in energy content than naturally occurring food (Mennechez & Clergeau 2001). In China, Black-billed Magpies *Pica pica* exploit suburbia by altering the position of their nests, increasing in height along the rural to urban gradient (Wang *et al.* 2008). The European Blackbird *Turdus merula*, once a forest specialist and now well established in urban centres throughout its range, has genetically related behavioural adaptations to urban life including alterations in reproductive cycles, migratory patterns and changes in responses to stress (Evans *et al.* 2010). A combination of physiological and behavioural factors also favours a reduction in responses to stresses in urban environments, including shortened flight distance from a perceived danger (Blumstein 2006, Møller 2008) and lower production of cortico-steroids (Partecke *et al.* 2006, Bonier *et al.* 2007).

### 1.6.2 Remnant species

In the Australian context, remnant species (those once widespread and now restricted to narrowly defined areas) have also been termed ‘neglected foliophiles’ because they are small, often inconspicuous, scarce in suburbia and not as well known to the general public as ‘Aussie icons’, such as the Australian magpie *Gymnorhina tibicen* (Catterall 2004). Small birds in this category are usually insectivores foraging in dense habitat and reliant upon the abundance of insects and cover offered by undisturbed and unfragmented areas (Bhullar & Majer 2000, Parsons *et al.* 2003, Recher 2010). These species detect rapidly moving prey and also disturbances, and hence do not tolerate close approaches (Blumstein 2006). Declines in these insectivores may in turn promote declines in the health of the native vegetation, which in turn experiences heavy herbivory if insect numbers increase (Christie *et al.* 2004).

### 1.6.3 Effect of local and regional habitat on urban avifaunal communities

The impact of local versus regional effects varies with characteristics of the study site such as proximity to and size of natural bushland, latitude, and seasonal effects. For example, in Canada, both local and regional factors influenced sensitive species such as
ground and shrub nesters across their ranges, whereas mainly local factors influenced the abundance of species adapted to urban life (Melles et al. 2003). Alternatively, in southern California, USA, models predicting the bird abundance of approximately 50% of the 20 species studied, had a better fit when both landscape and local variables were included, particularly for species sensitive to edge effects. The species were grouped according to their reaction to fragmentation and edge effects, the group containing edge/fragmentation insensitive species did not improve with the addition of landscape variables as these species seem not to rely on natural habitat (Bolger et al. 1997). Conversely, when Clergeau et al. (2001) compared bird species richness with local and landscape variables from three European towns, they found that bird species richness is influenced by local rather than landscape factors. Generally, diversity increased away from the city centre, but in winter, diversity in the city centre was often higher. In the UK, the size of natural habitat fragments, isolation, latitude and complexity of vegetation structure influenced the species richness of urban birds (Evans et al. 2009). In New Zealand, van Heezik & Adams (2014) found the presence of remnant bushland supported native birds in nearby suburban gardens. In Australia, large areas of open grassland support large bodied birds (> 60 g grams). Small bodied species rely on refuges for food, nesting opportunities and avoiding predators (Catterall et al. 2010).

The presence of street trees also affects species richness in a range of ways. For example, in Paris Huste et al. (2006) found that street vegetation was the second most important factor in species richness after patch size. Young et al. (2007) investigated the use of various street trees in suburban and inner city Adelaide by various foraging guilds and found different types of street tree supported different guilds. Plane trees, although introduced and deciduous, were favoured by insectivores, the least represented guild in this study. The abundance of insectivores in the surrounding remnant bush was far greater. The native bottle-brush and red gum were the preferred trees of nectarivores. These trees provided abundant nectar and psyllids (lerp) that produce rich supplies of carbohydrate. Surrounding vegetation had little impact on the results, although the authors noted that their
visual assessment of the vegetation was unlikely to give a reliable measure of the flowering plant biomass. White et al. (2005) found that, in urban Melbourne, the abundance and species richness of bird species differed depending upon the type of street vegetation and the location of the site. Total bird species richness was greatest in parks and native streetscapes. Insectivorous and nectarivorous native species decreased in abundance and richness as the vegetation gradient changed from mainly native and/or structurally diverse vegetation to structurally simple and/or exotic vegetation. The authors emphasise the importance of planting and managing vegetation that provides food and a refuge for urban avifauna (White et al. 2005).

In summary, landscape variables such as latitude interact with local variables such as street plantings, extent of remnant native vegetation, presence of introduced species and the original composition of the native bird communities to produce specific local responses of bird communities to urbanisation. Of these, the plantings in suburban gardens are under the greatest control of individual home owners.

1.6.4 Suburban gardens

Suburban gardens account for much of suburbia and, depending upon their size and structure, may support native wildlife and help maintain biodiversity (Daniels & Kirkpatrick 2006, van Heezik et al. 2008, Ashley et al. 2009, Evans et al. 2009, Loss et al. 2009, Luck et al. 2009, van Heezik et al. 2013, van Heezik & Adams 2014). For example in Dunedin, New Zealand, suburban gardens make up 36% of urban areas (Mathieu et al. 2007) and in the UK, where housing density is higher, the figure is 23% (Gaston et al. 2005). However, the size and structure of gardens are reducing as block sizes become smaller, houses increase in size and more gardens are replaced by surfaces such as decking or paving (van Heezik & Adams 2014).

As urbanisation is rapidly increasing (United Nations 2010), management of these areas in terms of maintaining biodiversity is paramount (Luck et al. 2009). Part of the management is to understand the residents’ characteristics, practices and motivation with
the aim of encouraging them to support biodiversity, as well as to motivate urban planners. Studies to date have identified garden types based upon age, affluence, gender, ethnicity, susceptibility to consumerism and socioeconomic status. For example, a Tasmanian study showed that residents over 65 years are less likely to have a native garden, affluent residents are more likely to live in suburbs with greater canopy, residents with a higher education are more likely to have a ‘woodland’ type garden and unemployed residents have a ‘non-garden’ (Kirkpatrick et al. 2007). Luck et al. (2009) also found that socioeconomic variables predicted vegetation cover throughout suburbs in south eastern Australia, with education and immigration status positively correlated with vegetation cover. Similarly, Hope et al. (2003) reported that income predicted greater garden plant diversity in their Central Arizona-Phoenix USA study area, coining the phrase ‘luxury effect’, whereby residents with a greater income are more likely to maintain a garden versus residents with a lower income. However, in reference to bird species richness in Chicago, USA, Loss et al. (2009) found that income per capita is inversely related to native bird species richness, but positively related to exotic bird species richness, tying in with the concept that maintained exotic gardens support exotic birds more than native bird species (Green et al. 1989).

Van Heezig et al. (2008) found that the size of suburban gardens is strongly related to the garden composition, with larger gardens supporting both greater numbers of species richness and total numbers of exotic and bush natives. Furthermore, van Heezik & Adams (2014) found that the proximity of remnant bushland supported the presence of native species found in nearby gardens and highlighted the importance of urban planning to incorporate remnant areas in new subdivisions for the maintenance of biodiversity.

The ages of suburbs, associated with changes in housing trends, are also important in managing urban biodiversity. In Chicago, newer suburbs supported a higher bird species richness compared to older areas. The likely difference in this study is that the new subdivisions retained a substantial portion of the native vegetation. Furthermore, older suburbs had more hard surfaces, were further from natural vegetation and had less undeveloped land (Loss et al. 2009). Hope et al. (2003) also found plant diversity related to
the age of suburb, with higher diversity in new housing areas, and attributed this to changes in landscape design, technology and cultural values. Original residents in arid environs created shade to provide cooling via evapotranspiration using exotic plants, but with widespread use of air conditioners, minimising water use, and greater interest in conservation, homeowners tended to retain and plant local natives. In contrast to these results, other studies (Vale & Vale 1976, Munyenyembe et al. 1989) have found that older, more mature suburbs often support greater avian community composition. In many new housing areas, houses are built on clear-felled land and gardens are simple in structure with impervious surfaces. The majority of trees found in new subdivision are young (Vale & Vale 1976) and offer better food sources and habitat as they mature, which is why, in studies such as Munyenyembe et al. (1989) and Vale & Vale (1976), the total number of bird species increases with suburb age.

In summary, there is strong evidence supporting the importance of suburban gardens for increasing diversity (Daniels & Kirkpatrick 2006, van Heezik et al. 2008, Ashley et al. 2009, Evans et al. 2009, Loss et al. 2009, Luck et al. 2009, van Heezik et al. 2013, van Heezik & Adams 2014). Organisations such as BARS (2011) in the UK and Wildlife Protection Association of Australia and Backyards for Wildlife in Australia provide information at a local level for residents to enhance their private gardens for the benefit of wildlife (Department of Environment and Natural Resources 2011). Nevertheless, suburban garden design and plantings cannot replace the vegetation in large regional bush fragments, in part because they also carry new risks to wildlife from factors such as traffic and pets. Urban/suburban community bird assemblages are not a subset of the surrounding periurban landscape (Clergeau et al. 2001, Catterall et al. 2010).

### 1.6.5 Impacts of pet cats on wildlife in the context of urbanisation

Private gardens in cities are important habitat for native and introduced birds and other wildlife. It is undeniable that pet cats kill large numbers of wildlife in these settings, although there is little strong evidence of deleterious impacts on wildlife populations. The
situation is complicated by factors such as road traffic, pollution and habitat destruction and fragmentation. Thus while some authors conclude that the sheer volume of cat predation must be having a detrimental impact (e.g. Paton 1991, Lepczyk et al. 2003, Woods et al. 2003, Gordon et al. 2010, Metsers et al. 2010, van Heezik et al. 2010), others such as Fitzgerald (1990), Nattrass (1992) and Chaseling (2001) argue that the impact of cat predation is overstated and detracts from more important impacts such as habitat destruction and traffic. Given the plausibility of impact but the high degree of uncertainty, it is appropriate to invoke the precautionary principle, which argues that in such situations actions should still be taken to protect the environment concurrent with research to reduce uncertainty (Ashford et al. 1998, UNESCO 2005). If the threat is ultimately found to be inconsequential, actions can be discontinued, whereas if it is found to be significant the strongest actions in mitigation are justified. Actions taken under uncertainty about the full extent of impact are called precautionary, whereas once a threat is definitively established they become preventive (Deville & Harding 1997).

The precautionary principle has its critics, who argue that it is simply a rationale for inaction (e.g. Goklany 2001). However, precaution need not mean this and it may allow activities to proceed subject to careful guidelines (Deville & Harding 1997, Calver et al. 1999). Furthermore, it requires extensive consultation as part of implementation and is readily adaptable to different environments, problems and human conditions (Harding & Fisher 1994, Deville & Harding 1997, Kruger et al. 1997). Therefore it is well suited to the debate over the putative impacts of owned domestic cats on wildlife (Grayson & Calver 2004) and it has been applied in this context (Lilith et al. 2006).

1.7 Recommendations for wildlife conservation

Recommendations for wildlife conservation in the face of cat predation appear to be on a case by case basis, often responding to local attitudes. In Perth, Western Australia, Lilith et al. (2006) recommended a buffer zone of 360 m around nature reserves or significant native bushland where residents would be forbidden to own a cat. Alternatively,
the large variation in distance travelled by cats in Dunedin, New Zealand (Metsers et al. 2010). In the UK, Thomas et al. (2014) recommend a general buffer zone with a radius of between 300 to 400 m, based on the maximum daily area ranged by one cat. They comment that this buffer zone is conservative and could be as small as 79 m based on the mean daily area ranged (1.94 ha), but also comment on the importance of erring on the side of caution. In Poland, Wierzbowska et al. (2012) recommended introducing legislation, supported by education campaigns, enforcing exclusion zones where cats would be trapped and then either euthanized or rehomed. Cats living in homes within these zones would be contained night and day, sterilised and registered. No buffer zone was specified. In areas where buffer zones and cat exclusion zones are introduced, the distances may need to be reviewed and expanded as the distances cats range is thought to be dependent upon cat density (van Heezik et al. 2010, Thomas et al. 2014). Similarly, as such measures are introduced, other pest control measures will also need to be included such as rat control (Dickman 2009, van Heezik 2010).

Confinement or curfews are more stringent options. In Sherbrook, Australia, a cat curfew was introduced in 1991 in an effort to protect the lyrebird (Menura novaehollandiae) (Pergl 1994). Lyrebird numbers are now steady and the curfew has been extended to 24 hours per day, 7 days per week (Dow 2014). Such stringent options are not likely to be well received elsewhere. In the UK, recommendations for cat control to protect wildlife are, in comparison, very mild (collar mounted electronic devices). The acceptance by the general public of anything more would be poorly received, partly because the general public do not perceive pet cats as negatively affecting wildlife (Thomas et al. 2012).

1.8 Aims and plans of this thesis

This thesis seeks to apply a precautionary approach specifically for the impact of pet cats on passerine birds in the city of Perth, Western Australia. Passerines were chosen because they are the most common native birds in suburban gardens and the majority of
passerines weigh 35 to 550 g, many of which are within the preferred prey weight range (< 200 g) of the domestic cat (Dickman 1996). The thesis aims to:

• justify a case for applying the precautionary principle to this problem.

• reduce uncertainty regarding the impacts of pet cats in this environment by testing for relationships between cat density and bird species richness and community structure. I reasoned that, if pet cats had a negative impact, then bird species richness should be reduced in the presence of cats, with smaller ground-foraging or ground-nesting species likely to be the most severely impacted.

• consult with citizens to determine a range of acceptable precautionary measures that could be applied.

• recommend a precautionary strategy that could be applied in Perth while awaiting the results of future research on the extent of impacts.

It is organised as follows:

• Chapter II reviews the basic tenets of the precautionary principle and establishes a general framework for applying the precautionary principle to the problem of pet cat predation on wildlife.

• Chapter III presents background on the study site and the resident bird community, so readers can appreciate the unique Perth situation.

• Chapter IV attempts to reduce uncertainty by using data from detailed passerine bird surveys across Perth together with information on a range of variables including housing density, proximity to bushland, garden plantings and cat density to predict the presence/absence of a range of passerine species and also bird community structure.

• Chapter V assesses the attitudes and practices of cat owners in suburban Perth, with particular reference to their concern over wildlife issues and willingness to take
action to mitigate them. Data were also collected on the attitudes of non-cat owners and their requirements for cat regulation.

- Chapter VI synthesises the data to suggest the extent of precaution required in relation to cat predation and the precautionary measures likely to enjoy strong community support.

Chapters II, IV and V are published and are presented as the unedited text of published papers. Their chronological order of publication is not the same as their order in the thesis, nor of course are the literature reviews within them ‘up to date’ as of late 2015 (for family reasons the final version of the thesis was delayed several years after publication of the thesis). Therefore Chapter VI has been used to place the findings in the context of the most recent literature. Where appropriate, footnotes and appendices are also used to indicate important updates. Appendix A expands on analytical issues related to Chapter IV and Appendix B addresses specific issues to other data chapters.
2. Regulation of domestic cat ownership to protect urban wildlife: A justification based on the precautionary principle

This chapter was published as a book chapter. To maintain consistency with the rest of the thesis, the abstract, acknowledgements and keywords have been removed and the references included in an amalgamated reference list at the end of the thesis. Otherwise, the text is identical to that of the publication.

2.1 Introduction

protect the environment and the level of uncertainty in existing information, while also considering the views of all participants in the debate.

The precautionary principle provides an appropriate framework which is familiar to wildlife biologists from debates over the natural resources (e.g. Calver et al. 1999). It argues that:

‘Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, public and private decisions should be guided by: (i) careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment; and, (ii) an assessment of the risk-weighted consequences of various options’ (The Intergovernmental Agreement on the Environment, May 1992, quoted in Deville & Harding 1997, p. 13).

The explicit recognition of the need for action despite uncertainty is appropriate to the cat-control debate. However, application of the precautionary principle is generally accepted as a consultative process (e.g. Kruger et al. 1997) in which specialist scientific opinion is only one voice (Santillo et al. 1998). Therefore wildlife biologists working within this framework would benefit from complementing their thorough understanding of what is known and unknown about the impacts of owned domestic cats on wildlife with an appreciation of the attitudes and practices of cat owners, the concerns of citizens who do not own cats, the perspectives of veterinary professionals and the views of local government councillors and officers who have the power to enact and enforce cat control regulations.

In this paper we summarise both the current understanding of the potential impacts of owned domestic cats on suburban wildlife in Australia and the attitudes toward cat regulation expressed by major interest groups. We then integrate these elements into a precautionary framework arguing for regulation of cat ownership. Our perspective is
predominantly Western Australian, as our state is among those yet to introduce uniform, state-wide legislation on this issue\(^1\). However, the explicit acknowledgement of uncertainty and the incorporation of viewpoints from divergent groups into a precautionary approach will be applicable across Australia.

### 2.2 Predation by owned domestic cats in Australia

*While we may have sympathy for individual animals that die, it is possible to take a substantial ongoing harvest of animals from a population and not cause any decline in numbers. It is perfectly possible that cats might simply take a sustained harvest of many native species without threatening their populations at all.*

Bomford *et al.* (1995, p. 203)

Dietary studies confirm that feral cats eat Australian native fauna and abundant circumstantial and anecdotal evidence suggests that they may suppress prey populations (see Dickman 1996, Calver & Dell 1998, Risbey *et al.* 2000 for full reviews). However, numerous authors have argued that demonstrating that feral cats prey on native species is not proof of an impact on prey populations and that experimental evidence from manipulation of predator densities is required (Bomford *et al.* 1995, Dickman 1996, Risbey *et al.* 1999). Recent field experiments demonstrating increases in native fauna following cat removal, failed fauna reintroductions in the presence of feral cats, and studies of mammalian extinctions on off-shore islands in either the presence or absence of feral cats, all strengthen the case for feral cats causing population declines in native fauna (e.g. Christensen & Burrows 1994, Risbey *et al.* 2000, Burbidge & Manly 2002). However, the evidence may not be strong enough to convince all critics.

Unfortunately, experimental manipulations of predator densities are harder to achieve in a suburban setting when the predator is a domestic pet. Cat curfews or the establishment of cat exclusion zones where cats cannot be owned do alter cat density in

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\(^1\) This has now changed with the passing of Western Australia’s Cat Bill 2011.
time or space, but we are unaware of any situation in which they have been implemented and monitored in conjunction with control areas where cats roam freely. This restricts interpretation to an uncontrolled before/after design. Therefore, studies of the putative impacts of owned cats on suburban wildlife are restricted mainly to surveys and uncontrolled manipulations. While these confirm that some owned cats do eat native wildlife, they do not resolve the issue of whether or not this impacts upon prey populations.

Surveys of predation by owned cats on wildlife in Australia are mostly less than a decade old, reflecting the recent surge of interest in this question (e.g. Paton 1991, Trueman 1991, Paton 1993, REARK 1994a, b, Barratt 1995, McHarg et al. 1995, Barratt 1997, 1998, Perry 1999, Grayson et al. 2002). Barratt (1994), Ruxton et al. (2002) and Gillies & Clout (2003) reviewed the relevant international literature. Methods varied, including telephone polls of owners, owner self-assessment via forms completed in veterinary surgeries, mailed questionnaires and collection of all prey caught by the cat. Some studies were highly localised, focusing on a specific township or city, while others attempted nation-wide assessment (Table 2.1). Very few of the studies were peer-reviewed. Cat ownership was estimated nationally at between 25.2% of households (REARK 1994a, b) and 27% (McHarg et al. 1995), with 8% of owners having more than one cat (Perry 1999). Although differences in residential zoning mean that the actual density of cats implied by these figures will vary according to housing density, Paton (1991) estimated the density of owned cats in suburbia at c. 2/ha. This is markedly greater than the densities of 0.003 - 0.01/ha known for feral populations (Paton 1991, Risbey et al. 2000). The overall trend of cat ownership over time was in decline (REARK 1994a, b, McHarg et al. 1995, Kelly 1999, Perry 1999, Baldock et al. 2003).

The telephone or paper surveys found that approximately half of all pet cats hunted, ranging from 49% in Mt Isa, Queensland (Perry 1999), to 56% nationally (REARK 1994b). In the warm Queensland climate at Mt Isa and Brisbane, lizards were the most common prey, followed by birds and then mammals (Perry 1999). Elsewhere in Australia, mammals and birds predominated as prey, followed by lizards. The mammals and birds taken were
mainly introduced species such as house mice *Mus domesticus*, starlings *Sturnus vulgaris* and sparrows *Passer domesticus* (REARK 1994b, Perry 1999). While owners did not identify the lizard species taken, they presumably were native species.

**Table 2.1** Summary of the study methods and target populations of major Australian surveys of predation by owned cats or studies of the attitudes and practices of owners and non-owners towards owned cats in suburbia.

<table>
<thead>
<tr>
<th>Criteria for responsible ownership</th>
<th>Australian sites</th>
<th>Other sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total confinement on owner’s land</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Containment at night only</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>Sterilisation</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Vaccination</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Worming</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Feeding</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Not feeding strays</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Not declawing the cat</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Identifying/registering the cat</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Housing the cat correctly</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Placing a bell on the cat’s collar</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Arranging care when on holiday</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total sites visited</strong></td>
<td><strong>33</strong></td>
<td><strong>27</strong></td>
</tr>
</tbody>
</table>

Where owners collected the prey killed by their cats, similar or higher proportions of hunting cats were noted, prey species were identified more accurately, mean predation rates were estimated and demographics of hunting cats were noted. In Paton’s (1991) study, 50 to 60% of cats caught birds or mammals and c. 30% caught lizards. On average, cats caught eight birds, 16 mammals and eight reptiles each/year. However, the range was broad and cats in country towns and rural areas caught up to twice the number of prey/year than cats in large cities. Native species comprised a large proportion of the prey (*e.g.* only 9 of the 76 bird species caught were introduced), although this was probably influenced by the inclusion of rural cats in the sample. Barratt’s (1995, 1997, 1998) studies concentrated on suburban Canberra. In a given year, 70% of the cats caught less than 10 prey animals and 6% of the cats caught greater than 50 prey animals. The estimated mean predation rate was 10.2 prey items per cat per year, considerably less than the rate of 23.3 prey items per cat per year estimated by owners before the study started. Prey species comprised 64%
introduced mammals, 27% birds (approximately half of which were native species) and 7% lizards. Native mammals comprised only 1% of prey. Hunting declined with age, but there was no evidence that the age a cat was neutered, its sex or its breed influenced hunting behaviour. Night time curfews on cats were recommended to reduce predation on mammals, but they were unlikely to protect diurnal birds or lizards. However, these figures do not indicate any impact of cat predation on prey population numbers because there was no quantitative assessment of the prey populations.

A before/after study, albeit uncontrolled, was provided when the municipality of Sherbrooke in Victoria responded to pressure for over four years from groups concerned about dwindling lyrebird *Menura novaehollandiae* numbers in Sherbrooke Forest. The council implemented cat registration by marking animals with microchips inserted under the skin, offered a reduction in registration fees for desexed animals and instigated controls on pet movement and a night-time curfew (Anderson 1994). Opposition groups argued that the regulations violated the rights of cat owners and their pets, and were also inhumane (Hartwell 1994), so council officers used education campaigns to change the perception of the community to cat legislation. The actions appeared successful as the lyrebird population recovered and there was a decrease in the number of lyrebirds brought in with cat related injuries. However, attacks on diurnal native birds increased markedly, presumably because cats hunted by day rather than by night (Pergl 1994).

Overall, it is evident that owned cats do kill a range of suburban wildlife, including some native mammals, birds and lizards. The proportions of native species taken increases on suburban fringes adjacent to bushland and in rural areas (Paton 1991, Barratt 1997, 1998). The dense cat populations sustained in suburbs by human support may also lead to high predation rates. However, there is no conclusive evidence of suppression of populations of any native species in suburbia as a result of cat predation and accurate estimates of predation rates are difficult (Barratt 1998).

Based on this information, several authors take the view that the impact of owned domestic cats on urban wildlife is overstated: few cats hunt often and their impact is likely
to be small relative to losses caused by other factors such as land clearing and road mortality. Furthermore, there is no compelling evidence that wildlife populations are endangered by predation by owned domestic cats. Although wildlife losses can and should be minimised, pets should not be demonised (e.g. Nattrass 1992, REARK 1994b, Perry 1999, Chaseling 2001). The position was summarised succinctly by Chaseling (2001):

*In Australia it seems cats have been painted as environmental vandals and their popularity as pets has suffered as a consequence. Whilst it is true that some household cats do kill wildlife, by far the biggest threat to native animals is habitat destruction by humans.*

On the whole, well-managed, responsibly owned cats present little threat to native animals. Most domestically owned cats live in highly modified environments and it would be hard to differentiate their impact from the impact of introduced species and habitat change. In environmentally sensitive areas, both cats and wildlife can and should be managed to reduce predation.

We respect that view, but prefer to emphasise that uncertainty as to whether or not cat predation poses a serious risk to remnant wildlife populations in suburbia is no reason for inaction until the question is resolved. Therefore, it is appropriate to invoke the precautionary principle, which argues that where either risk or uncertainty are high, action should be taken to anticipate possible environmental damage (Deville & Harding 1997). Such action could include incentives to neuter pets to reduce the possibility of strays, restricting the number of cats that can be kept by one household to limit cat densities, requiring identification and licensing of cats so nuisance animals can be traced, confining cats to owners’ premises at all times or at least at night to lessen the exposure of potential prey and prohibiting cat ownership in environmentally sensitive areas. The need for such measures is greatest on suburban fringes and adjacent to bushland remnants, where opportunities for attacks on native species are greatest (Barratt 1998).
However, gaining community acceptance of cat regulation on the basis of wildlife welfare alone is challenging, given the lack of convincing data. This suggests that arguments beyond the suspicion of impacts on wildlife are necessary if regulation is to attract widespread support. Such arguments come from the attitudes and practices of other stakeholders in the debate.

2.3 Attitudes and practices of cat owners

“When there was room on the ledge outside of the pots and boxes for a cat, the cat was there – in sunny weather – stretched at full length, asleep and blissful, with her furry belly to the sun and a paw curved over her nose. Then that house was complete, and its contentment and peace were made manifest to the world by this symbol, whose testimony is infallible. A home without a cat – and a well-fed, well-petted and properly revered cat – may be a perfect home, perhaps, but how can it prove title?”

(Twain 1894, pp. 21-22)

Cat ownership confers significant health benefits including lower blood pressure and reduced incidence of heart attack and stroke (Anderson et al. 1992, Jackson 1999). Pet ownership is used to teach children responsibility, respect and compassion (Murray & Penridge 1997), while children who grow up with pets appear to develop fewer allergies to cats and dogs than those who do not grow up with pets in their household (Roost et al. 1999). Several authors estimate significant economic benefits to society as well. In 1995 it was estimated that $2.2 billion was spent on pet care in Australia and over 30,000 people were employed in the pet food industry, veterinary services and manufacture of associated pet products (Murray & Penridge 1997). Mangosi (1999) estimated that Australians spent $365 million on cat care alone in 1998, with approximately 41% of this being veterinary bills. Headey (1999) estimated that cat and dog ownership saved the Australian health budget $988 million in the 1994-95 financial year. Therefore, many people have significant practical, emotional and financial reasons for defending cats.
What constitutes responsible cat ownership and are Australian cat owners responsible? For some authors, the incidence of sterilisation is a simple yardstick which shows that Australian cat owners are, on the whole, responsible (see Perry 1999, Chaseling 2001, Grayson et al. 2002 for use of this approach). However, results of an internet search for ‘responsible cat ownership’ using the Google search engine on April 28th 2003 indicate a much broader range of criteria for responsibility (Table 2.2). In total, 651 sites were identified, of which we considered the first 60 listed. Twelve criteria of responsible ownership were recognised from these sites, with sterilisation, identification/registration and confining cats between dusk and dawn being the three most mentioned for the Australian sites. Internationally, sterilisation, identification/registration and total confinement (the cat always being inside the home or within an outdoor enclosure) were the three criteria mentioned most often.

With regard to sterilisation, Australian cat owners appear highly responsible. Perry (1999) found that 83% of pet cats were sterilised before they were a year old, 93% were sterilised by the age of five years and few owners permitted a cat more than one litter. These figures agree closely with estimates of desexing in other surveys (88% of all cats and 94% of cats older than one year in REARK 1994b, 90% of all cats in McHarg et al. 1995, and 93% of all cats in Murray et al. 1999). Grayson et al. (2002) reported 85% agreement by cat-owners with the statement: ‘Excluding cats owned by licensed breeders, all pet cats should be desexed.’ These desexing rates are considerably higher than that of 78% reported for the United States by the American Bird Conservancy (1997).
Table 2.2  Results of an internet survey for sites describing ‘responsible cat ownership’. The numbers indicate the total number of sites which mentioned each criterion of cat ownership.

<table>
<thead>
<tr>
<th>Study</th>
<th>Survey methods</th>
<th>Target population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paton (1991), (1993)</td>
<td>Questionnaire distributed through schools and natural history clubs. A sub-sample of respondents agreed to supply data on prey caught by their cats over a year.</td>
<td>Adelaide suburbs, South Australian country towns, rural South Australia</td>
</tr>
<tr>
<td>REARK (1994b)</td>
<td>Telephone survey of residents regarding the hunting behaviour of cats relative to owners’ husbandry practices. Owners recalled predation histories over the past 12 months</td>
<td>Each capital city except Darwin</td>
</tr>
<tr>
<td>REARK (1994a)</td>
<td>As above, but target population restricted. More detailed data are presented than in the previous study</td>
<td>Sydney and Melbourne only</td>
</tr>
<tr>
<td>McHarg et al. (1995),</td>
<td>Telephone survey determining type and number of pets owned, as well as some questions of husbandry</td>
<td>Nationwide telephone survey</td>
</tr>
<tr>
<td>Headey (1999)</td>
<td>Owners collecting remains of prey caught by their cats over a 12 month period</td>
<td>Canberra suburbs</td>
</tr>
<tr>
<td>Barratt (1995, 1997,</td>
<td>Door to door delivery and collection (or postal return) of a written questionnaire</td>
<td>All residents aged 16 and over on Magnetic Island, off Townsville, Queensland</td>
</tr>
<tr>
<td>1998)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reid &amp; Speare (1995)</td>
<td>Postal or door to door delivery and collection of a written questionnaire</td>
<td>All residents aged 16 and over on Magnetic Island, off Townsville, Queensland</td>
</tr>
<tr>
<td>Murray et al. (1999)</td>
<td>First study addressed cat hunting behaviour, owners’ husbandry practices and likely compliance with cat regulations. Data collected door to door by council employees. Second study investigated methods for tagging cats and the effect of bells on hunting behaviour. Forms were completed at veterinary surgeries and a major pet retailer</td>
<td>Mt Isa (first study) and Brisbane (second study), Queensland</td>
</tr>
<tr>
<td>Perry (1999)</td>
<td>Postal survey assessing (i) cat-owners’ husbandry practices, attitudes to proposed regulations, nuisances caused by roaming cats and perceptions of cat/wildlife issues, (ii) non-owners’ attitudes to proposed regulations, nuisances caused by roaming cats and perceptions of cat/wildlife issues</td>
<td>Electoral district of Melville, Perth, Western Australia</td>
</tr>
</tbody>
</table>
Australian cat owners also show strong agreement with provisions to identify or register cats, although actual compliance may be lower. Grayson et al. (2002) reported that 93% of female cat-owners and 82% of male cat-owners surveyed in Perth, Western Australia agreed that they would licence their cat with the local council if it became compulsory. Similarly, Murray et al. (1999) found that 96.3% of residents on Magnetic Island off the Queensland coast were in favour of identifying and registering cats, although this figure includes non-owner responses as well. Despite these reports, data on actual registration of animals when legally required suggests a lower acceptance. Pert (2001) noted that approximately 500,000 dogs and cats were microchipped for identification under the New South Wales Companion Animals Act 1998, but only 200,000 dogs and cats were registered with local councils. Similarly, Scheele (2001) noted that mandatory cat registration in Manningham City Council (Victoria) was taken up by only 15% of households, well beneath the estimated 26% of households owning a cat. These figures may suggest a reluctance to register a pet cat, or alternatively a misconception by owners that an identified cat is automatically a registered cat.

Australian cat owners also appear less responsible when it comes to containing their cats. McHarg et al.’s (1995) nation-wide telephone survey found that only 6% of owners kept their cats solely indoors, although 50% of owners claimed their cats lived primarily indoors and 61% kept their cats inside at night. The similar REARK (1994b) survey found that 39% of cats were contained at night and that 79% of all cats were believed not to roam away from their home during the day. However, there were marked variations in these figures from city to city. REARK (1994b) concentrated specifically on Sydney and Melbourne, where between 17% and 45% of cats were contained securely at night, depending on the suburb. Perry (1999) found that only total confinement prevented hunting although (REARK 1994a, b) confirmed that those cats that stayed close to home hunted less. The Australian Veterinary Association (Media release October 18, 1996, http://www.ava.com.au/content/press/cat.htm) estimated that 50% of owners confined their cats at night and argued that this figure indicated high responsibility. Despite this opinion,
the overall incidence of confinement is markedly lower than the proportion of cats sterilised.

Moreover, it is important to note that many cat owners question the value of wildlife protection measures, seeing confinement primarily as a cat welfare measure reducing the risk of fighting, theft and road accidents. In Western Australia, Grayson et al. (2002) found that 86% of cat owners agreed that cats in nature reserves were detrimental to wildlife, but only 50% of cat owners agreed that cat predation was a significant factor for suburban wildlife. Grayson et al. (2002) also sought opinions on the proposition that local councils should have the power to prohibit cat ownership in new subdivisions. Cat owners registered only 17% agreement. If such attitudes are reflected nationally, then cat owners are unconvinced that their pets are a menace to suburban wildlife although they do concede the value of confinement in protecting cats from injury. They are also strongly opposed to the imposition of cat exclusion zones.

2.4 Attitudes of the non-owners

Dear Tarpey Neighbor,

Is your cat missing?

Was he the fuzzy black and white one that used to come over my fence and fight with that big orange striped one under my bedroom window at two in the morning? Or was he the young sleek one that liked to whiz in the flower bed near my front door and then move on to the backyard to make his pile in my kid’s sandbox?

I’m familiar with all these creatures and know where they went. After several seasons of enduring these invasions and mid-nocturnal awakenings by uncontrolled pets, I phoned the SPCA and was advised that I could rent a live trap from them, catch the offending beasts, and bring them in to their facility.

The trap was baited with a generous portion of healthy food, possibly better stuff than they got at home, so that they would be well nourished and content for the ride to their new home at the SPCA impoundment. The nice folks at the SPCA said
that I was well within the law to trap them live and humanely, and that they’d take
good care of them for a few days until their owners came for them. If the owners
didn’t come within a few days, since the SPCA has limited space, that the cats would
have to go to - well - go to that big litter box in the sky.

So, that may be where your missing cat is, or was. (I wonder if there’s a big
enough trap for that brown tail-less dog that drops his messages in my front yard?)

Name withheld by request
Letter to the Editor, reproduced on http:
//www.purrfectangels.org/responsible_cat_ownership.html

Some of the surveys of community attitudes towards cat ownership and
husbandry considered the views of non-owners as well as owners and found varying
degrees of concern about the nuisance caused by roaming cats or their possible impact on
suburban wildlife. In Queensland, 71% of cat owners and 66% of non-owners reported
roaming cats as a problem (Perry 1999), while in McHarg et al.’s (1995) stratified national
survey, 22% of respondents (cat ownership status not indicated) complained that unwanted
cats were constantly or frequently on their property. Local council officers also reported
numerous complaints regarding roaming cats after the passing of the Domestic (Feral and
Nuisance) Animals Act 1994 in Victoria (e.g. Baker 2001). In Perth, Western Australia,
74% of non-owners agreed that cats were a menace to wildlife in the suburbs (Grayson et
al. 2002).

In Grayson et al.’s (2002) study, non-owners were also emphatic about what they
wanted done to resolve the issues of nuisance and wildlife protection. They advocated
compulsory sterilisation of all cats not owned by licensed breeders (86% support) and

\[ \text{2 The link to this quote is now broken and we have been unable to find another posting online.} \]
confining cats to their owners’ properties (87% support). The exact opinions of non-owners are more difficult to identify in other studies which targeted whole communities rather than non-owners specifically. However, high support for compulsory identification of pet cats and also for sterilisation of cats excepting those owned by licensed breeders is noted (e.g. 96% and 93% respectively in Murray et al. 1999). Importantly, Grayson et al. (2002) found that only 48% of non-owners agreed that local councils should have the power to prohibit cat ownership in environmentally sensitive areas, perhaps feeling that such a move contravenes basic civil liberties. However, some councils in Victoria have implemented such measures successfully (e.g. Buttriss 2001, Moore 2001). In the latter case, a key element in success was imposing a cat exclusion regulation before a new sub-division was developed.

Overall, non-owners support such measures as identification, sterilisation, confining cats at night and restricting cats to their owners’ properties, which could reduce predation on wildlife. However, they show only lukewarm support for cat exclusion zones unless these are implemented before an area is developed.

2.5 The veterinarian’s perspective

All companion animals cause community problems – dogs bark, parrots screech – but both provide companionship whose value outweighs the problems they cause. Cats are particularly misunderstood and often cat owners feel guilt for the sins of their much loved couch potato’s feral counterpart. It is important that the benefits of responsible cat ownership be acknowledged and that strategies are put in place to educate owners on the value of early desexing, confinement and correct identification.

Perry (1999 p. 4)

Veterinarians deal with cats and their owners daily and, in some cases, also treat wildlife victims of cat attacks. They therefore have first-hand experience of the significance of cat ownership for people, the welfare problems such as fighting and road accident
trauma associated with roaming cats and the extent of attacks on wildlife. Treating cats is also a substantial component of many veterinarians’ practices. However, we are unaware of any specific survey of the attitudes of veterinarians to cat regulations or of the advice they give owners on husbandry in relation to wildlife issues. A limited but possibly unrepresentative assessment can be made by considering available publications on the topic by veterinarians, media releases by the Australian Veterinary Association and debates in the letters pages of the *Australian Veterinary Journal*.

Publications by veterinarians on the issue of cats and wildlife argued that most cat owners are responsible, highlighting statistics such as the high rates of identifying and desexing pet cats in Australia, the small number of households owning more than one cat and the preponderance of introduced vermin in the prey of owned cats (*e.g.* Perry 1999, Fougere 2000). Veterinarians also encouraged clients to sterilise animals early, with 78% of the Sydney practices surveyed by McGreevy *et al.* (2002) answering negatively to the question: ‘Would you delay desexing of selected clients’ cats until after a litter has been produced and assist with rehoming?’ However, in the same survey only 26% of respondents answered negatively to the question: ‘Would you maintain a register of local entire toms (in clinic or with selected clients) for breeding if a client wanted to breed their female cat?’

The Australian Veterinary Association (AVA) was also quick to defend cat ownership against extreme suggestions that cats should be eradicated from Australia. Their media release on the topic emphasised the companionship and health benefits of cat ownership, the low likelihood of owned domestic cats threatening endangered populations of native species, the high responsibility of Australian cat owners as indicated by sterilisation and confinement statistics and the roles of educating owners and controlling feral cats in preventing problems (Media release October 18, 1996, [http://www.ava.com.au/content/press/cat.htm](http://www.ava.com.au/content/press/cat.htm)). Other media releases by the AVA sought to improve the measures for compulsory identification of pet cats under the Companion Animals Act 1998 (NSW) (Media Release July 23, 1998, [http://www.ava.com.au/content/press/980723b.htm](http://www.ava.com.au/content/press/980723b.htm), Media Release June 8, 1999,
The AVA also praised the general intent of the Companion Animals Act 1998 (NSW), although arguing that the implementation of compulsory identification needed reform (Anonymous 1999).³

Veterinarians’ views were also expressed in the letters pages of the Australian Veterinary Journal in 1999, in response to the Companion Animals Act 1998 (NSW). Five correspondents supported the identification provisions of the Act, but found major problems with the implementation (e.g. McPartland 1999). Another expressed concern that problems with identification and costs of retrieving animals from shelters was actually increasing the number of impounded animals destroyed (Rogers 1999). Lastly, Shirley (1999) advocated declawing cats to protect wildlife and prevent furniture damage, but the point was contested strongly on cat welfare grounds by Stokes (1999).

Could regulation of cat ownership reduce the popularity of cats as pets, or otherwise change the proportion of cat-related business in veterinary surgeries? Following the introduction of a cat curfew in the Sherbrooke municipality, the local veterinarian’s subjective impression was that fewer cats were presented with fighting injuries or road accident injuries (Pergl 1994). Perry (1999) also expressed concern about the decline in cat ownership in Australia, a view shared by some non-veterinary authors (REARK 1994b, Chaseling 2001). Baldock et al. (2003) confirmed the decline recently, citing survey evidence that this may be caused by a dislike of cats or because of the concern about the impacts of cats on wildlife. They found that cats were not being replaced regardless of the demographic of the household. Whatever the reasons, the decline contrasts with the increased popularity of pet cats in the United States and the United Kingdom (American Bird Conservancy 1997, Chaseling 2001, Baldock et al. 2003).

The decline in cat numbers may be reflected in a fall in cat-related clinical work in some Australian veterinary practices (McGreevy et al. 2002). Their data for Sydney practices in the years 1996 – 2000 indicated that cat related activities declined for

³ This document is no longer available on AVA website.
approximately 20% of practices, increased for 20% of practices and remained the same in others compared to the previous five years. Nevertheless, the authors concluded that the majority of practices surveyed promoted cat ownership.

Overall, the sources consulted show that veterinarians recognise that owned domestic cats do attack wildlife in the suburbs, but at least some argue that available data indicate that impacts of this predation are probably exaggerated. Cat welfare issues may therefore be paramount for veterinarians when advising their clients, although specific surveys of veterinarians are needed to confirm this opinion. Nevertheless, veterinarians offer strong support for measures such as confinement, identification and sterilisation as issues of cat welfare and these also provide some wildlife protection. They also have legitimate concerns over the possible impact of regulations on their businesses.

2.6 Views of local government

In a subject such as cat legislation lobby groups can be so loud it becomes difficult to hear what the average Joe Blow really wants. The cat provisions of the Dog and Cat Management Act 1995 were an honest attempt to define and regulate the views of ordinary people in a manner that provides the flexibility for local government to manage cats in accordance with the wishes of their local communities. Now, four years down the track, it is still ‘enabling’ legislation and is still criticised as being draconian and wishy-washy. On this basis, we probably got it about right for the South Australian community today. If public attitudes change then it is imperative that the legislation be amended accordingly.

Kelly (1999, p. 1)

Initial steps to regulate cat ownership in Australia were taken by local councils (e.g. Anderson 1994, Pergl 1994). Several state legislatures have followed their lead by enacting bills to regulate cat ownership (Penson 1995, Kelly 1999). These include South Australia’s Dog and Cat Management Act 1995
Chapter II


Victoria’s Domestic (Feral and Nuisance) Animals Act 1994 (http://www.legislation.vic.gov.au/domino/Web_notes/LDMS/LToObject_Store/LToObjectSt1.nsf/da8d8a9bed958efca25761600042ef5/0adbd9eb52a14c1eca257761001ac328/$FILE/94-81a028.pdf), the New South Wales Companion Animals Act 1998 (http://www.austlii.edu.au/au/legis/nsw/consol_act/caa1998174/) and the Australian Capital Territory Domestic Animals Act 2000 (http://www.legislation.act.gov.au/a/2000-86/current/pdf/2000-86.pdf)\(^4\). With no implied order of priority, all share concerns for predation on wildlife, transmission of disease to wildlife and humans, cat welfare, nuisance caused by roaming cats and the social and economic importance of cats as pets. All Acts include provision for identification of cats, action against nuisance animals and, with the exception of the South Australian legislation and ACT legislation, compulsory registration of cats with discounts for neutered animals. The ACT legislation also requires the desexing of all cats born after 21 June 2001 unless the owner has a permit to keep the animal sexually entire. Local municipalities are required to implement the Acts and have the option to enforce more stringent regulations within their jurisdictions. Kelly (1999) overviews the arguments for and against regulation in regard to these and other contentious issues.

Given the recent implementation of regulation, there has been little opportunity to assess the community attitudes and compliance to the new laws, highlighting areas that need more attention via community education to make the new legislation successful. However, Kelly (1999) reported that South Australia’s Dog and Cat Management Act was well received and

\(^4\) Australian Institute of Animal Management papers - these have a history of frequent movement from site to site, but there do not seem to be current url’s for these papers. The Australian Institute of Animal Management has a library link on their site, where they claim that proceedings of their conferences will appear in future. The link is https://aiam.org.au.
the Magnetic Island council resurveyed the opinions of the community as to the effectiveness of new cat and dog legislation (Murray et al. 1999). Their follow-up survey, 14 months after the introduction of the legislation, found that the implementation of a ‘pet management plan’ did not discourage members of the community from owning pets. Furthermore, the attitudes of Magnetic Island residents to the cat management plan did not alter significantly. Residents supported all points of the plan including limiting the number of cats to two/ household; desexing pet cats; identifying owned cats and confining cats at night (Murray et al. 1999).

Pergl (1994) described the experiences of Sherbrooke Council in detail. He believed that the council’s Animal Welfare Local Law focused residents’ attention on the needs of both wildlife and pets, with both being valued. It was workable and the provisions for cat identification and registration, exclusion from some public areas and a night-time curfew led to a reduced incidence of cat injuries as well as declines in a range of wildlife (but not diurnal birds) being presented with injuries from cat attacks. Other councils in Victoria report success with specific measures including complete confinement of cats to owners’ premises (Baker 2001), prohibiting cat ownership in new sub-divisions before owners move in (Buttriss 2001) and declaring nature conservation areas where free-roaming cats will be impounded (Moore 2001).

However, because the issue of enforcement of regulations lies with local government it must carry the cost and resolve any issues confronting officials in their duties (see Pert 2001 for a discussion of these issues in relation to the Companion Animals Act 1998, NSW). These are important topics, because half-hearted enforcement by local councils may undermine the value of any regulations.

2.7 Integrating perspectives in a precautionary approach

2.7.1 Justification for a precautionary approach

The precautionary principle applies in situations where risk is suspected but is to a greater or lesser extent unknown. This is distinct from ‘prevention’ which is appropriate
where the risk is accepted and well-known and the objective is to minimise or eliminate it (Deville & Harding 1997). Thus application of the precautionary principle requires a reasonable supposition of risk but uncertainty about its magnitude.

The conservation value of remnant urban bushland includes possible conservation of rare species, maintenance of representative biotic communities and preservation of an on-going resource for migratory species (How & Dell 2000 and references therein). All these values might be disrupted by cat predation. With regard to uncertainty, Barratt (1998) highlighted the few published studies of predation by owned domestic cats, the wide variability in both the incidence of hunting by different cats and in estimations of total predation rates, and the lack of definitive population studies to demonstrate any declines in abundance in response to cat predation. Overall, the combination of significant risk and high uncertainty justify precautionary action. However, the possibility of significant impacts will vary with suburb, with the risk greatest in suburbs close to bushland remnants or on the fringes of suburbia (e.g. Barratt 1998). Therefore these areas should require the highest levels of precaution and it may be appropriate to have differing precautionary standards in different suburbs (e.g. Moore 2001).

### 2.7.2 Applying precautionary measures

Cat welfare issues appear to be the key to the successful implementation of cat control regulations that implement a precautionary approach to protection of urban wildlife from cat predation. A welfare emphasis appeals to a very broad section of the interested public as well as to veterinarians, while almost all measures proposed to protect wildlife also have a cat welfare benefit (e.g. Kelly 1999, Perry 1999, Fougere 2000, Chaseling 2001). Regulations to enforce registration/identification, desexing, and a maximum number of cats per property have general acceptance and are already widely practised by cat owners (REARK 1994a, b, McHarg et al. 1995, Kelly 1999, Murray et al. 1999, Grayson et al. 2002). However, confinement of cats at night and restriction of cats to their owners’ properties are less popular measures for cat owners, who currently are far less likely to do
this than to sterilise or tag their pets (REARK 1994a, b, McHarg et al. 1995, Grayson et al. 2002). Wider acceptance might be gained by appealing to the benefits of these measures for cat welfare and reducing the incidence of nuisance, following the example of Sherbrooke Council (Pergl 1994). However, cat exclusion zones were extremely contentious in Perth, Western Australia (Grayson et al. 2002) and these attitudes may be reflected elsewhere. Exclusion zones confer no benefits to cat welfare beyond restricting roaming and have only moderate support from non-owners (Grayson et al. 2002). Including provision for cat exclusion zones in cat control regulations will require a sensitive education campaign.

2.7.3 Further research to reduce uncertainty

As more municipalities move to enact cat regulations, there may be opportunities for treating these as experimental manipulations to determine any benefits arising for wildlife (Tideman 1994). This is analogous to the ‘adaptive management‘ approaches already practised or called for in wildlife management (e.g. Norton & May 1994). Studies could involve before/after designs, in which wildlife numbers were monitored in multiple municipalities before implementation of cat control regulations in some of them, with others remaining as controls. Further monitoring would continue in all areas post-implementation to determine any impact of the regulations on wildlife populations. Data from such experiments would provide stronger evidence for or against the impact of owned cats on suburban wildlife. Some surprising results might also arise if rat or raven populations increased in the presence of cat curfews, increasing predation on bird eggs and nestlings (see Barratt 1998 for consideration of this hypothesis in relation to cats in suburbia, Courchamp et al. 1999 for a case study involving feral cats on islands). Van Dyke’s (2001-2002) hypothesis that Antechinus spp. would co-exist happily in Australian suburbia in the absence of cats could also be tested. It will also be valuable to focus explicitly on the potential impact of cat predation on lizards in suburbia, rather than the prevailing emphasis on mammals and birds. Many lizards are small enough in size and
have sufficiently limited ranges for impact studies to be designed and implemented at small spatial scales.

Given the current reluctance of cat owners to adopt total confinement, it may also be valuable to examine ways of reducing cats’ inclination to hunt and the success of hunts. Barratt (1998) highlighted the considerable variability in hunting behaviour of individual cats, which is largely unexplained. Controlled behavioural and breeding studies of the influence of rearing on hunting behaviour may suggest husbandry approaches that can reduce hunting tendencies. The controversy over the efficacy of attaching bells to a cat’s collar in reducing predation might also be resolved by careful experimental studies (see Paton 1991, Paton 1993, REARK 1994b, Ruxton et al. 2002 for relevant observations and studies, American Bird Conservancy 2007). Lastly, the studies to date on the attitudes of people towards cat control and wildlife protection have not targeted the key groups of veterinarians and local government officials. Veterinarians are important because they are in frequent contact with cat-owners and may have considerable influence over their attitudes and behaviour. They also have legitimate concerns for the possible impact of regulations on their business. Local government officials are also critical as they often have considerable freedom to design, implement and enforce regulations, while possibly being responsible for community education campaigns. They also have basic responsibilities under some state legislation. Together, these two groups can have a significant influence on compliance with regulations so their attitudes and practices are worthy of specific study.
3. **The Perth metropolitan region and its avifauna**

This study occurred in Perth, Western Australia, which is located on the Swan Coastal Plain (SCP) in the southwest corner of the continent (Figure 3.1). The first section of this chapter describes the local environment including its climate, vegetation communities, major landforms, soils and environmental history, as well as anthropogenic pressures on the natural environment and the Bush Forever conservation program. The second section of the chapter examines the fauna in the context of the physical environment and the vegetation, with special reference to the changing avifauna of Perth.

3.1 **Perth, Western Australia: Environmental and natural history**

The Western Australian landscape is characterised by eroded flat terrain with nutrient poor soils. Prior to Gondwana splitting with Antarctica, rainforest dominated the landscape, but underlying soils were lateritic, gravelly and infertile. Sclerophyllous plants grew on the exposed areas of this soil type and began to dominate the landscape as Gondwana split from Antarctica, moving northward into drier and warmer conditions (Hopper & Gioia 2004).

The Southwest Australian Floristic Region (SWAFR), where Perth is located, covers 302,627 km\(^2\) and is considered to be one of the earth’s biological hotspots; an area with high endemism and whose conservation status was and is threatened by European land management practices (Hopper & Gioia 2004). The vegetation is dominated by sclerophyllous trees, shrubs and herbs; specifically eucalypt forest and woodland, including mallee (eucalypts that regenerate from lignotubers after fire). The flora is particularly diverse due to the age of the landscape, floral lineages, complex soil mosaics, and dynamic climatic and sea level changes that occurred during the late Tertiary-Quaternary (Hopper & Gioia 2004).
Figure 3.1  The Perth Metropolitan Region (PMR) (orange) of the Swan Coastal Plain (SCP) (green), Western Australia. This study is restricted to the PMR that lies within the SCP approximately 15 km north, 15 km south, 10 km west and 30 km east of the Perth CBD: 31.955°S, 115.8°E.
The city of Perth is located close to the Indian Ocean, within a 30 km wide strip of land extending from north of the city centre south to Cape Naturaliste known as the Swan Coastal Plain (Figure 3.1). This study is restricted to a smaller subset of the central Perth Metropolitan Region that is 25 kilometres south and 15 kilometres north of the Perth Central Business District, and 30 kilometres to the east from the Swan Coastal Plain’s western border, the Indian Ocean (31.955°S, 115.8°E), and will be referred to as the ‘study site’ (Figure 3.1).

3.2 Climate

Perth weather is described as ‘Mediterranean’: a sub classification of a subtropical climate, based upon rainfall and temperature. Mediterranean climates have a short, rainy, cold season and a longer hot season (Bureau of Meteorology 2005). The mean minimum and maximum temperatures from 1993 to 2012 in Perth ranged from 18.2 to 31.4 °C in February and 7.7 to 18.3 °C in July (Figure 3.2). Mean rainfall in Perth from 1993 to 2012 ranged from 8.9 mm in February to 165 mm in July, with a yearly average of 733 mm (Figure 3.3). July had the most days of rainfall (14.7 days) greater than 1mm, averaging 152.7 mm, while February had the least amount of rain days (1.1 days) that register more than 1 mm (Figure 3.3) (Bureau of Meteorology 2005).

3.3 Perth demographics

The population density for Australia is 2.9 people per km², but in Western Australia it is 0.9 people per km². Specifically Perth, the capital of Western Australia, has 310 people per km² (Figure 3.4) compared to Sydney Australia’s most populous city with 380 people per km² (Australian Bureau of Statistics 2010).

Compared to Sydney, Perth is the second most culturally diverse city in Australia, with 33.6% of residents in Perth born outside of Australia (Australian Bureau of Statistics 2006). English born migrants make up the majority of these, followed by maritime Southeast Asia and southern and eastern Africa (37.8, 14.9 and 14.8%, respectively) (Kennewell & Shaw 2008). Perth residents with university qualifications are most likely to
Figure 3.2  Mean maximum (●) and minimum (▲) temperatures (°C) recorded in Perth, Western Australia, from 1993 to 2012 (Bureau of Meteorology 2005).

Figure 3.3  Mean rainfall (mm) (●) and mean number of days of rain ≥ 1mm (▲) recorded in Perth, Western Australia, from 1993 to 2012 (Bureau of Meteorology 2005).
live in the more affluent western suburbs, whereas residents with a trade qualification tend to live in the southern coastal areas. There is a similar trend for children attending government schools versus private schools; private school children are more likely to be found in western suburbs and children attending government schools reside on the fringes of the metropolitan area (Kennewell & Shaw 2008).

Presently, 17% of the population is over 60 years of age and mostly live in a 10 km radius of the city centre and coastally in Rockingham and Mandurah (Australian Bureau of Statistics 2006). Families with young children tend to live in newer inland subdivisions (Australian Bureau of Statistics 2006).

**Figure 3.4** Population densities by statistical local area, Perth SD - June 2011 (Australian Bureau of Statistics 2006).
3.4 Physical features of the study area

3.4.1 Vegetation

The Perth Metropolitan Region (PMR) contains at least 1,200 native floral taxa, including 21 that are declared as ‘rare’ and 74 as ‘priority flora’ (taxa that are poorly known; are considered for declaration as ‘rare flora’ and given a rating from 1 to 4 depending upon the perceived level of threat, 1 being most threatened and 4 considered rare but not currently threatened according to the Western Australia’s Wildlife Conservation Act 1950, http://www.slp.wa.gov.au/legislation/statutes.nsf/main_mrtile_1080_homepage.html).

The PMR contains 9 taxa that are endemic and approximately 16 taxa that reach their range at the ends of the PMR of the SCP. The area also has high species richness, with figures in different landforms ranging from 8.6 – 64.5 species/100 m² (Table 3.1) (Western Australian Planning Commission 2000).

The vegetation on the entire SCP has been classified into 38 vegetation complexes (‘series of plant communities forming regularly repeating complexes associated with a particular soil unit’ as defined by Churchward & McArthur (1980)). Twenty-six vegetation complexes occur in the PMR, including wetlands and marine deposits. Each complex is further divided into floristic groups that are distributed over the SCP (Western Australian Planning Commission 2000).

3.4.2 Landforms and soils

Two types of sedimentary processes formed the SCP; alluvial and aelion. Alluvial sediments, found on the eastern border of the Swan Coastal Plain, were washed down the water courses forming the foothills and the Pinjarra Plain. At the western border of the Pinjarra Plain, the alluvial sediment is replaced by the aeolian sediments (deposited by wind) as sand dunes, decreasing in age from east to west, beginning with Bassendean, then Spearwood, to the youngest and most westerly sand dune, Quindalup (Figure 3.5). In
Table 3.1  Major landform units of the study area on the Swan Coastal Plain with main vegetation formations, area and percentage of remnant of original vegetation remaining (% proposed to be protected), current land use, number and status of threatened ecological communities and range of species richness of floristic communities.

<table>
<thead>
<tr>
<th>Major landform in study area</th>
<th>Dandaragan Plateau</th>
<th>Foothills/ Pinjarra Plain</th>
<th>Bassendean Dune System</th>
<th>Spearwood Dune System</th>
<th>Quindalup Dune System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main vegetation association</td>
<td>Open woodlands with a second smaller story; low open woodland to closed heath depending upon depth of soil</td>
<td>Low open forest; open woodland; tall open forest; closed scrub &amp; fringing woodland</td>
<td>Low open forest; low &amp; open woodland</td>
<td>Low &amp; open forest; low &amp; open woodland</td>
<td>Low closed forest and scrub</td>
</tr>
<tr>
<td>Number of vegetation complexes</td>
<td>2</td>
<td>10</td>
<td>4 confined &amp; 3 associated with Bassendean Dune system</td>
<td>5 confined to &amp; 2 associated with Spearwood Dune system</td>
<td>1</td>
</tr>
<tr>
<td>% Original vegetation complexes remaining (proposed to be protected %)</td>
<td>24 to 40 (20 to 33)</td>
<td>5 to 18 (5 – 11)</td>
<td>17 to 100 (13 – 100)</td>
<td>18 to 79 (8 – 79)</td>
<td>48</td>
</tr>
<tr>
<td>Current landuse</td>
<td>The more fertile valleys were originally cleared for grazing and agriculture, sparring the sandy slopes and lateritic ridges. Recent rural subdivisions have caused more clearing.</td>
<td>Very little natural vegetation remaining due to early clearing because of fertile soils for agriculture.</td>
<td>Low soil fertility limited land use to low level grazing, but more fertile wetlands used for agriculture. Land now used for urban development.</td>
<td>More fertile than Bassendean &amp; able to hold nutrients – hence used for pine plantations, market gardens, particularly wetlands. Some mining and housing. Unusable limestone outcrops have protected some areas of vegetation.</td>
<td>Stock grazing in swales. Housing development.</td>
</tr>
<tr>
<td>Threatened* communities</td>
<td>Not recorded</td>
<td>15 (5 Cr; 4 En; 6 Vu)</td>
<td>9 (2 Cr; 3 En; 4 Vu)</td>
<td>2 (1 Cr; 1 En)</td>
<td>3(2 Cr; 1 Vu)</td>
</tr>
<tr>
<td>Range of species richness (per 10 x 10m plot) of floristic** communities</td>
<td>35.7 – 44.2</td>
<td>16.8 – 64.5</td>
<td>10.6 – 59.0</td>
<td>13.4 – 64.5</td>
<td>8.6 – 35.0</td>
</tr>
</tbody>
</table>

*Cr = Critically; En = Endangered; Vu = Vulnerable; ** distinctive floristic assemblages as defined by Gibson et al. (1994); *** as defined by (Heddle et al. 1980)
Comparison to the surface sediment on the Darling Scarp and Pinjarra Plain, the soils on the Coastal Plain are geologically young. Each of the geomorphic elements are distinctive with regard to geology, soil, topography, drainage pattern and vegetation (Seddon 1972).

3.4.2.1 Description of landform units within this study

The Dandaragan Plateau is geologically part of the SCP and is situated in the North West corner (Figure 3.5). The presence of inhospitable lateritic ridges has aided in conserving the vegetation in these areas, however, the more fertile valleys were cleared for agriculture. More recent clearing has occurred due to population increases in city areas, encouraging people to move to a ‘tree change’ – clearing of more bushland for small rural subdivisions. Between 24 and 40% of the two vegetation complexes associated with this area remain, with the intent to preserve 20 to 33% respectively (Western Australian Planning Commission 2000). Within this area, 10 taxa are considered significant. Vegetation on lateritic soils ranges from low, open woodlands to a species rich closed heath. The watercourses support open woodland with a second storey. Although only two vegetation complexes exist in the PMR of this landform, the species richness is very high, ranging from 35.7 – 44.2 species per 10 m² (Table 3.1).

The Pinjarra Plain and Foothills form the eastern boundary of the Swan Coastal Plain and slope gently downwards (Figure 3.5). Complex drainage patterns occur as a result of different soils and underlying, interleaving layers of limestone and ironstone. Historically, this area was subject to seasonal flooding with excessive drainage from surface water runoff. Now, purpose built drainage channels prevent the Pinjarra plain from becoming a seasonal wetland. Prior to clearing, marri (Eucalyptus calophylla), jarrah (E. marginata) and wandoo (E. wandoo), with banksia (Banksia spp.), casuarina (Casuarina fraseriana) and ‘woody pear’ (Xylobiuna occidentale) understory formed the tall open forest (Western Australian Planning Commission 2000). Alluvial soils predominate on the plain and, relative to the other soils on the SCP, the soils of the Pinjarra Plain are considered fertile, although they are low in phosphate and the trace elements zinc, copper, molybdenum and cobalt (Seddon 1972).
The eastern aspect of the SCP has minimal remaining vegetation (7%); however the PMR portion has, at most, 18% left, with 119 significant taxa. Within this remnant vegetation are 10 vegetation complexes associated with 15 threatened communities (Table 3.1) (Western Australian Planning Commission 2000).

The Bassendean Dune System covers most of the Swan Coastal Plain (Figure 3.5) and is formed from accumulated beach sand. The sand was once calcareous like current
beach sand, but is now grey and infertile quartz soil. Initially, clearing of vegetation on this system was minimal due to the low soil fertility and land was used for low level grazing; demand for housing has caused further land to be cleared. Swamps, once present through the Bassendean Dune System, were used for agriculture and more intensive grazing, but have now been reclaimed for suburban housing (Table 3.1) (Western Australian Planning Commission 2000).

The vegetation of the Bassendean Dunes has a high level of species diversity, with 43 species considered as significant taxa with nine groups classified as threatened (Table 3.1) (Western Australian Planning Commission 2000).

The younger, more fertile soils of the Spearwood Dune System lie west of the Bassendean Dune System (Figure 3.5). Although more fertile than the Bassendean Dunes, calcium carbonate has been leached from the soil and the soils overlay columns of limestone that in some areas add height to the system. The inhospitable nature of these columns of limestone did provide protection to the surrounding vegetation, but recently, some have been mined or totally removed. Between 18 and 79% of the 5 vegetation complexes associated with the Spearwood system remain (Table 3.1) (Department of Planning and Infrastructure WA 2000).

The Spearwood Dunes are associated with 37 significant taxa, including 2 species that are declared as Rare Flora and 11 as Priority Flora. Banksia attenuata woodlands with species rich dense shrub lands are considered a threatened ecological community, as are shrub lands on the limestone ridge comprising of Melaleuca huegelii and M. acerosa (Western Australian Planning Commission 2000).

The Quindalup System is the third and smaller dune system that makes up the SCP (Figure 3.5). The vegetation in this system is quite different to the others, comprising mainly wattles (Acacia rostellifera and A. cyclopis), Swan River cypress (Callitris preissii) and Rottnest tea-tree (Melaleuca lanceolata), which are primarily found offshore on Rottnest and Garden Islands. There are no eucalypts or banksias, or other understory families such as Proteaceae, Fabaceae and Myrtaceae (Seddon 1972).
Due to the poor fertility levels of the soil, this area has been left relatively untouched, with 48% of the vegetation remaining, but only 21% of this vegetation will be set aside for conservation. Eighteen taxa are classified as significant within the one vegetation complex (Table 3.1) (Western Australian Planning Commission 2000).

3.5 Environmental history and conservation

History since first settlement

The City of Perth was founded in 1829. Fremantle, Perth and Guildford were the initial settlements along the Swan River (Kennewell & Shaw 2008). The river connected the three original sites and the outlying settlements, encouraging settlers to extend outward along its banks. The laying of the Fremantle to Perth to Midland rail line in 1881 enabled new suburbs to develop. Toward the end of the Great Depression, private transport became more affordable, allowing an increase in a string of new low density suburbs independent of public transport (Kennewell & Shaw 2008).

3.5.1 Conservation of native vegetation

Currently, only 28% of natural bushland remains within the Perth metropolitan portion of the Swan Coastal Plain (Beardmore 2000) and the effects are documented in Figure 3.6. The remaining natural bushland is heavily fragmented, with some remnants as small as a single hectare (Figure 3.7).

Threats to bushland other than land clearing include dieback disease, caused by the oomycete pathogens Phytophthora spp., which affect the Proteaceae spp. comprising much of the coastal heathland (Garkaklis et al. 2003), and invasive exotic weeds that compete with native plants and increase susceptibility to intense fires. Frequent fire can alter plant communities, allowing fire tolerant species to flourish rather than maintaining a balance between fire tolerant and fire sensitive species (Hopper et al. 1996). While fire is important to the growth and reproduction of many native plants, it is detrimental to local fauna in isolated remnants as their food and refuge are affected. Immigration from other remnants is minimal because of distance or lack of corridors (How & Dell 2000). For conservation of
flora, reserves need to be within 15 km of each other throughout the landscape for adequate inclusion of all plant species, especially rare plants (Hopper et al. 1996). Similar proximities may be needed for terrestrial fauna, although birds may disperse more widely if the intervening areas are not hostile (How & Dell 2000).

Figure 3.6  Vegetative cover on the Swan Coastal Plain before and after European colonisation. The green signifies original vegetation and white is cleared vegetation.
Figure 3.7  Map of the Swan Coastal Plain showing 57 study sites in relation to housing density. This map includes Bush Forever sites and unprotected areas of vegetation.
3.5.2 Recent conservation efforts in Perth

To minimise further degradation as urbanisation continues, the State Government in 1995 implemented the Urban Bushland Strategy, ‘to ensure that bushland, an important aspect of the urban environment, is given proper recognition and consideration in the development of Western Australia’s cities, particularly Perth’ (Western Australian Planning Commission 2000). Bush Forever is an important part of this strategy. Launched in 2000, it planned to protect 287 Bush Forever sites, totalling over 51,200 ha of bushland, representing each of the original 26 vegetation complexes of the SCP and protecting 18% of the original vegetation (Government of Western Australia 2000). The median site size is 40.38 ha (range 0.56 ha to 9,683.50 ha) (Table 3.2). Ninety-six Bush Forever sites are larger than 100 ha, ranging to 11 sites which are less than one hectare (Table 3.2). Many of these smaller sites are in the higher population density areas (Figure 3.7), are disconnected from other areas of bushland and were included as Bush Forever sites as a representative of the original bushland and for residents' enjoyment rather than conservation purposes (Stenhouse 2004). Bush Forever sites are often isolated, vary in size and leave important remnant bushland unprotected throughout the PMR (Figure 3.7).

<table>
<thead>
<tr>
<th>Size category of Bush Forever Site (ha)</th>
<th>Number of Bush Forever Sites</th>
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<tbody>
<tr>
<td>&lt; 5</td>
<td>47</td>
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<tr>
<td>≥ 5 &lt; 20</td>
<td>58</td>
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<td>≥ 20 &lt; 50</td>
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<tr>
<td>≥ 50</td>
<td>128</td>
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<tr>
<td>Total number of sites</td>
<td>287</td>
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</table>

Along with Bush Forever sites, which are protected at the State Government level and focus on regionally significant areas, Local Governments, with the aid of the State Government, are responsible for the conservation management of 7,800 ha of native vegetation and are also responsible for the decision making on the future of 75,000 ha of
native vegetation. Of this 75,000 ha, 58,000 ha are on private land and 8,900 ha are earmarked for intensive development (Del Marco et al. 2004).

As in all conservation areas, size and shape of the remnants are important to minimise edge effects including increased predation, invasion by weeds and feral animals, increased solar radiation and wind exposure (Stenhouse 2004). Shapes best suited to minimising edge effects are ‘regular shapes’, where all the sides are equal and all interior angles are equal, resulting in a smaller perimeter to area ratio, thereby minimising the edge effect (Stenhouse 2004). To account for the size of the remnant area, Shape Index (SI) is incorporated into the measurement. SI accounts for the irregularity of the shape and values approaching 1 have a reduced edge effect. However, on the SCP, reserves with irregular shapes, such as long narrow reserves (high SI), also have high conservation values for vegetation communities because they follow the shapes of the geomorphic land form units (see Figure 3.7) (Stenhouse 2004).

Large reserves on the SCP are associated with a high number of floristic communities and more likely to have greater floristic heterogeneity. Although not all the reserves are of the optimum size for conservation, they are still of great importance because they provide representation and protection for the natural communities that were once widespread in the area, and opportunities for residents to be in contact with nature (Stenhouse 2004). Small urban remnants also support endemic invertebrates, while remnants with a minimum of 4ha can support vertebrate groups, especially reptiles (Western Australian Planning Commission 2000).

3.5.3 Classification of Bush Forever Sites

Each Bush Forever site utilizes the criteria outlined in Table 3.3 to achieve a classification over three levels: landscape (geomorphological landforms), regional (vegetation complexes) and local (floristic groups), resulting in a 5 section description for each Bush Forever site (Western Australian Planning Commission 2000).
 Structural units (Western Australian Planning Commission 2000) describe vegetation patterns in the Perth Metropolitan Regions of the SCP and are used at local and regional levels to map vegetation and include the percent of canopy cover and height class of the majority of plants. The classification ‘Open Forests’ and ‘Woodlands’ includes the major tree taxa of eucalypts, sheoaks, banksias, melaleucas and Rottnest Island cypress. The classifications Shrublands, Herblands, Sedgeland and Grasslands are also used to describe the structural units.

When determining the suitability of possible Bush Forever sites, the vegetation condition is assessed and a rating given based upon Keighery (1994), cited in Department of Planning and Infrastructure WA (2000). This ranges from (1) ‘Pristine’ – where there is minimal sign of disturbance to vegetation structure to (6) ‘Completely Degraded’ – where there is little to no vegetation structure or native species and includes parklands.

**Table 3.3** Hierarchy of information used to determine Bush Forever sites according to the Department of Planning and Infrastructure WA (2000)

<table>
<thead>
<tr>
<th>Section 1</th>
<th>Cadastral Information</th>
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<td>Section 2</td>
<td>Regional Information</td>
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<td>Landforms &amp; soil</td>
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<td>Vegetation and flora</td>
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<td>Vegetation Complexes</td>
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<td>Section 3</td>
<td>Specific Site Detail</td>
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<td>Landscape Features</td>
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<td>Significant Flora</td>
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<td>Wetlands</td>
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<td>Fauna</td>
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<td>Linkage (to adjacent bushland)</td>
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<td>Section 4</td>
<td>International and National Significance</td>
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<tr>
<td>Section 5</td>
<td>Selection Criteria and Recommendations</td>
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</tbody>
</table>
3.6 Fauna of the Swan coastal plain and Perth metropolitan region

Since European settlement, vertebrate fauna in the PMR has undergone many changes. Hunting by Europeans, predation by feral mammals and habitat removal are believed to have had the strongest impacts on mammals, followed by birds, while reptiles are least affected (How 1978), although Recher (1999) believes that the avifauna is just as affected by European settlement as mammals. Within the study area, six species of mammals are listed as threatened, as are two species of reptiles, one species of fish, one species of mollusk, and arthropods including five species of bees as well as crickets, moths, springtails and amphipods (Western Australian Planning Commission 2000).

Approximately half of the mammal species that occurred originally in the PMR are locally extinct, and the remaining species are declining in abundance and distribution (How & Dell 1993). The most widespread species of native cursorial mammals inhabiting remnant bushland in suburbia are the Western Grey Kangaroo *Macropus fuliginosus*, Western Brush Wallaby *Macropus irma*, Brushtail Possum *Trichosurus vulpecula* and Southern Brown Bandicoot (Quenda) *Isoodon obesulus* (How & Dell 1993). The latter two seem to have adapted to suburban gardens that have adjoining remnant native vegetation (How & Dell 1993, Howard et al. 2012).

There have been no recorded local extinctions of indigenous reptiles across the entire Swan Coastal Plain. However, several reptile species have decreased in abundance in *Banksia* woodlands, some becoming locally extinct in several remnants. Assemblages of reptiles are associated with the landforms of the SCP rather than flora, so small urban remnants are valuable for reptile assemblages (How & Dell 1989). Similarly, Garden et al. (2006) found that habitat structure was more important than vegetation structure for native reptiles and small mammals in urban bushland remnants. The reptiles may, however, be vulnerable to predation by cats (Bamford & Calver 2012).

Frogs are most diverse and abundant around ephemeral wetlands, especially on the Pinjarra Plain and the Foothills. The Bassendean Dunes once supported many wetlands although approximately 60% have been reclaimed for housing development.
there have been no reported extinctions of individual amphibian species in the PMR (How & Dell 1993).

Invertebrates of the PMR are often rare and endemic because of the patchiness of the landscape (How 1978). Recent surveys of the PMR (How et al. 1996, Harvey et al. 1997) found species recorded on the SCP for the first time. Some species such as Mygalomorph spiders are short range endemics and, by their very nature, likely to be threatened by habitat loss, habitat degradation and climate change (Harvey et al. 2011).

When discussing urban fauna, the list is not complete until exotic animals in the form of pests and pets and newly colonised wildlife, not indigenous to the region, are included. These animals must be included as they are now part of the urban fauna and to understand how they fit in culturally, economically and environmentally is important for management practices (Recher 2010).

3.6.1 The bird fauna

Prior to European settlement 311 avian species, including seabirds and trans-equatorial migrants, were recorded on the SCP. Excluding the seabirds and trans-equatorial migrants, 140 species (94 non-passerines and 71 passerines) were believed to be residents or regular visitors. Annually, 34 non-passerine migratory species from the northern hemisphere add to this number, and are sometimes accompanied by another two species that occasionally visit the SCP (Storr & Johnstone 1988). The PMR is now home to 10 non-passerine species that have colonised the areas from other parts of Western Australia. Other introduced species from overseas and Australia include eight non-passerines and two passerines (Storr & Johnstone 1988).

3.6.1.1 Kings Park – A microcosm of change in Perth’s birds

Within the central business district of Perth lies Kings Park, a 400 ha A Class reserve (the most highly protected category of public land in Western Australia), of which 267 ha is bushland in various levels of disturbance. Its birds can be regarded as a microcosm of the changes in the Perth avifauna. Longitudinal studies spanning 1928 to
2002 by a variety of observers recorded 61 species of terrestrial birds in the park (see Recher 2004). Of these species, 16 have decreased in abundance (three of which have decreased substantially) and 10 have become locally extinct. Human disturbance has benefited 13 of the birds, only one of which is not native to Perth, the Rainbow Lorikeet 

*Trichoglossus haematodus*. Twenty-six species showed no change in abundance. Events such as fire throughout the park caused 23 of regularly recorded species to decline. Continuing urban sprawl reduces the ability of populations from the urban fringe to recolonise island fragments such as Kings Park (Recher 1999, 2004). The Kings Park story is reflected elsewhere throughout the metropolitan area.

### 3.6.1.2 Changes in avian species in the Perth Metropolitan Region

‘...... the number of increases and decreases in the distribution and abundance of birds provides a better measure of the impact of European settlement on the Australian continent than either does alone’ (Recher 1999, p. 21). In accord with this sentiment, I present changes in the abundance and distribution of the Perth avifauna.

**Declining avian species in the Perth Metropolitan Region**

Since European settlement, approximately 40% of non-passerine species (including waterbirds and birds of prey) and 50% of passerines, primarily insectivores and nectarivores, have declined in population on the SCP (How & Dell 1993). The range of many indigenous birds has retracted from the PMR and its environs as well as from the wider SCP and many species are now restricted to the Darling Scarp where habitat remnants are less disturbed and less isolated (Storr & Johnstone 1988, How & Dell 1993, Armstrong & Abbot 1995). Eighty bird species, both passerine (41) and non-passerine (39), have either declined substantially in abundance or become locally extinct in the study area for a wide range of reasons. Their decline is most often inferred from the decline of the species elsewhere in Australia (Table 3.4). However, the table was originally based on peer reviewed studies specifically carried out within the study site and included birds that were

All but 7 of the declining species have either a category of significance (Western Australian Planning Commission 2000) or a conservation status the Department of Environment and Conservation (2014) assigned to them. Of these 7 species, the Tawny Frogmouth *Podargus strigoides*, Grey Butcherbird *Cracticus torquatus*, Purple-crowned Lorikeet *Glossopsitta porphyrocephala*, Pallid Cuckoo *Cacomantis pallidus* (the latter two are both extinct in Kings Park (Recher 2004)); Fan-tailed Cuckoo *Cacomantis flabelliformis* (dependent on host species – Thornbills and White-browed Scrub Wren *Sericornis frontalis* – all of which have a category of significance of 3) and Western Gerygone *Gerygone fusca* (listed as declining in Kings Park by Recher 2004) are also listed as declining species in the PMR (Barrett, G. Department of Parks and Wildlife, pers. comm. 2013). However, the Grey Fantail *Rhipidura albiscapa* was not included in this list (Barrett pers. com. 2013). The introduced European Goldfinch was recorded as declining in Kings Park (Recher 2004). The Category of Significance (Western Australian Planning Commission 2000) was published in 1998 (17 years ago at the time of writing) and is in urgent need of renewal, but there are no immediate plans to update this list (Cullity pers. com. 2015). Alongside the use of lists such as Threatened Species, Recher (1999) recommends monitoring changes in vegetation and patterns of land use to determine species composition and abundance instead of species by species assessments because habitat degradation and loss are the reasons for regional changes of avifauna.

Fire, livestock grazing, and clearing of natural vegetation for agriculture, urbanisation and unspecified uses were identified as the five main causes for decline of 19 (23.75%), 16 (20%), 32 (40%), 23 (28.75%) and 19 (23.75%) species respectively within the study area (Table 3.4). Cat predation was linked with the decline for eight (10%) of the species: Bush Stone-curlew *Burhinus grallarius*; Painted Snipe *Rostratula benghalensis*; Common Bronze-wing *Phaps chalcoptera*; Barking Owl *Ninox connivens*; Southern Emu-wren *Stipiturus malachurus* and Western Bristlebird *Dasyornis longirostris*. The Bush
Stone-curlew and the Barking Owl are locally extinct (Western Australian Planning Commission 2000), while the Painted Snipe is listed as ‘Endangered’ (Department of Environment and Conservation 2014) with a Significant Conservation status of 4: ‘wide ranging species with reduced populations on the SCP’ (Western Australian Planning Commission 2000).

The habitats of the majority of these declining species are natural wetlands and woodlands. Woodland remnants are increasingly fragmented and isolated (Recher 2004), while suburban wetlands are often polluted, drained or stripped of riparian vegetation by livestock, or by local government in an effort to ‘beautify’ the area (Storr & Johnstone 1988). As a result, nearly all indigenous insectivorous and nectarivorous passerines have decreased in abundance and range (Storr & Johnstone 1988, How & Dell 1993).

How & Dell (1993) noted a natural trend of decreasing species richness as one moves east from the coast across the SCP with coastal regions generally supporting a higher species richness. Of the landform units on the Swan Coastal Plain, the coastal Quindalup dune system currently has the most remnant vegetation, but much of this land is earmarked for future residential development. Like many coastal areas throughout the world, the Quindalup dune system is considered prime land because of its proximity to the ocean. Although the Quindalup System has the most remaining vegetation, some species, such as the Western Whipbird *Psophodes nigrogularis nigrogularis*, which is naturally restricted the Quindalup and Spearwood systems, are now considered locally extinct. Conversely, the Variegated Fairy-wren *Malurus lamberti*, which was also thought to be limited to the Quindalup system, has now been observed in Kings Park (How & Dell 1993) (although not by Recher 2004) and in areas along the Swan River.
Table 3.4 Avifauna that are in decline: reasons why and conservation status on the Perth Metropolitan Region (the legend for this table is on p 89 and the references are on p 91).

<table>
<thead>
<tr>
<th>Bird Species</th>
<th>Category of Significance on PMR&lt;sup&gt;49&lt;/sup&gt;, Conservation Status&lt;sup&gt;53&lt;/sup&gt;</th>
<th>Fire</th>
<th>RG</th>
<th>LG</th>
<th>Fox</th>
<th>Cat</th>
<th>UnP</th>
<th>PD</th>
<th>AgC</th>
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<th>FD</th>
<th>S</th>
<th>KT</th>
<th>PA</th>
<th>FP</th>
<th>COMP</th>
<th>Total causes of decline for each species</th>
<th>total number of studies</th>
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<tbody>
<tr>
<td>Order Struthioniformes</td>
<td>Emu &lt;i&gt;Dromaius novaehollandiae&lt;/i&gt;&lt;sup&gt;25, 49&lt;/sup&gt;</td>
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<tr>
<td>Order Anseriformes</td>
<td>Freckled Duck &lt;i&gt;Stictonetta naevosa&lt;/i&gt;&lt;sup&gt;49&lt;/sup&gt;</td>
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<td>Blue-billed Duck &lt;i&gt;Oxyura australis&lt;/i&gt;&lt;sup&gt;49&lt;/sup&gt;</td>
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<td>Musk Duck &lt;i&gt;Biziura lobata&lt;/i&gt;&lt;sup&gt;49&lt;/sup&gt;</td>
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<td>Australasian Shoveler &lt;i&gt;Anas rhynchos&lt;/i&gt;&lt;sup&gt;59&lt;/sup&gt;</td>
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<td>Pink-eared Duck &lt;i&gt;Malacorhynchus membranaceus&lt;/i&gt;&lt;sup&gt;49&lt;/sup&gt;</td>
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<td>Hardhead &lt;i&gt;Aythya australis&lt;/i&gt;&lt;sup&gt;59&lt;/sup&gt;</td>
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<td>Order Ciconiiformes</td>
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<td>Australasian (Brown ) Bittern &lt;i&gt;Botaurus pociloptilus&lt;/i&gt;&lt;sup&gt;25, 49&lt;/sup&gt;</td>
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<tr>
<td>Bird Species</td>
<td>Category of Significance on PMR (^{49}), Conservation Status (^{53})</td>
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<td>RG</td>
<td>LG</td>
<td>Fox</td>
<td>Cat</td>
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<td>Rufous (Nankeen) Night Heron (Nycticorax caledonicus) (^{49})</td>
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<td>Little Bittern (Ixobrychus minutus) (^{49})</td>
<td>4, P4 (^{53})</td>
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<td>Whistling Kite (Haliastur sphenurus) (^{25,49, a}) Extinct in Kings Park (^{34})</td>
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<td>Brown Falcon (Falco berigora) (^{25, 49, b})</td>
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<td>Peregrine Falcon (F. peregrines) (^{49, 50})</td>
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Chapter III
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<th>LG</th>
<th>Fox</th>
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|                     | 5 | 8 | 9 | 16 | 20 | 22 | 47 | 53 | 5 | 53 | 19 | 20 | 26 | 53 | 19 | 53 | 10 | 19 | 53 | 53 | 53 | 7 | 13 |
|---------------------|---|---|---|----|----|----|----|----|---|---|----|----|----|----|----|----|----|----|----|----|----|---|----|---|----|
|                     | 18| 19| 26 | 34 | 41 | 42 | 47 |    | 5 | 20 | 20 |    |    |    |    |    |    |    |    |    |    |    |    |    |
|                     | 6 | 18| 19 | 34 | 41 | 42 | 47 |    | 5 | 20 | 20 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
|                     | 4 | 10| 10 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

Chapter III

83
| Bird Species | Category of Significance on PMR\(^5\) | Conservation Status\(^5\) | Fire | RG | LG | Fox | Cat | UnP | PD | AgC | UrC | UnC | W | D | H | Dt | FD | S | KT | PA | FP | COMP | Total causes of decline for each species | Total number of studies |
|--------------|-----------------------------------|--------------------------|------|----|----|-----|-----|-----|----|-----|-----|-----|---|---|---|---|---|---|---|---|---|--------------------------------|------------------|
| Purple-crowned Lorikeet *Glossopsitta porphyrocephala*\(^{25}\) Extinct in Kings Park\(^{54}\) | | 38 | | | | | | | | | | | | | | | | | | | | | | | 38 | 3 | 1 |
| **Order Cuculiformes** | | | 0 | 0 |
| Fan-tailed Cuckoo *Cacomantis flabelliformis*\(^{25, 1}\) | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pallid Cuckoo *C. pallidus* Extinct in Kings Park\(^{52}\) | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Order Strigiformes:** Barking Owl *Ninox connivens*\(^{49, d}\) Locally extinct\(^{49}\) P2\(^{53}\) | | | 53 | 53 | 53 | 53 | 20 | 20 | 20 | | | | | | | | | | | | | | 53 | 20 | 53 | 9 | 3 |
| **Order Caprimulgiformes:** Tawny Frogmouth *Podargus strigoides*\(^{25}\) | | | 41 | 41 | 2 | 1 |
| **Order Passeriformes** | | | 450 | 0 | 0 |
| Black-faced Woodswallow *Artamus cinereus*\(^{25, 49}\) | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Broad-tailed (Inland) Thornbill *Acanthiza apicalis*\(^{25, 49, 50, g}\) Extinct in Kings Park\(^{54}\) | | | 350 | 45 | 55 | 48 | 48 | 48 | 48 | 45 | 48 | 6 | 4 |
| Brown-headed Honeyeater *M. brevirostris*\(^{51}\) Extinct on SCP\(^{51}\) | | | | | | | | | | | | | | | | | | | | | | | | | | |

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\(^{1}\) Species are listed in the IUCN Red List 2006.

\(^{2}\) Species are listed in the IUCN Red List of Threatened Species 2006.

\(^{3}\) Species are listed in the IUCN Red List of Threatened Species 2004.

\(^{4}\) Species are listed in the IUCN Red List of Threatened Species 2002.

\(^{5}\) Species are listed in the IUCN Red List of Threatened Species 2000.
| Bird Species                          | Category of Significance on PMR* | Fire  | FG | LG | Fox | Cat | UnP | PD | A$^8$C | U$^C$ | UnC | W | D | H | Dt | FD | S | KT | PA | FP | COMP | Total causes of decline for each species | Total number of studies |
|--------------------------------------|----------------------------------|-------|----|----|-----|-----|-----|----|--------|------|-----|---|---|---|----|----|---|----|----|----|----------|------------------------|
| Crested (Western) Shrike-tit *Falcunculus frontatus* | locally extinct*49, P4* | 12 | 20 | 30 | | | | | | | 19 | | | | | | | | | | 2 | 4 | |
| Crested Bellbird *Oreoica gutturalis* | P4* | 41 | | | | | | | | | | | | | | | | | | | 1 | 1 | |
| Dusky Woodswallow *A. cyanopterus* | Extinct in Kings Park*54 | 4 | | | | | | | 41 | | | | | | | | | | | 1 | 1 | |
| European Goldfinch *Carduelis carduelis* | introduced to Perth, extinct in Kings Park*54 | | | | | | | | | | | | | | | | | | | | 0 | 0 | |
| Golden Whistler *Pachycephala pectoralis* | Extinct in Kings Park*54 | 3 | 12 | 13 | 38 | | | | | | 3 | | 41 | | | | | | | | 4 | 6 | |
| Grey Butcherbird *Cracticus torquatus* | | | | | | | | | | | | | | | | | | | | | 1 | 2 | |
| Grey Currawong *Strepera versicolor* | | 3 | | | | | | | | | | | | | | | | | | | 0 | 0 | |
| Grey Fantail *Rhipidura fuliginosa* | | | | | | | | | | | | | | | | | | | | | 0 | 0 | |
| Grey Shrike-thrush *Colluricincla harmonica* | | 3 | | | | | | | 41 | 41 | 51 | | | | | | | | 41 | | 3 | 2 | |
| Hooded Robin *Melanodryas cucullata* | | 3 | | | | | | | 41 | 51 | | | | | | | | | | | 4 | 3 | |

*Refer to the text for detailed descriptions.*
<p>| Bird Species | Category of Significance on PMR&lt;sup&gt;49&lt;/sup&gt;, Conservation Status&lt;sup&gt;53&lt;/sup&gt; | Fire | RG | LG | Fox | Cat | UnP | PD | AgC | Urc | UnC | W | D | H | Dt | FD | S | KT | PA | FP | COMP | Total causes of decline for each species | Total number of studies |
|--------------|--------------------------------------------------------------------------------|-----|----|----|-----|-----|-----|-----|-----|-----|-----|----|----|----|----|----|----|----|----|-----|---------------------------------------------|------------------------|
| New Holland Honeyeater &lt;i&gt;Phylidonyris novaehollandiae&lt;/i&gt;&lt;sup&gt;49, 50&lt;/sup&gt; | 4 | | | | | | | | | | | | | | | | | | | | 1 | 1 |
| Red-eared Firetail &lt;i&gt;Stagonopleura oculata&lt;/i&gt;&lt;sup&gt;25&lt;/sup&gt; | | | | | | 19 | | | | | | | | | | | | | | | | 3 | 3 |
| Red-winged Fairy-wren &lt;i&gt;M. elegans&lt;/i&gt;&lt;sup&gt;25, 49&lt;/sup&gt; | | | | | | | | | | | | | | | | | | | | | 4 | 4 |
| Restless Flycatcher &lt;i&gt;Myiagra inquieta&lt;/i&gt;&lt;sup&gt;49&lt;/sup&gt; | | | | | | | | | | | | | | | | | | | | | 0 | 0 |
| Rufous Tree-creeper &lt;i&gt;Climacteris rufa&lt;/i&gt;&lt;sup&gt;25, 49, c&lt;/sup&gt; | | | | | | | | | | | | | | | | | | | | | 5 | 5 |
| Scarlet Robin &lt;i&gt;Petroica multicolor&lt;/i&gt;&lt;sup&gt;25, 49, 50&lt;/sup&gt;, g Extinct in Kings Park&lt;sup&gt;54&lt;/sup&gt; | | | | | | | | | | | | | | | | | | | | | 5 | 5 |
| Southern Emu-wren &lt;i&gt;S. malachurus&lt;/i&gt;&lt;sup&gt;25, 49&lt;/sup&gt; | | | | | | | | | | | | | | | | | | | | | 5 | 2 |
| Splendid Fairy-wren &lt;i&gt;Malurus splendens&lt;/i&gt;&lt;sup&gt;25, 49, 50&lt;/sup&gt; | | | | | | | | | | | | | | | | | | | | | 3 | 4 |
| Tawny-crowned Honeyeater &lt;i&gt;P. melanops&lt;/i&gt;&lt;sup&gt;25, 49&lt;/sup&gt; | | | | | | | | | | | | | | | | | | | | | 2 | 1 |
| Varied (Australian) Sittella &lt;i&gt;Daphoenositta chrysoptera&lt;/i&gt;&lt;sup&gt;25, 49&lt;/sup&gt; | | | | | | | | | | | | | | | | | | | | | 1 | 1 |</p>
<table>
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<th>Bird Species</th>
<th>Category of Significance on PMR(^{53}), Conservation Status(^{53})</th>
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<th>RG</th>
<th>LG</th>
<th>Fox</th>
<th>Cat</th>
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<th>PD</th>
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<th>Fp</th>
<th>Comp</th>
<th>Total causes of decline for each species</th>
<th>total number of studies</th>
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<tr>
<td>Variegated Fairy Wren <em>M. lamberti</em>(^{49})</td>
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<tr>
<td>Western Bristlebird <em>Dasyornis longirostris</em>(^{4, h})</td>
<td>No longer recorded on PMR of SCP, S1: VU(^{53})</td>
<td>1</td>
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<tr>
<td>Western Gerygone <em>Gerygone fusca</em>(^{44})</td>
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<td>Western Little Wattlebird <em>Anthochaera lunulata</em>(^{49, 50})</td>
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\(^{4}\) Data from R. Adams, 1982.
\(^{49}\) Data from M. Lamberti, 1990.
\(^{53}\) Data from various sources.
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<th>Bird Species</th>
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<th>COMP</th>
<th>Total causes of decline for each species</th>
<th>total number of studies</th>
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<td>Western Yellow Robin &lt;i&gt;Eopsaltria griseogularis&lt;/i&gt;&lt;sup&gt;35, 49, c&lt;/sup&gt;</td>
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<td>Yellow-throated Miner &lt;i&gt;Manorina flavigula&lt;/i&gt;&lt;sup&gt;25, 49&lt;/sup&gt;</td>
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</table>
Legend for Table 3.4

**Column 1:**
Common and species name with reference/s to species inclusion to the table
a) was once considered as a vagrant/visitor, but is now common in the southwest\(^{26}\). Was once common on the SCP when there were more wetlands where it fed on eggs and dying chicks\(^{46}\)
b) opportunistic feeder of carrion. Abundance has been affected by feeding on poisoned fox carcas\(^{46}\)
c) vagrant or visitor\(^{25}\)
d) considered locally extinct\(^{25}\)
e) subject to predation when introduced prey decline\(^{32}\)
f) population dependent upon host species abundance\(^{40}\)
g) was once common throughout the metropolitan SCP, but now restricted to Darling Scarp\(^{25}\)
h) First specimen collected near Perth in 1839, but now not recorded there.

**Column 2:**
Status on the PMR of the SCP\(^{50}\): based upon Department of Environment and Conservation (1998)
‘3’ habitat specialists with a reduced distribution on the SCP
‘4’ wide ranging species with reduced populations on the SCP

Conservation Status\(^{53}\)

The Minister for the Environment (Western Australia) has the authority to declare species of fauna or flora, that are rare or extinct, or in need of special protection, to be ‘Specially Protected’. These taxa are considered as ‘Threatened’ and schedules 1 to 4 can be applied to them and relate to the species in the Swan Region of Western Australia.

**Schedule 1:** being fauna that is rare or likely to become extinct with the following categories: endangered, vulnerable, critical

**Schedule 2:** begin fauna that is presumed to be extinct;

**Schedule 3:** being birds that are subject to an agreement between the governments of Australia and Japan relating to the protection of migratory birds and birds in danger of extinction;

**Schedule 4:** being fauna that is in need of special protection otherwise than for the reasons mentioned under Schedules 1, 2 & 3.
The following categories are a ‘supplementary list of fauna’ maintained by Department of Environment and Conservation and relate to the Swan Region of Western Australia (http://www.dpaw.wa.gov.au/images/documents/plants-animals/threatened-species/Listings/Threatened_and_Priority_Fauna_Rankings.pdf).

Priority 1 (P1): Taxa with few, poorly known populations on threatened lands. Fauna in this group need urgent surveying and evaluation.

Priority 2 (P2): Taxa with few, poorly known populations on conservation lands. Fauna in this group require urgent surveying and evaluation before they can be considered as ‘threatened’

Priority 3 (P3): Taxa with several, poorly known populations, some on conservation lands. Fauna in this group require urgent surveying and evaluation before they can be considered as ‘threatened’

Priority 4 (P4): Taxa in need of monitoring. Taxa in this group are considered to have been ‘adequately surveyed, or for which sufficient knowledge is available, and which are considered not currently threatened or in need of special protection, but could be if present circumstances change. These taxa are usually represented on conservation lands.

Columns 3 to 20:

<table>
<thead>
<tr>
<th>Fire = changed fire regimes</th>
<th>D = damming/flood control</th>
</tr>
</thead>
<tbody>
<tr>
<td>RG = rabbit grazing</td>
<td>H = human persecution.usage</td>
</tr>
<tr>
<td>LG = livestock grazing</td>
<td>Dt = drought/climate change</td>
</tr>
<tr>
<td>Fox = fox predation</td>
<td>FD = decline in food</td>
</tr>
<tr>
<td>Cat = cat predation</td>
<td>S = salinization</td>
</tr>
<tr>
<td>UnP = unspecified predation</td>
<td>RT = road traffic</td>
</tr>
<tr>
<td>PD = plant disease</td>
<td>PA = pesticide accumulation</td>
</tr>
<tr>
<td>AgC = agricultural clearing</td>
<td>FP = forestry practices</td>
</tr>
<tr>
<td>UrC = urban clearing</td>
<td>COMP = competition from feral and native animals</td>
</tr>
<tr>
<td>UnC = unspecified clearing</td>
<td></td>
</tr>
<tr>
<td>W = draining wetlands</td>
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</tr>
</tbody>
</table>
Key to the references for Table 3.4

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</thead>
<tbody>
<tr>
<td>5</td>
<td>Blakers et al. (1984)</td>
<td>19</td>
<td>Garnett (1992b)</td>
</tr>
<tr>
<td>9</td>
<td>Burbidge et al. (1990)</td>
<td>23</td>
<td>Grice et al. (1986)</td>
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<td>29</td>
<td>Luck (2002a)</td>
<td>43</td>
<td>Smith (1977)</td>
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<td>34</td>
<td>Massam &amp; Long (1992)</td>
<td>48</td>
<td>Whitlock (1914)</td>
</tr>
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<td>36</td>
<td>Mawson &amp; Long (1994)</td>
<td>50</td>
<td>Davis et al. (2013)</td>
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<td>38</td>
<td>Recher et al. (2002)</td>
<td>52</td>
<td>Garnett et al. (2011)</td>
</tr>
<tr>
<td>41</td>
<td>Saunders et al. (1985)</td>
<td>42</td>
<td>Serventy &amp; Whittell (1976)</td>
</tr>
</tbody>
</table>

**Increasing Avian Species in the Perth Metropolitan Region**

Species that are increasing in number are of similar importance to species in decline for several reasons. Firstly, they indicate disruption of the environment and ecological processes (Recher 1999). Secondly, they can indicate the health of the ecosystem, its ecological processes and community structures (Rapport et al. 1998), particularly when combined with research on decreasing species (Recher 1999). Thirdly, increasing indigenous and exotic species should be monitored because they compete with more fragile
indigenous species for nesting and foraging sites. Examples of this in Perth are the Rainbow Lorikeet, which competes with smaller parrots for nesting sites, the Australian Raven *Corvus coronoides perplexus*, that predates nestlings and eggs, and the Ring-necked Parrot *Platycercus zonarius*, that breaks the leaves off *Xanthorrhoea* grass trees to obtain moisture, thereby destroying nesting material for Western Thornbill *Acanthiza apicalis* and reducing nectar production for honeyeaters and larger cockatoos (Recher 1999).

Forty-five species have increased in abundance in the PMR (Table 3.5), 14 of which are passerines (How & Dell 1993). Native species include large passerines, such as the Australian Magpie *Gymnorhina tibicen* and Australian Raven that prospered because of the increase in open areas for foraging. Welcome Swallows *Hirundo neoxina* increased in abundance because of nesting opportunities on buildings, while suburban gardens support medium to large nectarivores such as the Singing Honeyeater *Lichenostomus virescens virescens* and Red Wattlebird *Anthochaera carunculata wardwardi*. Birds such as the native Magpie-lark *Grallina cyanoleuca* and the introduced Laughing Dove *Streptopelia senegalensis* and Domestic Pigeon *Columba livia* survive well as opportunistic feeders (Recher 2004).

Increases in a particular species may be as a result of disturbance in the original habitat. For example, Recher (2004) observed an increase in the White-naped Honeyeater *Melithreptus chloropsis* in Kings Park and believed the increase to be caused by drought conditions in the bird’s previous habitat. Also, events such as fire in habitats such as Kings Park allow smaller passerines such as the White-cheeked Honeyeater *Phylidonyris niger* to colonise new areas (Recher 2004).

New wetlands, which tend to be shallow with little to no riparian vegetation, have been created either as a consequence of a rise in the water table after mass clearing of vegetation or to enhance new suburban developments. They have been responsible for the increase of several native species (*e.g.* Great Crested Grebe *Podiceps cristatus*) and provided habitat for several colonising species such as the Straw-necked Ibis *Threskiornis spinicollis* (Storr & Johnstone 1988).

How & Dell (1993) listed Freckled Duck *Stictonetta naevosa* and Pink–eared Duck *Malacorhynchus membranaceus* as increasing on the PMR, however, the Department of
Planning and Infrastructure WA (2000) have these species listed as ‘3’ - habitat specialists with a reduced distribution on the SCP and ‘4’ wide ranging species with reduced populations on the SCP respectively. A possible reason is that much of their habitat has been destroyed, causing populations to move to remaining habitat. Birds such as the Red-capped Robin *Petroica goodenovii* and White-fronted Chat *Epthianura albifrons* are also in a similar situation. They were listed by How & Dell (1993) as increasing on the PMR in Bassendean, Darling Scarp and Darling Plateau, although NatureMap (Department of Environment and Conservation 2013) shows only a scattering of observations throughout the PMR for both insectivores. Again, like the ducks mentioned earlier, their increase in abundance in some areas could be a reflection of birds concentrating in remnant habitat following habitat removal/destruction, falsely inflating their abundance.

### 3.6.1.3 Passerines recorded in gardens and remnant bushland throughout the study area

Forty nine species of passerines were recorded in six independent studies either in Perth gardens or remnant bushland within the Perth region. The five areas of bushland in Davis & Wilcox (2013), Recher (2004) and Berry & Berry (2008) range in size from 267 ha (Kings Park; A Class Reserve), 31 ha (Underwood Avenue; sampled over two years 1998/99 and 2000/01), 21 ha (Shenton; A Class Reserve and sampled for 11 years between 1994 to 2001), 6.5 ha (Hollywood Reserve; C Class Reserve; sampled in 2001/02) to 0.75 ha (Monash; unnamed remnant; sampled in 2001/02). Gardens presented in Table 3.6 include data from Grayson *et al.* (2007) and one garden each from Berry & Berry (2008) and Abbott (2009). The sites surveyed by Gole (2003) were part of the Perth Biodiversity Project, which aimed to improve biodiversity conservation within the PMR and to help 30 local councils manage existing local biodiversity. The surveys began in 2002 and are ongoing (Gole 2004). Only sites occurring on the PMR portion of the SCP are included in Table 3.6.

Passerine species common across sites include: Australian Magpie, Australian Raven, Black-faced Cuckoo Shrike *Coracina novaehollandiae*, Brown Honeyeater *Lichmera indistincta*, Red Wattlebird, Silveryeye *Zosterops lateralis*, Singing Honeyeater, Striated Pardalote *Pardalotus striatus* and Willie Wagtail *Rhipidura leucophrys* (Table 3.6). These species (excluding the Striated Pardalote) were also recorded as mobile species
that traverse a busy road between a remnant bushland and nearby gardens (Davis & Wilcox 2013).

### Table 3.5
Avifauna that have increased in abundance in the Perth Metropolitan Region. New species continue to be introduced from aviary escapes.

<table>
<thead>
<tr>
<th>Podicipedidae</th>
<th>Podiceps cristatus (QS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANHINGIDAE</td>
<td>Anhinga melanogaster (QS, B)</td>
</tr>
<tr>
<td>Ardeidae</td>
<td>Ardea pacifica (QS, B, RHS, DS, DP)</td>
</tr>
<tr>
<td></td>
<td>White-faced Heron A. novaehollandiae (QS, B, RHS, DS, DP)</td>
</tr>
<tr>
<td></td>
<td>Great Egret Albatrosa alba (QS, B)</td>
</tr>
<tr>
<td></td>
<td>Little Egret Garza petroica (QS, B)</td>
</tr>
<tr>
<td></td>
<td>Cattle Egret Garza ibis (QS, B, RHS)</td>
</tr>
<tr>
<td>Threskiornithidae</td>
<td>Podocettus nigroaeneus (QS, B)</td>
</tr>
<tr>
<td></td>
<td>Glossy Ibis Plegadis falcinellus (QS, B)</td>
</tr>
<tr>
<td></td>
<td>Royal Spoonbill Platanea regia (QS, B)</td>
</tr>
<tr>
<td></td>
<td>Yellow-billed Spoonbill F. flavipes (QS, B)</td>
</tr>
<tr>
<td>Anatidae</td>
<td>Carina moschata (QS, B)</td>
</tr>
<tr>
<td></td>
<td>Tadorna tadoroides (QS, B, RHS, DS, DP)</td>
</tr>
<tr>
<td></td>
<td>Mallard Anas platyrhynchos (QS, B)</td>
</tr>
<tr>
<td></td>
<td>Wood Duck Chenonetta jubata (B, RHS, DS, DP)</td>
</tr>
<tr>
<td></td>
<td>Pink-eyed Duck Malacorhynchus membranaceus (QS, B, RHS)</td>
</tr>
<tr>
<td></td>
<td>Freckled Duck Stilsonette naevosa (B)</td>
</tr>
<tr>
<td>Accipitridae</td>
<td>Elanus caeruleus (QS, B, RHS, DS, DP)</td>
</tr>
<tr>
<td>Rallidae</td>
<td>Cotula tricolor (QS, B, RHS, DS, DP)</td>
</tr>
<tr>
<td>Charadriidae</td>
<td>Vanellus tricolor (QS, B, RHS, DS, DP)</td>
</tr>
<tr>
<td></td>
<td>Black-fronted Plover Charadrius melanops (QS, B, RHS, DS, DP)</td>
</tr>
<tr>
<td>Columbidae</td>
<td>Columba livia (QS, B, RHS, DS)</td>
</tr>
<tr>
<td></td>
<td>Spotted Dove Streptopelia chinensis (QS, B, RHS, DS, DP)</td>
</tr>
<tr>
<td></td>
<td>Laughing Dove S. senegalensis (QS, B, RHS, DS, DP)</td>
</tr>
<tr>
<td></td>
<td>Crested Pigeon Ocyphaps lophotes (QS, B)</td>
</tr>
<tr>
<td>Psittadidae</td>
<td>Trichoglossus haematodus (QS, B)</td>
</tr>
<tr>
<td></td>
<td>Ring-necked Parrot Platycercus zonarius (QS, B, RHS, DS, DP)</td>
</tr>
<tr>
<td></td>
<td>Galah Cacatua roseicapilla (QS, B, RHS, DS, DP)</td>
</tr>
<tr>
<td></td>
<td>Little Corella C. sanguinea (QS, B, RHS, DS)</td>
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<tr>
<td></td>
<td>Sulphur-crested Cockatoo C. galerita (RHS)</td>
</tr>
<tr>
<td>Halcyonidae</td>
<td>Dacelo gigas (QS, B, RHS, DS, DP)</td>
</tr>
<tr>
<td>Hirundinidae</td>
<td>Cheramoeca leucosterina (QS, B, RHS, DS)</td>
</tr>
<tr>
<td></td>
<td>Fairy Martin Hirundo ariel (RHS)</td>
</tr>
<tr>
<td></td>
<td>Welcome Swallow H. neoxena (QS, B, RHS, DS)</td>
</tr>
<tr>
<td>Petroicidae</td>
<td>Petroica goodenovii (B, DS, DP)</td>
</tr>
<tr>
<td>Maluridae</td>
<td>Melanotis leucotera (QS, B)</td>
</tr>
<tr>
<td>Sylvidae</td>
<td>Melanotis leucotera (QS, B)</td>
</tr>
<tr>
<td>Meliphagidae</td>
<td>Meliphas minor (QS, B, RHS, DS, DP)</td>
</tr>
<tr>
<td></td>
<td>White-fronted Chat Epthianura abilis (QS, B, RHS, DS, DP)</td>
</tr>
<tr>
<td>Passeridae</td>
<td>Poephila guttata (QS)</td>
</tr>
<tr>
<td></td>
<td>Chestnut-breasted Mannikin Lonchura castaneothorax (QS, B)</td>
</tr>
<tr>
<td>Dicuridae</td>
<td>Grallina cyanoleuca (QS, B, RHS, DS, DP)</td>
</tr>
<tr>
<td>Cracticidae</td>
<td>Cacatua rossicapilla (QS, B, RHS, DS, DP)</td>
</tr>
<tr>
<td>Corvida</td>
<td>Corvus coronoides (QS, B, RHS, DS, DP)</td>
</tr>
</tbody>
</table>

(How & Dell 1993) *colonising species, ++marked increase in abundance, Land formations where birds are common: QS: Quindalup/Spearwood, B: Bassendean; RHS: ridge Hill Shelf, DS: Darling Scarp, DP: Darling Plateau.)
Table 3.6   Passerines recorded in gardens and remnant bushland throughout the Perth Metropolitan Region of the Swan Coastal Plain, including the species’ foraging mode and category of conservation significance. The frequency of mobility between gardens and Kings Park is also included for passerines recorded in Davis & Wilcox (2013).

<table>
<thead>
<tr>
<th>Common and scientific name</th>
<th>Foraging Mode</th>
<th>Category of Significance (DEC)</th>
<th>Suburban gardens</th>
<th>Bush Forever sites</th>
<th>West Leederville</th>
<th>Kings Park (n = 50)</th>
<th>Kings Park opposite (n = 83)</th>
<th>Gardens (per 7 years)</th>
<th>Frequency of occurrence (Index of relative mobility)</th>
<th>Frequency of occurrence (Index of relative mobility)</th>
<th>Davis &amp; Wilcox (2013) %</th>
<th>Berry &amp; Berry (2008) 4 remnants and a garden (+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australian (Clamorous) Reed-Warbler Acrocephalus australis</td>
<td>Insectivore⁴</td>
<td></td>
<td>26.32</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australian (Richard's) Pipit Anthus australis</td>
<td>Insectivore⁴</td>
<td></td>
<td>5.26</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australian Magpie Gymnorhina tibicen</td>
<td>Omnivore¹</td>
<td></td>
<td>100</td>
<td>94.74</td>
<td>52.71 (21.20)</td>
<td>97</td>
<td>46 (1.0)</td>
<td>25 (0.4)</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td></td>
</tr>
<tr>
<td>Australian Raven Corvus coronoides</td>
<td>Omnivore¹</td>
<td></td>
<td>100</td>
<td>89.47</td>
<td>74.42 (20.46)</td>
<td>100</td>
<td>50 (0.4)</td>
<td>17 (6.2)</td>
<td>y</td>
<td>y</td>
<td>y</td>
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<tr>
<td>Black-faced Cuckoo-shrike Coracina novaehollandiae</td>
<td>Generalist³</td>
<td></td>
<td>84.48</td>
<td>68.42</td>
<td>26.86 (12.54)</td>
<td>14</td>
<td>40 (1.9)</td>
<td>10 (3.2)</td>
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<td>y</td>
<td>y (breeding)</td>
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<tr>
<td>Black-faced Woodswallow Artamus cinereus</td>
<td>Insectivore²</td>
<td></td>
<td>4</td>
<td></td>
<td>5.26</td>
<td></td>
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<tr>
<td>Broad-tailed (Inland) Thornbill A. apicalis</td>
<td>Insectivore²</td>
<td></td>
<td>3</td>
<td></td>
<td>13.15</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Brown Honeyeater Lichmera indistincta</td>
<td>Nectarivore¹</td>
<td></td>
<td>91.38</td>
<td>92.10</td>
<td>45.33 (35.58)</td>
<td>100</td>
<td>84 (0.4)</td>
<td>89 (0.4)</td>
<td>y</td>
<td>y</td>
<td>y (breeding)</td>
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<td>Common and scientific name</td>
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<td>Category of Significance (DEC)</td>
<td>Suburban gardens</td>
<td>Bush Forever sites</td>
<td>West Leederville</td>
<td>Kings Parks (n = 50)</td>
<td>Gardens opposite (n = 83)</td>
<td>Shen-ton</td>
<td>Under-wood</td>
<td>Holly-wood</td>
<td>Monash</td>
<td>Garden (Nedlands)</td>
</tr>
<tr>
<td>-----------------------------</td>
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<tr>
<td>Brown-headed Honeyeater <em>Melithreptus brevirostris</em></td>
<td>Insectivore²</td>
<td>extinct on SCP</td>
<td>4</td>
<td>2.63</td>
<td>0</td>
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<tr>
<td>Dusky Woodswallow <em>Artamus cyanopterus</em></td>
<td>Insectivore²</td>
<td></td>
<td>4</td>
<td>2.63</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>European Goldfinch <em>Carduelis carduelis</em></td>
<td>seeds/ insectivore⁴</td>
<td></td>
<td>2.63</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Golden Whistler <em>Pachycephala melanura</em></td>
<td>Insectivore²</td>
<td></td>
<td>3</td>
<td>7.89</td>
<td>0²</td>
<td></td>
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<td></td>
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<tr>
<td>Grey Butcherbird <em>Cracticus torquatus</em></td>
<td>Predator¹</td>
<td></td>
<td>65.52</td>
<td>50.00</td>
<td>5.00 (4.24)</td>
<td>63</td>
<td>46 (0)</td>
<td>0 (-)</td>
<td>y</td>
<td>y (breeding)</td>
<td>y</td>
<td>y</td>
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<td>Vertebrates²</td>
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<tr>
<td>Grey Fantail <em>Rhipidura fuliginosa</em></td>
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<td>28.94</td>
<td>89</td>
<td>66 (0)</td>
<td>0 (0)</td>
<td>y</td>
<td>y (breeding)</td>
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<tr>
<td>Grey Shrike-thrush <em>Colluricincla harmonica</em></td>
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<td></td>
<td>3</td>
<td>12.07</td>
<td>2.63</td>
<td></td>
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<tr>
<td>Western Little Wattlebird <em>Anthochaera carunculata</em></td>
<td>Nectarivore²</td>
<td></td>
<td>4</td>
<td>53.45</td>
<td>34.21</td>
<td>2.00</td>
<td></td>
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<td>Common and scientific name</td>
<td>Foraging Mode</td>
<td>Category of Significance (DEC)</td>
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<td>Garden (Ned-lands)</td>
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<td>---------------------------</td>
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</tr>
<tr>
<td>Little Grassbird</td>
<td>Insectivore 4</td>
<td>—</td>
<td>10.52</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><em>Megalurus gramineus</em></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magpie-lark</td>
<td>Insectivore 2</td>
<td>—</td>
<td>84.48</td>
<td>89.47</td>
<td>42.66 (39.95)</td>
<td>0 (-)</td>
<td>0 (-)</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Grallina cyanoleuca</em></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Mistletoebird</td>
<td>Frugivore 1</td>
<td>—</td>
<td>32.76</td>
<td>18.42</td>
<td></td>
<td>2 (0)</td>
<td>1 (0)</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td>y (not</td>
<td>recorded since 1982)</td>
</tr>
<tr>
<td><em>Dicaeum hirundinaceum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>New Holland Honeyeater</td>
<td>Nectarivore 2</td>
<td>4</td>
<td>67.24</td>
<td>63.16</td>
<td></td>
<td></td>
<td></td>
<td>y</td>
<td>y (recorded</td>
<td>y</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Phylidonyris novaehollandiae</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>since 1998)</td>
<td>y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red Wattlebird</td>
<td>Nectarivore 1</td>
<td>—</td>
<td>94.83</td>
<td>97.37</td>
<td>55.96 (32.96)</td>
<td>100</td>
<td>92 (3.1)</td>
<td>y (breeding)</td>
<td>y (breeding)</td>
<td>y</td>
<td>y</td>
<td>y (breeding)</td>
</tr>
<tr>
<td><em>Anthochaera carunculata</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red-capped Robin</td>
<td>Insectivore 2</td>
<td>—</td>
<td>7.89</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><em>Petroica goodenovii</em></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Red-eared Firetail</td>
<td>Seed 2</td>
<td>extinct on SCP</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td><em>Stagonopleura oculata</em></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Rufous Whistler</td>
<td>Insectivore 1</td>
<td>—</td>
<td>34.48</td>
<td>36.84</td>
<td>91</td>
<td>76 (0)</td>
<td>0 (0)</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Pachycephala rufiventris</em></td>
<td></td>
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</tr>
<tr>
<td>Common and scientific name</td>
<td>Foraging Mode</td>
<td>Suburban gardens</td>
<td>Bush Forever sites</td>
<td>West Leederville</td>
<td>Kings Parks (n = 50)</td>
<td>Gardens opposite (n = 83)</td>
<td>Shen-ton</td>
<td>Under-wood</td>
<td>Holly-wood</td>
<td>Monash</td>
<td>Garden (Nedlands)</td>
<td></td>
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<td>---------------------------</td>
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<td></td>
</tr>
<tr>
<td>Scarlet Robin <em>Petroica multicolor</em></td>
<td>Insectivore²</td>
<td>3</td>
<td>12.07</td>
<td>5.26</td>
<td>0⁵</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Silvereye <em>Zosterops lateralis</em></td>
<td>Omnivore¹</td>
<td>79.31</td>
<td>71.05</td>
<td>53.71 (9.62)</td>
<td>91</td>
<td>96 (0.3)</td>
<td>54 (1.0)</td>
<td>y</td>
<td>y</td>
<td></td>
<td>y</td>
<td></td>
</tr>
<tr>
<td>Singing Honeyeater <em>Lichenostomus virescens</em></td>
<td>Nectarivore¹</td>
<td>94.83</td>
<td>92.11</td>
<td>99.71 (0.76)</td>
<td>74</td>
<td>66 (3.2)</td>
<td>100 (0.6)</td>
<td>y (breeding)</td>
<td>y (breeding)</td>
<td>y</td>
<td>y</td>
<td></td>
</tr>
<tr>
<td>Splendid Fairy-wren <em>Malurus splendens</em></td>
<td>Insectivore²</td>
<td>3</td>
<td>12.07</td>
<td>15.79</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spotted Pardalote <em>Pardalotus punctatus</em></td>
<td>Insectivore²</td>
<td>15.52</td>
<td>5.26</td>
<td>0⁶</td>
<td>y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Striated Pardalote <em>Pardalotus striatus</em></td>
<td>Insectivore¹</td>
<td>55.17</td>
<td>60.53</td>
<td>6 (5.6)</td>
<td>86</td>
<td>44 (0)</td>
<td>19 (0)</td>
<td>y (breeding)</td>
<td>y (breeding)</td>
<td>y</td>
<td>y</td>
<td></td>
</tr>
<tr>
<td>Tawny-crowned Honeyeater <em>Phylidonyris melanops</em></td>
<td>Nectarivore²</td>
<td>4</td>
<td>5.26</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tree Martin <em>Petrochelidon nigricans</em></td>
<td>Insectivore²</td>
<td>68.97</td>
<td>50.00</td>
<td>49.29 (25.92)</td>
<td>0⁶</td>
<td></td>
<td>y</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Varied (Black-capped) Sitella <em>Daphoenositta chrysoptera</em></td>
<td>Insectivore¹</td>
<td>3</td>
<td>5.26</td>
<td>29</td>
<td>4 (0)</td>
<td>0 (0)</td>
<td>y</td>
<td>y (breeding)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common and scientific name</td>
<td>Foraging Mode</td>
<td>Category of Significance (DEC)</td>
<td>Suburban gardens</td>
<td>Bush Forever sites</td>
<td>West Leederville</td>
<td>Kings Park (n = 50)</td>
<td>Gardens opposite (n = 83)</td>
<td>Shenton</td>
<td>Underwood</td>
<td>Hollywood</td>
<td>Monash</td>
<td>Garden (Nedlands)</td>
</tr>
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<td>-----------------</td>
</tr>
<tr>
<td>Variegated Fairy-wren <em>M. lamberti</em></td>
<td>Insectivore¹</td>
<td>3</td>
<td>7.89</td>
<td></td>
<td></td>
<td>10 (0)</td>
<td>0 (0)</td>
<td>y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weebill <em>S. brevirostris</em></td>
<td>Insectivore¹</td>
<td>3</td>
<td>12.07</td>
<td>10.53</td>
<td></td>
<td>84 (0)</td>
<td>0 (0)</td>
<td>y (breeding)</td>
<td>y (breeding)</td>
<td>y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welcome Swallow <em>Hirundo neoxena</em></td>
<td>Insectivore²</td>
<td>68.97</td>
<td>65.79</td>
<td>34.71 (18.33)</td>
<td></td>
<td>40</td>
<td></td>
<td>y</td>
<td>y</td>
<td>y</td>
<td>y</td>
<td>y</td>
</tr>
<tr>
<td>Western Gergoyne <em>Gerygone fusca</em></td>
<td>Insectivore¹</td>
<td>32.76</td>
<td>28.95</td>
<td></td>
<td></td>
<td>97</td>
<td>72 (0)</td>
<td>0 (0)</td>
<td>y</td>
<td>y (breeding)</td>
<td>y</td>
<td></td>
</tr>
<tr>
<td>Western Spinebill <em>Acanthorhynchus superciliosus</em></td>
<td>Nectarivore¹</td>
<td>39.66</td>
<td>15.79</td>
<td></td>
<td></td>
<td>77</td>
<td>46 (0)</td>
<td>0 (0)</td>
<td>y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western Thornbill <em>Acanthius inornata</em></td>
<td>Insectivore²</td>
<td>3</td>
<td>5.26</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Western Yellow Robin <em>Eopsaltria australis griseogularis</em></td>
<td>Insectivore²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White-browed Scrubwren <em>Sericornis frontalis</em></td>
<td>Insectivore²</td>
<td>3</td>
<td>15.79</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White-cheeked Honeyeater <em>Phylidonyris nigra</em></td>
<td>Nectarivore¹</td>
<td>4</td>
<td>37.93</td>
<td>57.89</td>
<td>96 (only 1 recording)</td>
<td>2 (0)</td>
<td>0 (0)</td>
<td>y (recorded since 2000)</td>
<td>y (recorded since 2000)</td>
<td>y (recorded since 2000)</td>
<td>y (recorded since 2000)</td>
<td></td>
</tr>
</tbody>
</table>

¹ Abbreviated for brevity.
<table>
<thead>
<tr>
<th>Common and scientific name</th>
<th>Foraging Mode</th>
<th>Category of Significance (DEC)</th>
<th>Grayson et al. (2007) % occurrence in gardens based on +/− (n = 57)</th>
<th>Gole (2003) % occurrence based on +/− (number of sites found divided by total number of sites)</th>
<th>Abbott (2009) % frequency based on +/−</th>
<th>Recher (2004) % frequency of occurrence based on average number of sightings over 7 years, 50 to 53 observations per year (±1SD)</th>
<th>Davis &amp; Wilcox (2013) % Frequency of occurrence of relative mobility</th>
<th>Berry &amp; Berry (2008) 4 remnants and a garden (+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White-naped Honeyeater <em>Melithreptus lunatus</em></td>
<td>Nectarivore 2</td>
<td>4</td>
<td>13.79</td>
<td>5.26</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White-winged Triller <em>Lalage tricolor</em></td>
<td>Insectivore 2</td>
<td></td>
<td>18.42</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Willie Wagtail <em>Rhipidura leucophrys</em></td>
<td>Insectivore 1</td>
<td></td>
<td>81.03</td>
<td>81.58</td>
<td>35.33</td>
<td>0</td>
<td>0 (0)</td>
<td>2 (0)</td>
</tr>
<tr>
<td>Yellow-plumed Honeyeater <em>Lichenostomus ornatus</em></td>
<td>Nectarivore 2</td>
<td>3</td>
<td></td>
<td>2.63</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellow-rumped Thornbill <em>Acanthiza chrysorrhoa</em></td>
<td>Insectivore 1</td>
<td></td>
<td>22.41</td>
<td>18.42</td>
<td>77</td>
<td>38 (0)</td>
<td>0 (0)</td>
<td>y</td>
</tr>
<tr>
<td>Yellow-throated Miner <em>Manorina flavigula</em></td>
<td>Nectarivore 2</td>
<td>4</td>
<td></td>
<td>7.89</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total species richness</strong></td>
<td></td>
<td></td>
<td>28</td>
<td>41</td>
<td>15</td>
<td>24</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

Grayson: % freq based on +/− occurrence in 57 gardens
1Davis & Wilcox (2013)
2Davis *et al.* (2013)
3Gole (2003) Bird surveys in selected Perth metropolitan reserves
4Bird Life Australia (2015)
5Not detected during counts, but recorded out of census period
6As a migrant. Expected counts to be 20
7Serventy recorded 28 in 1928-37 & 22 from 1952-55
81928-37 Serventy recorded at 57% and 1952-55: 4%
9not recorded in counts but recorded outside census (Recher 1999)
**migrant (Davis *et al.* 2013)
*introduced European Goldfinch (Recher 2004)
Table 3.7  Data from Birdlife Australia from 1998 to 2012 in the Perth Metropolitan Region for bird species listed as declining in Table 3.4, but not recorded in studies presented in Table 3.6. Note, there are no records for the Restless Flycatcher from Birds Australia on the Perth Metropolitan Region.

<table>
<thead>
<tr>
<th>Year of observation (number of observations)</th>
</tr>
</thead>
<tbody>
<tr>
<td>------------------</td>
</tr>
<tr>
<td>385</td>
</tr>
<tr>
<td>556</td>
</tr>
<tr>
<td>526</td>
</tr>
<tr>
<td>394</td>
</tr>
<tr>
<td>387</td>
</tr>
<tr>
<td>535</td>
</tr>
</tbody>
</table>

When comparing Tables 3.4 and 3.6, six passerine species listed as decreasing in Table 3.4 were not recorded in any of the local studies presented in Table 3.6, indicating that the conservation status of these species may be in need of review. The Western Bristlebird and Western Whipbird *Psophodes nigrogularis* are now locally extinct (Table 3.6), but the six species listed in Table 3.7 were classed as habitat specialists with reduced ranges on the SCP (Western Australian Planning Commission 2010). One would hope species classified as ‘3’ would be recorded in some of the larger, more pristine sites mentioned in Table 3.6. Further, records on NatureMap (Department of Environment and Conservation 2013) are minimal for all these species, ranging from 0 to 5. Birdlife
Australia data (Geoff Barratt pers. com.) for the Perth Metropolitan area (Table 3.7) show these species to be either low in numbers, declining, or not observed at all (i.e. Restless Flycatcher *Myiagra inquieta*).

### 3.7 Discussion

Throughout this chapter, I introduced the study site, the Perth Metropolitan Region of the Swan Coastal Plain, including its vegetation characteristics, major landform units, climate and historical background. Avifauna, both increasing and decreasing species were also presented, with the main focus on the status of passerines recorded throughout the study region. Attention was given to passerines because they are the most common native birds in suburban gardens and the majority of passerines weigh 35 to 550 g, many of whom are within the preferred prey weight range (< 200 g) of the domestic cat (Dickman 1996). However, awareness by the public of many passerines, particularly those that are small, brown and inconspicuous is low, and their decline in abundance is often unwitnessed (Recher 1999). In contrast, the majority of non-passerines are charismatic, colourful and are often well researched and dominate threatened species lists (Recher 1999).

#### 3.7.1 Human impact on the study region

George Seddon describes the Swan Coastal Plain as a ‘kept woman’ (Seddon 1972). The land is unproductive due to its age and is dependent on external water sources for human use. Fauna, such as birds and, to a lesser extent, frogs and marsupials native to the Swan Coastal Plain, have adapted to the unpredictable rainfall and unfertile soil by being nomadic, following rainfall patterns and associated food sources (Burgman & Lindenmayer 1998).

The lack of fertile soil, rocky limestone outcrops and low water availability was the saving grace for the metropolitan SCP, allowing remnant bushland to remain and be available for preservation. However, the demand for housing has over-ridden these limitations, placing an even greater strain on remaining bushland, creating isolated, fragmented and degraded areas. Avian populations within these landscapes are reduced in
size, forming sub-populations. Further, species that are not mobile between fragments are unable to repopulate and supplement neighbouring populations. Thus habitat destruction and fragmentation have been the main anthropogenic impacts on the region.

Further consequences for avian populations include lack of genetic diversity and small numbers incapable of increase (Ford et al. 2001). Processes such as genetic drift, inbreeding, or too large a genetic variation between remaining populations are among the possible reasons that reduce the likelihood of survival for small populations (Burgman & Lindenmayer 1998). However, in situations where a species with extended range is linked by several populations that are able to exchange genetic information, minimizing the genetic variation at either end of the range, genetic fitness of the species is maintained instead of weakened (Burgman & Lindenmayer 1998).

The degree to which habitat is lost has a greater impact on the likelihood of extinction than fragmented areas. The risk of individual species extinction is greatest when habitat loss is greater than 80%. Over this proportion, fragmentation begins to be significant due to the factors of patch size and isolation (Ford et al. 2001). Further, rates of extinction may not be stable, for example: even though clearing may have ceased in remnant Victorian forest, the number and abundance of avian forest species have shown to be negatively related to time (years) since isolation (Ford et al. 2001). Hahs et al. (2009) explains that type III cities (recently established cities) have an extinction debt and the full impact of extinction is yet to be observed as compared to type I and II cities that have been transformed prior to 1600 AD and between 1660 to 1800 AD, respectively (Hahs et al. 2009).

The demise of linked populations may be affecting the genetic fitness of populations of species such as those listed in Tables 3.4, 3.6 and 3.7, who are either habitat specialists with reduced range on the SCP, wide ranging species with reduced populations on the SCP or showing strong signs of decline between 1998 and 2012. This leads to the conclusion that management of populations may be a more important unit of conservation than species or genomes (Burgman & Lindenmayer 1998).
Anthropogenic impact to the environment has further reduced precipitation and altered rainfall patterns via atmospheric pollutants (Junkermann et al. 2009) and clearance of habitat (Nair et al. 2011). This climate change has important conservation implications, because lower rainfall is predicted, which in turn reduces the productivity and of vegetation and changes its species composition (Chambers 2010). Climate-related changes may be particularly pronounced in heavily fragmented areas. The ability of Australian species to cope with climate change would be difficult given the natural geographic and physical limitations, not to mention anthropogenic changes to the landscape such as habitat loss, habitat fragmentation, isolation of remnants and pollutants (Hughes 2011).

3.7.2 Current status of the biodiversity

Throughout the study site, 28% of natural bushland remains fragmented in isolated sites of varying sizes (Department of Planning and Infrastructure WA 2000). Included in this 28% are Bush Forever conservation areas and Local Significant Natural Areas. Of the Bush Forever sites, 128 sites are over 50 ha, however, over 100 sites are less than 20 ha (Table 3.2). The individual Bush Forever sites in this study are owned by a variety of groups ranging from various government organisations at local, state and federal level and commercial and private land holders. Further to the complicated ownership of these sites, they are all managed by a variety of agencies, but over 10% have no management agency at all and, for over 20% of the sites, only parts of the site have a management agency (Del Marco et al. 2004). For example, the Underwood Bush Forever site (Berry & Berry 2008) (Table 3.6) is privately owned and has no management agency. The future for this site is a 300 lot housing and commercial development (http://www.bushlandperth.org.au/bush-forever-overview/19-bush-forever-report-card/192-report-card). Furthermore, only 18% of the remaining native vegetation is protected by Dept. Parks and Wildlife (http://www.dpaw.wa.gov.au), Bush Forever sites and as regional parks. Of the unprotected native vegetation, 77% is on private land, with 12% of this zoned for intensive
development *i.e.* urban, urban deferred, industrial, special industrial and central city area (Del Marco *et al.* 2004).

Throughout the study sites on the PMR (Table 3.6), approximately 9 species of passerines were regularly recorded. These species tended to be large bodied, indigenous species that have colonised the man-made environment and naturally tend to occur in open woodland type habitats. However, because these birds have prospered in current urban areas, further clearing and reduction in the size of housing blocks may see a decline in some of these species. For example, the Red Wattlebird that was once common in suburban gardens is now in decline (Recher 1999). These species require continuous food resources throughout their range and extensive habitats once used have now become fragmented, causing greater distances between foraging sites (Recher 1999).

Comparison of local studies has revealed that several passerines that were listed as ‘habitat specialists with reduced ranges on the SCP’ are no longer found in the metropolitan region and that their status is in need of review (Table 3.7). Further, assessment of the Bush Forever sites, their quality, and proximity to each other, are also in need of review if conservation of these populations is deemed to be important.

In 2010, the Urban Bushland Council (2012) initiated a conference to determine the success of the Bush Forever project and to determine if the targets proposed in 2000 had been achieved. They reported that four out of six policy objectives have been partially achieved (Urban Bushland Council 2014). These objectives cover protecting and managing regionally significant bushland to the needs and expectations of the Western Australian community; establishing a conservation system that is Comprehensive, Adequate and Representative (CAR) of the ecological communities in the PMR; protecting Bush Forever sites through involvement of all land owners and the community; promoting partnerships between land owners, government and community to conserve regionally significant sites by the use of assistance, incentives and advice (Gray & Cooper 2013).

The Western Australian State Government set aside $100 million to purchase regionally significant land for protection, and 96 ha was purchased. Privately owned land
can be protected; but it is the owner’s decision to participate in a Voluntary Nature Conservation Covenant. This is an ‘opt in’ agreement, but once in, the land is protected from there on. This covenant is also placed on land that is to be subdivided. Incentives for private land holders include tax concessions, grants and adjustments to land rates. As of 2006, 16 private land owners had voluntarily entered into this covenant (Gray & Cooper 2013).

3.7.3 What should be done?

To maintain and reduce further loss of biodiversity in the Perth Metropolitan Region improvement in management practices, increases in financial funding and providing legal protection for conservation areas are required to reduce the impacts of environmental pressures such as weed invasions, bush fires, development and pollution that face metropolitan Bush Forever sites and other conservation areas (http://www.bushlandperth.org.au/bush-forever-overview/19-bush-forever-report-card/192-report-card).

For example, the Anstey Keane Bushland, which is in pristine/excellent condition, has 381 plant species, a new species of bee, significant dampland, rare species and two threatened ecological communities and has no legal protection even though it is a Bush Forever site. This site has seven owners and managers including private land owners. One of them – Landcorp – a semi government land agency and developer, wants a road built through the most pristine portion of the site. There are no fences to prevent access by off road vehicles which create tracks leading to an increase in weed invasion and rubbish dumping http://www.bushlandperth.org.au/bush-forever-overview/20-bush-forever-case-studies/217-save-anstey-keane).

3.7.3.1 Government responsibilities

The Western Australian Government has yet to give protection to such areas. Policies include objectives to protect Bush Forever sites (Gray & Cooper 2013) and introduction of the 2002 Draft Biodiversity Conservation Bill to State Parliament that
replaces the 1950 Wildlife Conservation Act (Gray & Cooper 2013). This Act will increase the State Government’s power to conserve biodiversity and will bring Western Australia into line Federally and list all rare or threatened species and ecological communities, including all threatening processes to enable threat abatement plans to be developed (http://www.bushlandperth.org.au/bush-forever-overview/19-bush-forever-report-card/192-report-card). However, it is a highly debatable argument regarding what should be conserved. If only rare and endangered species are the focus of conservation, the species that are currently common may become rarer (Keighery 2013). A policy objective in the Bush Forever Project made a target to conserve 10% of the existing ecological communities; however this amount may not be enough to prevent the further loss of species. To be ecologically feasible, the portion of each community to be protected has been revised to 30%, but government needs to acknowledge this difference and amend legislation (Del Marco et al. 2004).

The following motion was passed unanimously at the 2012 Bush Forever Report Card conference and encapsulates what needs to be done:

“Given the rapid growth of Perth and encroachment of development around Bush Forever Sites, with the resulting degradation from illegal activities and neglect, it is recommended that substantial resources be allocated to complete the implementation of Bush Forever including acquisitions and management of sites, as an integral part of the provision of state infrastructure for Perth” (Keighery 2013).

3.8 Conclusion

Many species, both mammalian and avian, have become locally extinct since European settlement in the Perth Metropolitan Region. The changes associated with this settlement included introduction of feral animals such as cats, dogs, foxes and rabbits and clearing of vegetation for housing and agriculture on land that is comparatively infertile and requires additional nutrients for agriculture. Not only has vegetation been removed, leaving few isolated remnants throughout suburbia, but erosion and salinity problems have also
occurred. All these factors separately, or in combination have altered the habitat qualities that existed prior to European settlement.

The situation is not unique to the PMR, but symptomatic of avifauna declines in response to habitat fragmentation elsewhere in Australia (Ford et al. 2000, Ikin et al. 2014, Smallbone et al. 2014). Ford (2011) argued that habitat fragmentation and degradation had already created a substantial extinction debt that he feared still needed to be paid. Part of this would come from the loss of species that were poor dispersers, who would ultimately become locally extinct following the extinction of isolated populations. Many of the small insectivores are examples of these species. However, Ford (2011) was also concerned about nomadic species such as many of the honeyeaters, which have no trouble in traversing large distances, but are also in decline. He argued that attention to the matrix between habitat types may be essential for conserving these species (Ford 2011).

To be certain of the cause(s) of decline of individual species, experimental studies are required, whereby a controlled (unmanipulated) environment is compared with an environment where the independent variable(s), such as cat density, is manipulated and the effects measured, preferably in a longitudinal study utilising multiple sites for comparison. Obviously, studies such as these are often prohibitively expensive in time and cost and sometimes are just not logistically feasible. However, when there is contention over impacts that an activity causes, such as the impacts of suburban cats upon suburban passerines, manipulative experiments give the strongest inferences.

The following chapter explores the factors that affect bird species richness and community composition for fifteen passerines that were recorded in 20 to 80% of observations over 57 sites throughout the Perth metropolitan region (Table 3.6), using a wide range of habitat characteristics, including cat density.
4. Species richness and community composition of passerine birds in suburban Perth: Is predation by pet cats the most important factor?

This chapter was published as a book chapter. To maintain consistency with the rest of the thesis, the abstract, acknowledgements and keywords have been removed and the references included in an amalgamated reference list at the end of the thesis. Otherwise, the text is identical to that of the publication. Appendix A deals with critiques of some points in this chapter.

4.1 Introduction

In the hyperpredation hypothesis, predation by an introduced predator sustained by a large population of an introduced prey species adapted to high predation pressure threatens populations of native animals (Courchamp et al. 1999). Woods et al. (2003) suggested that predation by pet cats *Felis catus* (Mammalia: Felidae) in suburbia was analogous to hyperpredation, because domestication maintains cats at much higher populations than would otherwise be supported, leading to very high predation pressures on wildlife. Many Australian and international studies confirm that pet cats kill large numbers of wildlife (Churcher & Lawton 1987, Paton 1991, Barratt 1998, Gillies & Clout 2003, Lepczyk et al. 2003, Woods et al. 2003, Lepczyk et al. 2004). However, other authors query the methodologies used to estimate predation rates, suggest that cats might simply take a ‘doomed surplus’ of prey or point out that few studies demonstrate a decline in prey populations unequivocally linked to predation by pet cats (e.g. Patronek 1998, Chaseling 2001). These views have substantial practical implications. If predation by pet cats is a problem, it should be a focus in conservation management, whereas if the issue is overstated it may deflect attention from habitat destruction, road mortality, pollution or other critical factors (e.g. Fitzgerald 1990, Nattrass 1992, Chaseling 2001), see also evaluations of community attitudes in Grayson et al. (2002) and Lilith et al. (2006).

Conserving passerine birds in Australian suburbia illustrates the difficulty of resolving the respective impacts of habitat destruction and cat predation. Worldwide,
Chapter IV

habitat destruction associated with urbanization is proceeding rapidly (Marzluff et al. 2001) and Australian cities are also increasing in size and area (Van der Ree 2004). The Australian pet cat population in 2002 is also substantial with approximately 2.5 million pet cats spread across 23% of households (Pet Care Advisory Pet Care Advisory Service 2014) and it is undeniable that many (but not all) of these cats hunt and kill wildlife in suburbia, including birds (see review by Grayson & Calver 2004). However, testing the impact of pet cats on prey populations via controlled experiments, in which prey populations are monitored following predator removal/exclusion (e.g. Risbey et al. 2000), is logistically and ethically difficult in suburbia. Alternative approaches include regressing prey numbers against predator numbers or relating local extinctions of prey to presence of predators (following the model of the island studies of Burbidge & Manly 2002). There is an extensive precedent for using such approaches to determine the influence of habitat variables on bird species richness or abundance in suburbia (e.g. Sewell & Catterall 1998, Fernandez-Juricic 2000, Melles et al. 2003, Thorington & Bowman 2003, Crooks et al. 2004).

This study investigated if pet cat density is a significant predictor of passerine species richness (the number of species occurring), passerine community composition (the relative abundances of different bird species) and the presence/absence of common passerine species in suburban Perth, Western Australia, or if other factors such as dog density, housing density, garden composition and proximity and size of remnant habitat (bushland) were stronger predictors.

4.2 Materials and methods

4.2.1 Study area

In 2007, Perth, the capital of Western Australia, had a population of c. 1.4 million people. Perth was founded in 1829 and covers an area of c. 35 km east-west and 70 km north-south along the Swan Coastal Plain in the lower south-west corner of the Australian continent (Thackway & Cresswell 1995). This study was restricted to 25 km south and 15
km north of the Perth Central Business District (31.955° south and 115.8° east) and 30 km inland from the Indian Ocean. Agricultural clearing and urbanization have removed c. 78% of the vegetation from the Swan Coastal Plain and two species of vascular plant, 15 bird species and nine mammal species are believed extinct in the bioregion (Armstrong & Abbot 1995). Significant areas of remnant bushland remain within the Perth city environs (How & Dell 2000) and a long-term study in one of these demonstrated considerable changes in the species composition of bird communities over time, although overall bird abundance remained high (Recher 2004).

### 4.2.2 Collection of bird data

Members of Birds Australia, formerly the Royal Australasian Ornithologists’ Union, collected the bird data used in this study. Since August 1st, 1996, members contributed to a Suburban Bird Survey. Observers chose a particular day of the week as an observation day and recorded all birds seen in and around their gardens (within 100 m) on that day (Nealon 1996).

The records of 57 Birds Australia members who contributed bird records for 25 or more weeks from 1st August 1998 to 31st July 1999 were included in this study because this could account for seasonal trends. Each member’s contribution constituted one site. These 57 sites were spread over the Perth metropolitan area ranging from Cottesloe in the west to Parkerville in the east (a distance of c. 30 km) and from Wanneroo in the north to Warnbro in the south (a distance of c. 65 km). We restricted our analysis to passerines, which excluded a range of itinerant sea birds and parrots, as well as exotic doves.

### 4.2.3 Environmental variables

For all 57 study sites, data were collected on eight environmental variables suggested by Thomas et al. (1977), Green (1984) and Munynyembe et al. (1989) as potential influences on bird distributions in suburbia:

- Dog density;
- Cat density;
• Housing density;
• Age of suburb;
• Distance to nearest bushland less than five hectares;
• Size of nearest bushland less than five hectares;
• Distance to nearest bushland greater than five hectares and
• Size of nearest bushland greater than five hectares.

**Cat and dog density**

The pet cat and pet dog densities for each site including and surrounding the residential block where an observer resided were determined by a mailed survey to 27 households (four either side of, and including the observer’s block, the nine directly opposite and the nine behind). Surveys were accompanied by a covering letter, a self-addressed envelope and a tea bag (to be enjoyed while completing the survey). Residents were asked to include only their pet cats or dogs that spent the majority of time outside the house during the period of the bird survey. A reminder survey was sent within two weeks if no reply was received.

Geographical Information Systems (GIS) were used to create a map of the area for each site, which included the block size of each dwelling (in square meters) issued with a survey. Cat and dog density calculations were based upon the number of cats or dogs as reported by those who responded to the survey and the sum of the area of respondents’ house blocks.

**Housing density**

Housing density was calculated dividing the number of dwellings by the sum of the block sizes of the residents asked to participate in the survey.

**Suburb Age**

Information to determine the age of each suburb included in this study came from a variety of sources, such as Yarrow (1980) and personal communication with officers of the
Department of Land Administration and the Department of Local Government and Regional Development. The age of the suburb in years was taken to be the number of years elapsed from the date of the initial sub-division to 1998.

*Distance to nearest bushland and size of nearest bushland*

The Department for Planning and Infrastructure provided a map for each site which showed the distance to nearest bushland as well as the Size of the Bushland. Two sources were used to identify bushland. Firstly, we included bushland designated as such in the maps of Bushplan Native Vegetation and secondly, we included bushland designated in Bush Forever sites (Department of Planning and Infrastructure WA 2000). The maps and data (such as distances to nearest bushland) were viewed and generated using the software GRAPE (Department of Planning and Infrastructure WA 2002).

*Garden vegetation variables*

In 1999, 17 observers from the full 57 consented to have their gardens surveyed for vegetation structure and composition. These 17 gardens are referred to as the ‘primary gardens’. Neighbours either side, and those opposite the primary gardens, were also invited to participate in this study. In total, 77 gardens were surveyed over 17 sites. If an area of bushland or parkland was present rather than a homesite at a location that would normally be surveyed, then an area 20 m x 60 m from the kerb was surveyed. Each primary garden and those gardens immediately surrounding the primary garden will be referred to as a ‘site’.

Each garden was measured initially for the area covered by bare ground, paving, lawn and other vegetation. Vegetation was further categorised depending on whether it was: bird pollinated; flowering; deciduous, or could bear fruit that birds eat. These groupings were then recorded in the appropriate height category (< 1 m, 1 ≥ 3 m, 3 ≥ 5 m and > 5 m), giving 20 categories in all. Finally, each category was recorded as a function of area (m$^2$) covered.
Vegetation species richness, defined as the number of different species found in all gardens at the site divided by garden area (m$^2$), was also collected for each garden surveyed. The other vegetation variables were not standardised for area because it is their relative proportions, rather than absolute area, that were considered most important.

### 4.2.4 Data analysis

In all analyses reported below, data were screened for fundamental assumptions of the statistical test used before analysis and any transformations applied are indicated. The significance level adopted for all tests was 0.05. In cases where multiple tests of dependent data were used, the modified Bonferroni correction (Quinn & Keough 2002) was used to ensure an experiment-wide error rate of 0.05.

**Tests for redundancy in the environmental variables**

A correlation matrix was established for the eight environmental variables across all 57 sites. R$^2$ for all but one of the comparisons involving environmental variables ranged from 0.00 to 0.20, indicating only weak relationships between each pair of variables. The last correlation, between distance to nearest bushland less than 5km and distance to nearest bushland greater than 5km, was somewhat higher (R$^2 = 0.72$). It was decided to keep both variables because the correlation between them still left 28% of the variability unexplained.

**Predicting bird species richness across 57 sites**

Sites with more weekly records submitted are likely to record greater bird species richness because of the increased chance of observing rarer species. Therefore, the data across all sites were standardised for the number of weekly records using rarefaction, in which a common sample size (in this case, the number of individual birds seen) equal to or less than the smallest data set available was chosen for all sites and the species richness of each site corrected to what would be expected in the common sample size (Krebs 1999 p. 330). The minimum number of birds recorded for 25 weekly records was 132, so when
calculating the rarefaction using Ecometh 6.1 (Kenny & Krebs 2002), all sites were set to a sample size of $n = 130$.

Setwise regression\(^1\) was used to relate the eight environmental variables (housing density, dog density, housing density, age of suburb, distance to nearest bushland $< 5$ ha, distance to nearest bushland $> 5$ ha, size of bushland $< 5$ ha, size of bushland $> 5$ ha) to bird species richness. Setwise regression is an alternative to multiple regression in exploratory studies such as this where the ratio of cases observed to independent variables studied is low (Tabachnick & Fiddel 1996). Setwise regression regresses the dependent variable against all possible permutations of the independent variables and the regression giving the best fit is accepted as the most appropriate model. Cross-validation of the sample is important to ensure that the data are not over fitting, which was achieved by randomly dividing the whole data set into two equal subsets, each of which was analysed separately. Ideally, each analysis should yield the same best set of predictors that also agree with those determined from the full data set (Tabachnick & Fiddel 1996).

Analysis was carried out using Minitab 14 ‘Best Subset Regression’ (Minitab 14.1 2003). Prior to analysis, dog density, housing density, distance to nearest bushland $< 5$ ha, distance to nearest bushland $> 5$ ha and size of bushland $> 5$ ha were log transformed to improve their fit to the normal distribution. For purposes of comparison, the results of simple linear regression for each predictor variable independently were also determined, with the p-values in significance testing adjusted using the modified Bonferroni correction (Quinn & Keough 2002). Given that the predictor variable of housing density was of particular interest in this study, the power of a simple regression to detect a range of $R$-values

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\(^1\) Setwise regression, the choice when this chapter was published, is now largely supplanted by assessment of competing models using the Akaike Information Criterion (AIC). Rather than amend the analysis in a published chapter, I present an AIC analysis of the core hypotheses in Appendix A to this thesis.
values at the sample size of 57 was determined using the Power Analysis module of the Statistica package (Statsoft 1999).

**Predicting bird community composition across 57 sites**

A matrix of similarities in bird community composition among sites was estimated from square-root transformed bird count data using the Bray-Curtis coefficient (Bray & Curtis 1957). This similarity matrix was then correlated with similarity matrices based on Euclidean distance estimates between sites for each environmental variable and for all environmental variables combined. Preliminary analysis found that standardisation of environmental variables had no effect on the similarity matrices, so the results reported here are for unstandardised variables. Matrix correlations used the permutation procedure RELATE in PRIMER 5.0 (Clarke & Gorley 2001).

**Prediction of functional groups and individual bird species across 57 sites**

Those environmental variables which significantly affected species diversity or species composition (distance to nearest bushland < 5 ha, distance to nearest bushland > 5 ha, size of nearest bushland > 5 ha and housing density) were regressed against combined species counts for five different functional groups of birds, and against the presence/absence of particular bird species. Functional groups were formed based on bird size and feeding behaviour: small insectivores (wingspan < 60 mm, diet predominantly arthropods); medium insectivores (wingspan 60 – 150 mm, diet predominantly arthropods); large predators/omnivores (wingspan > 150 mm, diet predominantly arthropods and small vertebrates); nectarivores (various sizes, diet includes a substantial proportion of nectar and varying proportions of arthropod material); frugivores/granivores (various sizes, diet includes a substantial proportion of fruit or grain and varying proportions of arthropod material). Sizes were estimated from Schodde & Mason (1999) and diet was confirmed by reference to Barker & Vestjens (1990). There is inevitably some overlap between these groups, necessitating arbitrary decisions about placement for a number of species. The significance of individual environmental variables in forward stepwise multiple regressions
against each functional group were determined using a modified Bonferroni correction (Quinn & Keough 2002). Stepwise multiple regression rather than setwise regression was possible in this case because of the smaller number of predictor variables.

Bird species that occurred in at least 20% of sites, but no more than 80% of sites were selected for specific analysis to determine if their presence/absence could be predicted in a logistic regression using the eight environmental variables. It was unlikely that strong predictions could be determined for birds occurring in very few (< 20%) or nearly all (> 80%) sites. Although the Willie Wagtail occurred in 81% of gardens, it was included in the analysis group because of its status as a suburban icon. Once a logistic regression is fitted, Wald’s $\chi^2$ is commonly used for testing the significance of individual independent variables. However, it may be conservative when the absolute value of the regression coefficient is large and standard errors may be over-estimated, increasing the possibility of Type II errors (Tabachnick & Fidell 1996). Therefore, the significance of individual variables was tested in fitted logistic regressions by removing them and noting the change in $\chi^2$.

**Influence of vegetation characteristics at 17 sites**

The problem in analysing these sites was the large number of predictor variables (20 vegetation variables plus the eight other environmental variables) in relation to the 17 study sites available. Accordingly, factor analysis, followed by varimax rotation, was used to reduce the vegetation variables to five factors, which explained 87.5% of the variance:

Factor one – fruiting vegetation occurring in all of the four height categories (Fruiting)

Factor two – vegetation that was greater than five metres, bird pollinated, flowering and deciduous (Tall bird-pollinated deciduous)

Factor three – deciduous vegetation greater than two metres in height, grassed and paved areas (Medium deciduous and open areas)
Factor four – flowering plants across the two middle height groups, 1-3m and 3-5m and bare areas (Medium bird-pollinated and open areas)

Factor five – plants that are < 1 m, bird pollinated and flowering (Low bird-pollinated)

No correlation matrix was produced to check for redundancy in the vegetation factors, because factor analysis had already reduced the number of variables.

The five vegetation factors were then analysed, both as a separate group and together with the eight environmental variables, using setwise regression and similarity matrices in PRIMER 5.0 in the same manner as the environmental variables were analysed for the full 57 sites. Simple linear regressions were also run for each vegetation factor. Finally, logistic regression was used in an attempt to predict the presence/absence of specific bird species on the basis of the five garden vegetation factors.

4.3 Results

Forty-nine passerine species were observed during the census period at one or more of the 57 sites. Twenty-seven species (55%) occurred in fewer than 20% of sites, 14 species (29%) occurred at between 20% and 80% of sites and eight species (16%) occurred at more than 80% of sites (Table 4.1). To determine cat and dog densities surrounding the 57 study sites, over 1500 surveys were given to residences surrounding the member of Birds Australia residence. The response rate was 63.63% (SE ± 2.26) with cat and dog ownership in 19% and 28% of households respectively. Housing density ranged between 0.02 to 192.31 dwellings per hectare, but the average housing density in this study was 15.78 (SE ± 3.52) and the average age of the suburbs was 55.54 (SE ± 3.10) years old. Most study sites were 0.82 km (SE ± 0.1) away from small areas of bushland (< 5 km), which had an average size of 1.97 ha (SE ± 0.16). Larger areas of bushland (> 5 km) were on average, 1.71 km (SE ± 0.83) away from the study sites and a size of 102.17 ha (SE ± 69.23) (see Table 4.2).
Table 4.1  Birds observed during the census period, the proportion of sites where they were seen and the functional group in which they were placed. Birds occurring in 20-80% of sites were used in analysis as ‘selected species’. The Willie Wagtail was also included in this group because of its status as an iconic suburban species. Functional groups are indicated by superscripts: 1small insectivore; 2medium insectivore; 3large predator/omnivore; 4nectarivore; 5frugivore/granivore.

<table>
<thead>
<tr>
<th>0-19% (% occurrence)</th>
<th>20-80% (% occurrence)</th>
<th>&gt;80% (% occurrence)</th>
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<tbody>
<tr>
<td>Black-faced Woodswallow(^2) Artamus cinereus (3.45)</td>
<td>Grey Butcherbird(^3) Cracticus torquatus (65.52)</td>
<td>Australian Magpie(^3) Gymnorhina tibicen (100)</td>
</tr>
<tr>
<td>Clamorous Reed-warbler(^1) Acrocephalus stentorius (1.72)</td>
<td>Grey Fantail(^1) Rhipidura fuliginosa (39.66)</td>
<td>Australian Raven(^4) Corvus coronoides (100)</td>
</tr>
<tr>
<td>Golden Whistler(^2) Pachycephala pectoralis (3.45)</td>
<td>Little Wattlebird(^4) Anthochaera chrysoptera (53.45)</td>
<td>Black-faced Cuckoo-shrike(^2) Coracina novaehollandiae (84.48)</td>
</tr>
<tr>
<td>Grey Currawong(^5) Strepera versicolor (3.45)</td>
<td>Mistletoebird(^5) Dicaeum hirundinaceum (32.76)</td>
<td>Brown Honeyeater(^5) Lichmera indistincta (91.38)</td>
</tr>
<tr>
<td>Grey Shrike-thrush(^2) Colluricinclla harmonica (12.07)</td>
<td>New Holland Honeyeater(^4) Phylidonyris novaehollandiae (67.24)</td>
<td>Magpie-lark(^5) Grallina cyanoleuca (84.48)</td>
</tr>
<tr>
<td>Inland Thornbill(^1) Acanthiza apicalis (10.34)</td>
<td>Rufous Whistler(^2) Pachycephala rufiventris (34.48)</td>
<td>Red Wattlebird(^3) Anthochaera carunculata (94.83)</td>
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<td>Little Grassbird(^1) Megalurus gramineus (1.72)</td>
<td>Silvereye(^5) Zosterops lateralis (79.31)</td>
<td>Singing Honeyeater(^4) Lichenostomus virescens (94.83)</td>
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<td>Willie Wagtail(^2) Rhipidura leucophrys (81.03)</td>
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<td>Honeyeater⁴</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phylidonyris</td>
<td></td>
<td></td>
</tr>
<tr>
<td>melanops (6.90)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Varied Sittella⁴</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daphoenositta chrysoptera</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(5.17)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weebill⁴ Smicronis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>breviostris (12.07)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western Thornbill⁴</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acanthiza inorata (3.45)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White–browed Babbler⁴</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pomatostomus superciliosus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1.72)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White-browed Scrubwren⁴</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sericornis frontalis (3.45)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White-fronted Chat⁴</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epthianura albifrons (1.72)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White-naped Honeoyer⁴</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Melithreptus lunatus (13.79)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White-winged Triller⁴</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lalage suereurii (1.72)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellow-plumed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Honeoyer⁴ Lichenostomus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ornatus (1.72)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zebra Finch⁴</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taenopygia guttata (3.45)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 4.2** Means, standard errors (in parentheses) and ranges for eight independent variables in the study.

<table>
<thead>
<tr>
<th>Response rate (% of number of dwellings surveyed)</th>
<th>Cat density</th>
<th>Dog density</th>
<th>Housing density</th>
<th>Distance (km) (and size [ha] to nearest bushland** &lt; 5 ha)</th>
<th>Age at 1998</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>63.63(2.26)</td>
<td>3.30(0.35)</td>
<td>4.01(0.42)</td>
<td>*0.82(0.1) **1.97(0.16) **1.71(0.83) **102.17(69.23) **55.54 (3.10)</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>27-100</td>
<td>0-10.8</td>
<td>0-14.8</td>
<td>*0-4.07 **0.5-4.99 **0-48 **5.0-3941</td>
<td></td>
</tr>
</tbody>
</table>

① number of cats/total block size of respondents in hectares (cats/ha)
② number of dogs/total block size of respondents in hectares (dogs/ha)
③ number of dwellings/sum of block sizes in hectares (dwellings/ha)
4.3.1 Predictors of bird species richness

Cat density was not significant in predicting bird species richness in a simple linear regression ($p = 0.319$), nor was it included in the best fitting setwise regression. The best setwise regression included the variables: Distance to nearest bushland > 5 ha, housing density and size of nearest bushland > 5 ha as components of the regression model, although size of nearest bushland > 5 ha was not significant in the simple linear regression ($p = 0.210$) (see Table 4.3). Bird species richness declined with increasing distance to bushland > 5 ha and < 5 ha and increasing housing density, while the size of nearest bushland > 5 ha was associated with an increase in bird species richness (Figure 4.1). Together, these predictors explain almost half of the variability in bird species richness (adjusted $R^2$ for the complete data set = 0.414).

There was 80% power for a simple regression to detect even a modest $R$ of 0.38 given the sample size of 57 and this increased rapidly with larger $R$ values. Therefore the simple linear regressions were highly likely to detect even weak relationships between bird species richness and an individual predictor variable.

Table 4.3 Results of setwise regression and simple linear regression for predicting bird species richness from the eight core predictor variables. The setwise columns show all independent variables included in the best fitting multiple regression and the results of separate $t$-tests for the significance of each variable.

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Simple linear regression</th>
<th>Setwise regression ** (total data set)</th>
<th>Setwise regression</th>
<th>Split one, Split two</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat density</td>
<td>$F_{(1,55)}=1.01$</td>
<td>$F_{(1,55)}=0.018$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dog density</td>
<td>$F_{(1,55)}=0.733$</td>
<td>$F_{(1,55)}=0.018$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance to nearest bushland &lt; 5 ha</td>
<td>$F_{(1,55)}=6.05$</td>
<td>$F_{(1,55)}=0.017$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size of nearest bushland &lt; 5 ha</td>
<td>$F_{(1,55)}=0.20$</td>
<td>$F_{(1,55)}=0.018$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance to nearest bushland &gt; 5 ha</td>
<td>$F_{(1,55)}=10.48$</td>
<td>$t = -3.45$, $p = 0.001$</td>
<td>$t = -1.73$, $p = 0.098$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$p = 0.002\ast$, $R = 0.16$</td>
<td>$t = -3.68$, $p = 0.001$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Independent variable

<table>
<thead>
<tr>
<th></th>
<th>Simple linear regression</th>
<th>Setwise regression ** (total data set)</th>
<th>Setwise regression Split one, Split two</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of nearest bushland &gt; 5 ha</td>
<td>$F_{(1,55)} = 2.92$, $p = 0.093$, $R = 5$</td>
<td>$T = -1.27$, $p = 0.210$</td>
<td></td>
</tr>
<tr>
<td>Housing density</td>
<td>$F_{(1,55)} = 25.83$, $p = 0.0001^*$, $R = 0.32$</td>
<td>$t = -5.11$, $p = 0.000$</td>
<td>$t = -2.98$, $p = 0.007$</td>
</tr>
<tr>
<td>Age of suburb</td>
<td>$F_{(1,55)} = 4.83$, $p = 0.032$, $R = 0.081$</td>
<td></td>
<td>$t = -5.07$, $p = 0.000$</td>
</tr>
</tbody>
</table>

*Only p values marked with (*) are significant after modified Bonferroni.

**Only variables included in the best subset are displayed. Test statistics for best subset:

$R^2$ (adj) = 0.41, Mallows C$\overline{p}$ = -0.3, S = 3.68, ANOVA: $F_{3,53} = 14.17$, $p < 0.00$

---

**Figure 4.1** Relationship between bird species richness ($y$) and four significant predictor variables ($x$) over 57 sites (a) Log housing density, b) Log (ha) Size of nearest bushland > 5 ha, c) Log distance (km) to nearest bushland < 5 ha and d) Log distance (km) to nearest bushland > 5 ha.
4.3.2 Predictors of bird community composition

There was no significant relationship between the similarity of sites based on their bird community composition and the similarity of sites based on all the environmental variables combined (Rho = 0.076, p = 0.12). However, when sites were grouped by each individual environmental variable, the similarity in bird community composition was significantly related to the similarity in distance to nearest bushland < 5 ha, distance to nearest bushland > 5 ha, size of nearest bushland > 5 ha and housing density after modified Bonferroni correction (Table 4.4).

Table 4.4 Results of Primer analysis to assess bird community composition.

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Assessment of individual predictors</th>
<th>Assessment of all predictors combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat density</td>
<td>Rho = 0.103, p = 0.05</td>
<td>Rho = 0.076, p = 0.12</td>
</tr>
<tr>
<td>Dog density</td>
<td>Rho = 0.032, p = 0.257</td>
<td></td>
</tr>
<tr>
<td>Distance to nearest bushland &lt;5ha</td>
<td>Rho = 0.178, p = 0.004*</td>
<td></td>
</tr>
<tr>
<td>Size of nearest bushland &lt;5ha</td>
<td>Rho = 0.068, p = 0.86</td>
<td></td>
</tr>
<tr>
<td>Distance to nearest bushland &gt;5ha</td>
<td>Rho = 0.266, p = 0.001*</td>
<td></td>
</tr>
<tr>
<td>Size of nearest bushland &gt;5ha</td>
<td>Rho = 0.273, p = 0.001*</td>
<td></td>
</tr>
<tr>
<td>Housing density</td>
<td>Rho = 0.337, p = 0.001*</td>
<td></td>
</tr>
<tr>
<td>Age of suburb</td>
<td>Rho = 0.057, p = 0.172</td>
<td></td>
</tr>
</tbody>
</table>

Only p values marked with (*) are significant after modified Bonferroni.

4.3.3 Analysis of functional groups

Stepwise multiple regression analyses of bird counts for different functional groups against distance to nearest bushland < 5 ha, distance to nearest bushland > 5 ha, size of nearest bushland > 5 ha and housing density were strongest for small insectivores ($R^2 = 0.42$) and medium insectivores ($R^2 = 0.21$), with significant relationships (after a Bonferroni correction) only for housing density (for small insectivores $F_{(1,55)} = 27.91$, $p < 0.0001$; and medium insectivores $F_{(1,55)} = 10.35$, $p < 0.001$). The same significant
relationships were found when the data file was randomly split into two groups and each group was analysed separately.

4.3.4 Predictors of the presence/absence of 15 selected bird species

Logistic regression was used to test if the presence or absence of the selected passerine species over the 57 sites was related to the environmental variables. Each bird species was regressed against the eight environmental variables with modified Bonferroni corrections used to ensure an overall significance level of 0.05. Regressions approached significance for the Grey Fantail, Mistletoe Bird and Western Spinebill, with size of nearest bushland < 5 ha emerging as a possible predictor. Cat density was almost a significant predictor for the occurrence of the Western Spinebill (Table 4.5). Splitting the data file to determine the consistency of the predictions found that one of the two splits for the Grey Fantail, Mistletoe Bird and Western Spinebill data file approached significance (Table 4.5). Size of nearest bushland < 5 ha occurred in all these cases, suggesting that of all the predictors investigated, this factor is most likely to be important. Cat density was only significant in one half of the split for the Western Spinebill and was not reproduced in the other, making it a questionable predictor.

4.3.5 Effects of environmental and vegetation variables at 17 sites

When all 13 variables (environmental variables and vegetation factors one to five) were analysed, the best subset, containing eight independent variables (dog density, housing density, and factors one to five), were not significant ($R^2$ (adj) = 0.43, Mallows $C_p = 6.4$, $S = 4.08$, $F_{8,9} = 2.45$, $p = 0.11$). The inability to find a significant subset probably occurred because of the small number of cases ($n = 17$) in the vegetation subset. Although 77 gardens were surveyed for vegetation content, only 17 sites were represented. The power of a simple regression to detect a particular value of $R$ given the sample size of 17 is 80% for an $R$ of 0.62 and this increased rapidly with larger $R$ values. However, power is lower for modest $R$ values, being only 40% for an $R$ of 0.4.
There was also no significant relationship between the similarity of sites based on the 13 independent variables (including the vegetation factors) analysed as a group and the similarity of sites based on bird species composition (Rho = 0.06, p = 0.25).

### 4.3.6 Effect of the five vegetation factors alone

Setwise regression was used to select a best subset using only the five vegetation factors and bird species richness, but no significant best subset was found (result closest to significance was $F_{3,13} = 0.75$, $p = 0.54$). Similarly, logistic regression failed to indicate vegetation factors which predicted significantly the presence/absence of any of the 15 bird species tested after application of the modified Bonferroni correction. The Yellow-rumped Thornbill came closest to significance. Gardens which contained low bird-pollinated plants (Factor 5) may be more likely to contain Yellow-rumped Thornbills, while gardens dominated by fruiting vegetation (Factor 1), tall, bird–pollinated deciduous vegetation (Factor 2) and medium deciduous plants and open areas (Factor 3) may be less likely to contain Yellow-rumped Thornbills ($\chi^2 = 14.73$, $p = 0.02$, n.s. after modified Bonferroni of 0.003).

### Table 4.5 Logistic regression results of 15 selected bird species versus eight core predictors.

<table>
<thead>
<tr>
<th>Selected species</th>
<th>Logistic Regression results*</th>
<th>Significant Predictors**</th>
<th>Logistic regression on split data file for significant relationships* (Split 1, Split 2)</th>
<th>Significant predictors in split**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grey Butcherbird</td>
<td>$\chi^2 = 9.15, p = 0.329$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grey Fantail</td>
<td>$\chi^2 = 16.31, p = 0.038$</td>
<td>Size of nearest bushland $&lt;5$ ha. $\chi^2 = 10.40, p = 0.001$</td>
<td>$\chi^2 = 8.03, p = 0.43$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$\chi^2 = 13.62, p = 0.09$</td>
<td></td>
</tr>
<tr>
<td>Little Wattlebird</td>
<td>$\chi^2 = 6.26, p = 0.62$</td>
<td>Size of nearest bushland $&lt;5$ ha. $\chi^2 = 7.36, p = 0.007$</td>
<td>$\chi^2 = 20.62, p = 0.008$</td>
<td>Size of nearest bushland $&lt;5$ ha. $\chi^2 = 7.00, p = 0.008$</td>
</tr>
<tr>
<td>Mistletoebird</td>
<td>$\chi^2 = 15.59, p = 0.049$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(n.s. using modified Bonferroni)
<table>
<thead>
<tr>
<th>Selected species</th>
<th>Logistic Regression results*</th>
<th>Significant Predictors**</th>
<th>Logistic regression on split data file for significant relationships*</th>
<th>Significant predictors in split**</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Holland Honeyeater</td>
<td>(\chi^2 = 5.77), (p = 0.67)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rufous Whistler</td>
<td>(\chi^2 = 7.59), (p = 0.47)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silvery eye</td>
<td>(\chi^2 = 11.87), (p = 0.16)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Striated Pardalote</td>
<td>(\chi^2 = 5.07), (p = 0.75)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tree Martin</td>
<td>(\chi^2 = 7.69), (p = 0.46)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welcome Swallow</td>
<td>(\chi^2 = 14.37), (p = 0.07)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western Gerygone</td>
<td>(\chi^2 = 8.87), (p = 0.35)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western Spinebill</td>
<td>(\chi^2 = 17.95), (p = 0.022) (n.s. using modified Bonferroni)</td>
<td>Size of nearest bushland (\leq 5) ha: (\chi^2 = 8.84), (p = 0.003) Cat density: (\chi^2 = 6.70), (p = 0.01)</td>
<td>(\chi^2 = 9.88), (p = 0.27) (\chi^2 = 17.97), (p = 0.02)</td>
<td>No variables significant when model viewed ((i.e., no variables significant with Wald’s chi square). Dog density is closest: (\chi^2 = 3.41), (p = 0.065)</td>
</tr>
<tr>
<td>White-cheeked Honeyeater</td>
<td>(\chi^2 = 10.68), (p = 0.22)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Willie Wagtail</td>
<td>(\chi^2 = 11.81), (p = 0.16)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellow-rumped Thornbill</td>
<td>(\chi^2 = 14.71), (p = 0.06)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*(using Wald’s chi-squared), **(chi square and p values obtained using maximum likelihood)
4.4 Discussion

4.4.1 Is cat density related to species richness or community composition?

Cat density was not a predictor of species richness, bird community composition or, with the possible exception of the Western Spinebill, presence/absence of bird species across our study sites. Before considering the implications of these findings, it is important to establish the validity of the study design by rejecting the possibility of bias in the measurements of housing density, species richness, community composition or presence/absence of species, justifying the representativeness of the gardens sampled and confirming that the study had adequate power to detect effects.

Validity of the findings

One indication of bias in estimating cat densities would be if the percentage of households owning cats or the estimated cat densities differed markedly from those reported in other major Australian surveys. In this study, approximately 19% of households surveyed owned cats, compared to c. 23% nationally in a 2002 survey (Pet Care Advisory Service 2014). We estimated housing density across all sites at 3.30 cats per hectare, close to the density of 3.82 cats per hectare reported by Barratt (1998) for suburban Canberra. These comparisons give no reason to believe that the estimates of densities are biased significantly in this study. While it is possible that cat ownership was under-reported or denied (Lepczyk et al. 2003, Lepczyk et al. 2004), this would only be a problem in the unlikely event that the bias was unequal across sites. Otherwise, relativities between sites would be preserved and the effect of relative housing density would still be testable. Furthermore, the range in cat densities found across the sites was from 0.00 – 10.80 cats per hectare, eliminating the possible problem that cat densities were too uniform across sites to detect an effect.

Estimates of passerine species richness, community composition and presence/absence were unlikely to be a problem because members of Birds Australia were responsible for collecting these data. It is fair to assume that members of such a group are
passionate about their hobby and more than capable of recognising and recording birds correctly. It may be initially thought that a birdwatcher’s garden would bias results but this study included the gardens surrounding each birdwatcher’s garden also, totalling 77 gardens from 17 sites. Lastly, housing density did not approach significance as a predictor of bird species richness in a simple linear regression even though this had 80% power to detect even a moderate $R$ of 0.38. Overall, we believe that the estimates of housing density, bird species richness, bird community composition and presence/absence are robust, so the conclusion of no effect of density on bird species richness, bird community composition and presence/absence of individual species is sound.

### 4.4.2 Significance and comparison to other studies

Some other studies have also failed to link cat abundance or density with declines in the abundance of urban or suburban birds. Indeed, in the United States Thomas et al. (1977) found a significant positive relationship between cat density and abundance of House Sparrows *Passer domesticus* and Chipping Sparrow *Spizella passerina*. They concluded that these species are reliant upon the presence of humans and that this relationship overrides any loss of sparrows to cat predation. In Canberra, Australian Capital Territory, Barratt (1995, 1997, 1998) found that Blackbirds *Turdus merula* and House Sparrows were increasing in numbers despite being the favoured prey of cats, while Crimson Rosellas *Platycercus elegans* and Silvereyes were either stable or increasing in numbers despite extensive predation by cats. Barratt (1998) concluded that it was inappropriate to assume that prey populations were endangered because some individuals were killed by cats, although he acknowledged that cat predation might be a more significant influence in native vegetation adjacent to new suburban subdivisions. In contrast, Dickman (2002) found a negative relationship between cat activity (measured by presence of cat faeces) and bird species richness in 24 bushland sites in the Sydney UBD. The bird species most affected by cat activity foraged or nested at or close to the ground. However, in the same
study site, increased densities of cats correlated with reduced nest predation by introduced rats and other predators of nests, so a complex of interacting factors could be involved.

Overall, the most conservative interpretation is that in areas where the original vegetation has been removed and replaced with roads, buildings, open grassed areas and canopy trees with minimal coverage of local native foliage, cats do not appear to impact populations of passerine birds. The passerines occurring in these areas have either persisted through the disturbances of subdivision, or recolonised successfully as gardens and trees have established. They have done so in the presence of cats and are robust against the losses caused by cat predation (Mead 1982, Barratt 1998, Fitzgerald & Turner 2000). However, cat density may be negatively related to populations of birds that forage and nest close to the ground in remnant bushland where there is appropriate habitat (Dickman 2002).

4.4.3 What other environmental factors influence passerine species richness and passerine community composition?

Four environmental variables predicted bird species richness or bird community composition for the 57 sites throughout suburban Perth:

1) Housing density,
2) Distance to nearest bushland < 5 ha,
3) Distance to nearest bushland > 5 ha and
4) Size of nearest bushland > 5 ha.

Housing density and distance to nearest bushland (both less than and greater than 5 hectares) were negatively related to bird species richness, while size of nearest bushland > 5 ha was positively related to bird species richness. The two groups of birds most affected by these environmental variables seemed to be small and medium sized insectivores, such as fantails, thornbills and whistlers.

Placing these results in an international context is challenging, because much of the published work is North American or European, involving very different species assemblages and city layouts to those occurring in Australia in general and Perth in
particular. Even studies within Australia may not be fully comparable because of significant variations in study methodology (see discussion in Catterall 2004). Furthermore, Perth is very unusual in lacking the House Sparrow and the Common Starling *Sturnus vulgaris*, which are important components of many other urban avifaunas. Those cautions should be borne in mind when considering the following discussion.

**Housing density**

A strong negative effect of housing density on bird species richness was also found in a study in Arizona by Germaine *et al.* (1998). The driving force, which is applicable to a wide range of urban areas, appears to be that as housing density increases, remnant bushland areas generally become fragmented and smaller. In describing the central European situation, Bezzel (1985) noted that gardens also decrease in size and do not provide protection or food sources to replace the native habitat, while pesticides reduce biodiversity and pollute the soil and ground water. By contrast, gardens in the UK are viewed as possible refuges for remaining avifauna, particularly for the declining House Sparrow (Nelson *et al.* 2005). Increased housing density is often associated with more roads, possibly sealed parking lots and often increased traffic. When assessing factors relevant to bird conservation in a large bushland remnant in Perth, Recher (2004) observed that roads and open areas act as barriers to many small insectivores, preventing them from moving between islands of remnant bushland. Even if the birds were able to cross roads that fragmented their habitat, mortality from cars would be high because these birds occupy low canopy and fly at the same level as cars. Forman & Deblinger (2000) and Forman *et al.* (2002), who studied bird communities near Boston, USA, claimed traffic noise to be a greater disturbance to avian community changes than visual disturbance, air pollution or predators, perhaps because it interferes with communication between breeding pairs and their broods.

A meta-analysis of 18 studies from France, Finland and Canada raised the issue of people’s attitudes towards wildlife as perhaps the greatest long-term concern (Clergeau *et
al. 2001). This may change as housing density increases, influencing an individual’s receptivity to any measures proposed to increase the wildlife around properties. For example, in French urban areas, 12% of people surveyed reported never observing birds, 45% didn’t intentionally observe birds and 66% only noticed noisy birds. In support of this view, a US survey revealed that 63% of respondents disliked the noise and mess made by birds (Penland 1986). Interestingly, the birds that were observed most frequently were noisy, large birds that were most often associated with wildlife problems.

**Size and proximity of native vegetation remnants**

The association between size and distance to remnant bushland on the one hand and bird species richness and community composition on the other is not surprising in the light of recent Australian studies. Catterall (2004) described the small and medium sized insectivores most affected in our study as ‘neglected foliophiles’ because they are uncommon and inconspicuous in suburbia and the general public are often unaware of them. They are commonly found in undisturbed remnants greater than 10 - 20 hectares in size (Catterall 2004). Populations of sedentary birds such as the Rufous Whistler require territories of one to two hectares per breeding pair (Freudenberger et al. 1997, Watson et al. 2001) and there are limited numbers of large areas of bushland within suburban Perth to meet this need (How & Dell 1994, 2000). The Western Spinebill is able to utilise suburban native plantings, but still requires small amounts of remnant bushland to supplement its food source and for provision of nesting sites. Similarly, the Grey Fantail forages on the insects that are associated with human occupation, but requires some bushland for nesting and extra food sources. The Mistletoe Bird feeds wherever mistletoe parasitises other plants, which could include suburban gardens adjacent to small amounts of bushland, as well as on small exotic berries found in many gardens. Like the Western Spinebill and Grey Fantail, the Mistletoe Bird will still be dependent upon small amounts of bushland to supplement its food and to provide nesting sites.
The spatial distribution of the vegetation is also crucial for the presence and survival of populations of insectivorous birds, both in terms of habitat structure and the provision of resources (Green et al. 1989). For example, the abundance of small insectivores decreases as one moves toward the edge of a continuous habitat (Atkinson 2003). The shape of the remnant bushland is of great importance, particularly when attempting to maximise the usable internal space and minimise any detrimental edge effects. The most efficient way a bird can conserve energy and time is to minimise the perimeter of its territory, using concentric circles radiating from the nest and ending at the furthest range of the bird’s territory (Goldstein et al. 1981, Figure 12.2 in Recher 1996).

Given the importance of proximity to bushland and the vegetation structures it provides, it is surprising that we found no influence of garden vegetation structure and floristics on bird species richness or bird community composition, although the presence of the Yellow-rumped Thornbill may be associated with gardens which contained low bird-pollinated plants. However, these data were limited severely by sample size and it may be premature to discount them, or the possibility that they correlate with other environmental variables such as housing density.

**Other possible environmental factors**

Environmental factors other than those measured in this study may also influence suburban bird species diversity and community composition. For example, Recher (2004) suggested that small insectivorous birds fair poorly in suburban Perth because of changes in garden composition, high populations of raptors sustained by exotic prey and possibly increased nest predation.

Suburban gardens consist mostly of exotic plants or native cultivars that support few herbivorous arthropods and gardeners may actively discourage the few that occur. For example, Catterall et al. (1989) compared the use of Australian native and exotic plants by native birds in a temperate site and found that native birds utilised native plants significantly more than exotic plants. In general, local indigenous plants support a greater
diversity and number of insects and spiders than exotic plants (Bhullar & Majer 2000, Majer et al. 2000).

The diet, foraging behaviour and breeding requirements of the group of birds recorded in 80% of observations in this study reflect the most prevalent types of suburban vegetation. Birds such as Australian Ravens, Australian Magpies, Black-faced Cuckoo-shrikes and Magpie Larks may exploit open grassed areas, while Red Wattlebirds, Brown Honeyeaters and Singing Honeyeaters feed among exotic and native cultivars. Along the east coast of Australia the extremely aggressive Noisy Miner *Manorina melanocephala* occurs in increasingly large numbers throughout mature suburbs with canopy (Catterall 2004). Loyn (1987), Catterall et al. (1991), Catterall et al. (2002), Low (1994) and Woodall (2002) showed that birds such as the Noisy Miner exclude small foliage feeding birds from suburban areas that they would otherwise be able to inhabit. The Red Wattlebird is the most aggressive of the honeyeaters in suburban Perth (Ford 1989, Low 2002) and may exclude smaller insectivorous birds otherwise able to utilise garden vegetation.

Raptors represent a clear case of hyperpredation (Courchamp et al. 1999). They survive well in suburbia because of the constant supply of introduced Laughing Turtle-Doves *Streptopelia senegalensis* and the increased populations of raptors could impact populations of small insectivores, particularly in bushland or park areas (Recher 2004). Australian Ravens were often thought to be the culprit in nest predation, but unpublished work in suburban Perth found they predated only 4% of nests (Stewart 1997). However, if a particular population is already at risk, then a predation rate of 4% may indeed become significant (Recher 2004).

### 4.4.4 Suggestions for bird conservation in Perth suburbia and the role of pet cats

In summary, this study found no evidence that cat density was related to bird species richness and community composition in suburban Perth. Instead, housing density and proximity to native bushland of suitable size were the most critical determinants, largely through their effect on insectivorous species. Although some bushland species are restricted
to specific habitats because they are specialised in their foraging and nesting behaviours, other species may be more adaptable (Craig 2002). With some encouragement such as appropriate garden plantings and nearby remnant bushlands of reasonable size, shape and quality, these species may be able to use garden corridors connecting remnant bushland (Vale & Vale 1976, Lancaster & Rees 1979, Green 1984, Mills et al. 1989, Munyenyembe et al. 1989, Majer et al. 2001). Catterall (2004) highlights that the landscaping solutions required are far more complex than simply planting a range of native trees. Instead, they require planning for between-habitat diversity in an urban mosaic incorporating a range of different garden styles interlinked with bushland remnants.

The findings from our study do not exclude the possibilities that cat predation might be significant adjacent to remnant bushland or other areas of conservation significance, that some regulation of predatory pressure might lead to the re-establishment of a greater range of bird species in suburbia or that detrimental predatory impacts occur rapidly after the establishment of new subdivisions. However, they do suggest that blaming cats for bird conservation issues in long-established suburbs may be a scapegoat for high residential densities, inappropriate landscaping at a range of scales or poor conservation of remnant bushland.
5. **Attitudes of suburban Western Australians to proposed cat control legislation**

This chapter is a publication in the Australian Veterinary Journal. To maintain consistency with the rest of the thesis, the abstract, acknowledgements and keywords have been removed and the references included in an amalgamated reference list at the end of the thesis. The full survey used is reproduced in Appendix C. Otherwise, the text is identical to that of the publication.

5.1 **Introduction**

Ownership of domestic cats (*Felis catus*) confers health benefits such as decreasing the incidence of heart attack and stroke and lowering blood pressure (Anderson *et al.* 1992). Children benefit considerably from pet ownership as it teaches responsibility, respect and compassion (Murray & Penridge 1997). Pet ownership also makes a substantial contribution to the domestic economy. In 1995 it was estimated that $2.2 billion was spent on pet care in Australia and over 30,000 people were employed in the pet food industry, veterinary services and manufacturers of associated pet products (Murray & Penridge 1997).

However, surveys of community attitudes show that other people’s roaming cats are a significant nuisance for both cat-owners and non-owners (McHarg *et al.* 1995, Murray *et al.* 1999, Perry 1999). Furthermore, recent empirical studies have quantified the predation of owned cats on wildlife in large Australian cities, raising concerns that cat predation may be a threat to wildlife on suburban fringes and in remnant urban bushland (Paton 1991, Barratt 1994, REARK 1994b, Barratt 1998). While some cat enthusiasts (Hartwell 2001, Save our strays 2001) and others (Fougere 2000) are quick to defend domestic pet cats against such accusations, a more productive approach is to consider what aspects of cat husbandry could be regulated to minimise the problems, maintain or improve cat welfare and retain the established benefits of cat-ownership. For example, identification of pet cats, neutering of animals except those approved for breeding, and confining cats at night, will aid in returning lost or injured animals to owners and reduce the incidence of cat fights and
injuries in traffic. These measures will also reduce the dumping of unwanted kittens, attacks by cats on nocturnal wildlife and disturbance of neighbours by cats prowling at night. These motivations underlie the cat control regulations either in place or under consideration in several areas in Australia (Kelly 1999). Such approaches and the extent to which the cat-owning community complies, have direct implications for cat-ownership and cat husbandry and are a legitimate concern for the veterinary profession and local government officials.

Existing surveys of the public’s attitude to cat control measures vary in target population, sample size and methodology (Paton 1991, REARK 1994b, McHarg et al. 1995, Murray et al. 1999, Perry 1999) and only one study surveyed residents before and after the implementation of regulations to assess any changes in attitudes or practices (Murray et al. 1999). Although there is general agreement that cat-owners are responsible overall, these studies also indicate that perceptions of nuisance and predation are at levels that warrant action. The responsible behaviour already shown by many cat-owners augurs excellent prospects of success for measures undertaken sensitively and with a focus on cat welfare. Education may be a valuable adjunct to legislative action and its effectiveness can be improved by targeting community groups of particular significance.

We sought to identify such groups in a comprehensive survey that assessed the views of a suburban community in Perth, Western Australia, to a variety of issues relating to cat control legislation. Respondents were ranked on issues regarding restrictions on cat-ownership and cat roaming (control scale), attitudes to wildlife in suburbia and putative impacts of cats on wildlife (wildlife scale), knowledge of cat behaviour and husbandry (knowledge scale) and attitudes and practices regarding cat sterilisation (sterilisation scale). The results suggest that emphasising cat welfare is the key to gaining acceptance of cat regulations by owners, while the issue of cat exclusion zones is contentious for all citizens and needs to be approached cautiously by local councils.
5.2 Methods

In this study, we used a survey to examine the attitudes of the sample population to issues such as legislative control of cat ownership, the impact of cats upon wildlife in the suburbs and sterilisation of pet cats. Age, gender and cat-ownership status of respondents were chosen as possible explanatory variables and examined to see if specific groups could be identified for targeted education campaigns on responsible pet ownership.

5.2.1 Survey design

Pilot study

Initially, a pilot survey was designed using questions and statements or modified versions of statements contained in the Proposals for the Development of Cat Control (Department of Local Government WA 1994), which is still the fundamental basis for councils considering introducing regulations. It was administered to 50 respondents. The results of this pilot survey were analysed using modern latent trait analysis (specifically Rasch Analysis - see below) and then modified accordingly to construct the final survey.

Rasch analysis

The Rasch measurement model is widely employed in survey design and analysis in the social sciences and education (Hashway 1978, Andrich 1988). Rasch analysis allows examination of the fit of a set of data to a unidimensional measurement model. If the fit is acceptable, the model places survey questions and respondents’ attitudes on a single continuum, resulting in locations (scores) for individual survey questions and individual respondents, which are directly comparable with each other. These linearised (logit) scores, rather than raw scores, are more appropriate for use in common statistical tests (Andrich 1988). These scores may range from negative infinity to positive infinity, measuring respondents’ attitudes clearly in relation to the items that comprise the scale. Furthermore, Rasch measurement is ‘item free’, meaning that different subsets of items (or questions) in the ‘item bank’ administered to the same individual, yield scores that are not
appreciably different. Rasch measurement is also ‘person-free’ in the sense that, if the data fit the model, the estimation of the scale location of values or behaviours associated with survey items is not dependent on the population of subjects used to estimate them.

Analysis of the pilot survey responses using Rasch measurement indicated areas along the continuum where items tended to clump together and where there were large gaps on the continuum. This meant that the responses of some participants could not always be assessed reliably. In addition, a few items did not fit the model very well. To obtain a continuum where the attitudes could be assessed with greater validity and reliability, some items were removed or reworded and some new questions were also introduced to produce the final survey.

Rasch measurement analysis was used again in the initial analysis of the final survey to define four scales each reflecting a different topic: control, wildlife, knowledge and sterilisation.

**Final survey**

The final survey contained 43 questions and statements. The design (phrasing and layout) of both the pilot and final survey followed the suggestions by de Vaus (1995). These suggestions resulted in a survey that was easy and interesting to answer, whilst encouraging a high response rate that could reliably reflect the attitudes and knowledge of the survey respondents.

Several key questions and statements (listed below) from the survey were considered worthy of specific individual analysis because they reflected proposed actions for cat legislation in Western Australia.

- There is a need for cat legislation.
- Excluding a cat/s that are used for breeding, all cats should be desexed.
- Would you licence your cat with the council if it became compulsory?
- Local governments should have the power to limit the number of cats per household.
• Domestic cats killing wildlife in the suburbs is a problem.
• To stop cats from attacking wildlife, cats should be kept on their owner’s property.
• Domestic cats in nature reserves are harmful to wildlife.
• Local governments should have the power to establish cat free zones in new subdivisions.

Study area and administration of survey

Random number tables were used to select 2000 names from the 21,570 names on the State Electoral Roll for the Electoral District of Melville, Perth, Western Australia. The suburbs comprising this electoral district have been established for 15 to 60 years and contain a wide range of housing densities and socio-economic groups. Surveys were sent by mail to the participants in March of 1996. Included with the survey were: a covering letter explaining the project; a stamped self-addressed envelope and a teabag to be enjoyed whilst completing the survey. If no response was received within two weeks, a reminder letter and second survey were sent. Of the selected participants, 1261 (63%) responded to the survey.

5.2.2 Data analysis

Data screening

Multivariate analysis of variance (Tabachnick & Fiddel 1996) was used to examine the relationships between the person location estimates (linearised score in logits - the Rasch measurement unit) on the dependent variables of four scales (control, knowledge, sterilisation and wildlife) and the independent variables (age, gender and cat-ownership). MANOVA is an extension of the methods of analysis of variance (ANOVA) to cases where there is more than one dependent variable. In this study, the initial MANOVA analysis assessed whether there were significant main effects or interactions involving respondent age, gender and cat-ownership. Where significant effects or interactions were found,
univariate tests were used to determine which of the dependent variables (control, knowledge, sterilisation and wildlife) was responsible for the effect or interaction.

Prior to analysis, dependent variables were screened for compliance with the assumptions of MANOVA and the requirements of Rasch analysis. The only important issue to arise was the presence of extreme values of person fit statistics for some respondents. Unlike clinical studies where extreme values must be explained, substantial outlying values in survey data commonly indicate frivolous respondents deliberately selecting extreme choices wherever possible. Identification and elimination of these cases improves the final estimation of person and item locations because the estimates for these cases are not valid measures – as indicated by the tests of fit (Wright & Stone 1979). The 37 people who were outliers in terms of exhibiting extreme values for their person fit statistic (2.9% of the sample size) were removed from the data set. These misfitting people included only four cat-owners, so non-owners were responsible for most of the extreme values.

Responses to the eight survey statements (see below) were summarised as multi-way contingency tables using the categories of age, gender and cat-ownership and analysed using log linear analysis (Tabachnick & Fiddel 1996). The model fitting approach used begins by fitting a model with no relationship between factors. If that does not fit, as shown by a significant value, a model incorporating all two-way interactions is then tried, and if that does not fit then a model incorporating the three-way interactions is fitted and so on up until the four-way interaction if necessary. If, for example, the model incorporating all two-way interactions fits, then each interaction is tested for significance in turn until the most economical model that describes the data is defined. The significance of effects of interest in the model can be tested by removing them from the model and noting the change in model fit to the observed data. The significance of effects not in the model can be tested by adding them and noting the change in model fit. In our analyses, we were interested in any significant interactions between response to the statement and the three design variables of age, gender and cat-ownership. The interactions between the design variables were
irrelevant in this analysis. However, this three way interaction was included in the final model “…to avoid obtaining an overall lack of fit which may be entirely due to interactions between the design variables” (Statsoft 1999).

MANOVA and log linear analyses were performed using the appropriate modules of the STATISTICA software (Statsoft 1999). Rasch analysis used the RUMM software (Andrich et al. 1996). All analyses used a significance level of 0.05.

5.3 Results

5.3.1 Profile of respondents

Table 5.1 compares the profile of the survey respondents versus the approximate total population within the City of Melville. The total was based on suburban boundaries (Australian Bureau of Statistics 1996), which are slightly larger than the Melville Electoral District and hence the source population is greater than the electoral district population. Unfortunately, 114 of the 1261 respondents omitted either their gender or their age and so could not be included in this comparison. Log-linear analysis using the variables of age, gender and source (respondents or the electorate population) was performed to test whether the gender and age of survey respondents were representative of the total population within the electoral district. The log-linear analysis indicated a significant two-way interaction between gender and population source ($\chi^2_1 = 12.2, P < 0.01$) and between age and population source ($\chi^2_2 = 47.8, P < 0.01$). Men and women were not represented in the survey population in the same proportions as in the electorate, nor where the age groups represented in the survey population in the same proportion as in the electorate. However, examination of Table 5.1 shows the difference between survey respondents and the study population is slight and significance arises mainly from the large sample size. Table 5.2 shows the distribution of respondents by gender, age and cat-ownership. The minimum sample size in any category was 21 and in most categories sample sizes were over 50.
Chapter V

Table 5.1 Age and gender profile of the 33,856 electors in the study area and of 1177 of the 1261 survey respondents. Note that 114 respondents did not identify either their age or their gender and hence their details do not appear. The figures for electors come from the Australian Bureau of Statistics and are based on a slightly larger geographic area than the Melville Electoral District.

<table>
<thead>
<tr>
<th>Age Group (years)</th>
<th>Total population in electoral district (% of population)</th>
<th>Survey respondents (% of respondents)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male 18 - 34</td>
<td>5155 (15%)</td>
<td>98 (8%)</td>
</tr>
<tr>
<td>Male 35 - 54</td>
<td>5680 (17%)</td>
<td>201 (17%)</td>
</tr>
<tr>
<td>Male over 54</td>
<td>4799 (14%)</td>
<td>181 (15%)</td>
</tr>
<tr>
<td>Female 18 - 34</td>
<td>5614 (17%)</td>
<td>165 (14%)</td>
</tr>
<tr>
<td>Female 35 - 54</td>
<td>6263 (18%)</td>
<td>253 (22%)</td>
</tr>
<tr>
<td>Female over 54</td>
<td>6345 (19%)</td>
<td>279 (24%)</td>
</tr>
</tbody>
</table>

Table 5.2. Gender, age and cat ownership profile of 1177 of the 1261 survey respondents. Other respondents did not identify either their age, gender or cat-ownership status and hence their details do not appear.

<table>
<thead>
<tr>
<th>Gender and Age</th>
<th>Cat-Owner (%)</th>
<th>Non-Cat-owner (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male 18 - 34</td>
<td>21 (2%)</td>
<td>77 (6%)</td>
</tr>
<tr>
<td>Male 35 - 54</td>
<td>55 (5%)</td>
<td>146 (12%)</td>
</tr>
<tr>
<td>Male over 54</td>
<td>35 (3%)</td>
<td>146 (12%)</td>
</tr>
<tr>
<td>Female 18 - 34</td>
<td>74 (6%)</td>
<td>91 (8%)</td>
</tr>
<tr>
<td>Female 35 - 54</td>
<td>115 (10%)</td>
<td>138 (12%)</td>
</tr>
<tr>
<td>Female over 54</td>
<td>72 (6%)</td>
<td>207 (18%)</td>
</tr>
</tbody>
</table>

5.3.2 Analysis of the wildlife, control, knowledge and sterilisation scales

A summary of the results for the scales is shown in Table 5.3. Sample sizes are lower than the overall number of respondents after exclusion of some values on the basis of Rasch scores (see above) and a further 90 cases where respondents did not indicate their age, gender or cat-ownership status, or omitted questions relating to a particular scale. Initial MANOVA of available data using the factors age, gender and cat-ownership and the dependent variables of control, wildlife, sterilisation and knowledge found significant results for cat-ownership, gender, age and the cat-ownership x gender interaction (Table 5.4a). Table 5.4b indicates which of the dependent variables differed according to these factors and the interaction.
In relation to the effect of cat-ownership, cat-owners and non-owners differed significantly in attitudes towards control, wildlife and knowledge.

Cat-owners knew more about cat issues, but non-owners were more in favour of cat controls and more concerned about issues involving cats and wildlife in the suburbs. In relation to the effect of gender, females were more likely to support sterilisation of pet cats than males, whereas males were more supportive of cat controls. The age of respondents was also significant, with older people more in favour of cat controls. Lastly, the interaction between cat-ownership and gender was caused by the pattern of responses to the sterilisation and knowledge variables. In relation to sterilisation, women cat-owners were much more strongly in favour of sterilising pet cats than male cat-owners. However, male and female non-owners showed similar attitudes to sterilisation. In relation to knowledge, female cat-owners were much better informed than male cat-owners, whereas amongst non-owners men were better informed than women.

5.3.3 Questions/statements

We used log-linear analysis to test whether responses to a question/statement were significantly associated with respondents’ age, gender or cat-ownership status. Summary data for responses to the questions are shown in Tables 5.5a, b. Table 5.6 records the exact log-linear models fitted to data for each question and the significance of the model components. Only significant interactions determined by the log-linear analysis are described. The \( \chi^2 \) values presented in Table 5.6 are those calculated by the log-linear analysis after consideration of all factors in model building. They may therefore differ from values calculated from the significant subset of the table alone. Sample sizes may vary from those shown in Table 5.1 if not all respondents answered a particular question.

There is a need for cat legislation.

The only significant interaction was between cat ownership and agreement with the statement. Although non-owners (93%) were more strongly in favour of legislation than cat-owners (76%), it is extremely interesting that support from cat-owners was so high (Tables 5.5a and 5.6).
Table 5.3  Mean Rasch scores of 1134 respondents, ± standard deviations. Scores are grouped by age, gender and cat-ownership status, on the four scales of control, wildlife, sterilisation and knowledge. The sample excluded 37 respondents on the basis of extreme Rasch scores and a further 90 respondents who did not disclose their age, gender or cat-ownership status.

<table>
<thead>
<tr>
<th>Age</th>
<th>Gender</th>
<th>Cat-ownership</th>
<th>Sample size</th>
<th>Control</th>
<th>Wildlife</th>
<th>Sterilisation</th>
<th>Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 - 34</td>
<td>Male</td>
<td>Owner</td>
<td>21</td>
<td>-0.36 ± 1.60</td>
<td>-0.25 ± 1.26</td>
<td>-0.24 ± 1.34</td>
<td>-0.25 ± 1.65</td>
</tr>
<tr>
<td>18 - 34</td>
<td>Male</td>
<td>Non-owner</td>
<td>72</td>
<td>1.60 ± 1.55</td>
<td>1.59 ± 1.44</td>
<td>-0.12 ± 0.84</td>
<td>-0.59 ± 1.44</td>
</tr>
<tr>
<td>18 - 34</td>
<td>Female</td>
<td>Owner</td>
<td>73</td>
<td>-0.15 ± 1.07</td>
<td>0.04 ± 1.29</td>
<td>0.18 ± 0.46</td>
<td>0.33 ± 0.94</td>
</tr>
<tr>
<td>18 - 34</td>
<td>Female</td>
<td>Non-owner</td>
<td>88</td>
<td>1.34 ± 1.54</td>
<td>1.04 ± 1.42</td>
<td>-0.11 ± 0.63</td>
<td>-0.92 ± 1.72</td>
</tr>
<tr>
<td>35 - 54</td>
<td>Male</td>
<td>Owner</td>
<td>54</td>
<td>0.18 ± 1.28</td>
<td>0.19 ± 1.21</td>
<td>-0.07 ± 0.57</td>
<td>-0.34 ± 1.50</td>
</tr>
<tr>
<td>35 - 54</td>
<td>Male</td>
<td>Non-owner</td>
<td>138</td>
<td>1.88 ± 1.65</td>
<td>1.59 ± 1.55</td>
<td>-0.18 ± 0.78</td>
<td>-0.95 ± 1.84</td>
</tr>
<tr>
<td>35 - 54</td>
<td>Female</td>
<td>Owner</td>
<td>113</td>
<td>0.03 ± 0.87</td>
<td>0.14 ± 1.14</td>
<td>-0.01 ± 0.50</td>
<td>0.13 ± 1.30</td>
</tr>
<tr>
<td>35 - 54</td>
<td>Female</td>
<td>Non-owner</td>
<td>133</td>
<td>1.59 ± 1.46</td>
<td>2.67 ± 12.04</td>
<td>-0.10 ± 0.58</td>
<td>-0.81 ± 1.91</td>
</tr>
<tr>
<td>&gt; 54</td>
<td>Male</td>
<td>Owner</td>
<td>35</td>
<td>0.44 ± 1.39</td>
<td>0.51 ± 1.50</td>
<td>-0.34 ± 0.56</td>
<td>-0.70 ± 0.89</td>
</tr>
<tr>
<td>&gt; 54</td>
<td>Male</td>
<td>Non-owner</td>
<td>139</td>
<td>2.01 ± 1.68</td>
<td>1.51 ± 1.46</td>
<td>-0.14 ± 1.00</td>
<td>-0.72 ± 1.33</td>
</tr>
<tr>
<td>&gt; 54</td>
<td>Female</td>
<td>Owner</td>
<td>70</td>
<td>0.14 ± 1.00</td>
<td>0.09 ± 1.12</td>
<td>-0.02 ± 0.63</td>
<td>-0.26 ± 1.62</td>
</tr>
<tr>
<td>&gt; 54</td>
<td>Female</td>
<td>Non-owner</td>
<td>198</td>
<td>1.48 ± 1.44</td>
<td>1.50 ± 7.10</td>
<td>-0.22 ± 0.99</td>
<td>-1.08 ± 1.90</td>
</tr>
</tbody>
</table>
Table 5.4  MANOVA of data in Table 5.3. (a) Initial MANOVA. (b) Univariate tests where the multivariate effect or interaction is significant. Significant values are in bold.

(a)

<table>
<thead>
<tr>
<th>Effect</th>
<th>Rao’s R (df2, df2)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>2.20 (8, 2238)</td>
<td><strong>0.02</strong></td>
</tr>
<tr>
<td>Gender</td>
<td>3.24 (4, 1119)</td>
<td><strong>0.01</strong></td>
</tr>
<tr>
<td>Cat ownership</td>
<td>70.94 (4, 1119)</td>
<td><strong>&lt; 0.01</strong></td>
</tr>
<tr>
<td>Age x gender</td>
<td>0.79 (8, 2238)</td>
<td>0.61</td>
</tr>
<tr>
<td>Age x ownership</td>
<td>0.54 (8, 2238)</td>
<td>0.83</td>
</tr>
<tr>
<td>Gender x ownership</td>
<td>2.92 (4, 1119)</td>
<td><strong>0.02</strong></td>
</tr>
<tr>
<td>Age x gender x ownership</td>
<td>0.69 (8, 2238)</td>
<td>0.70</td>
</tr>
</tbody>
</table>

(b)

<table>
<thead>
<tr>
<th>Effect</th>
<th>Control</th>
<th>Wildlife</th>
<th>Sterilisation</th>
<th>Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>(F_{(2, 1123)} = 4.91, \ p &lt; 0.01)</td>
<td>(F_{(2, 1123)} = 0.68, \ p = 0.50)</td>
<td>(F_{(2, 1123)} = 1.47, \ p = 0.23)</td>
<td>(F_{(2, 1123)} = 2.63, \ p = 0.07)</td>
</tr>
<tr>
<td>Gender</td>
<td>(F_{(1, 1123)} = 4.64, \ p = 0.03)</td>
<td>(F_{(1, 1123)} = 0.02, \ p = 0.88)</td>
<td>(F_{(1, 1123)} = 5.87, \ p = 0.02)</td>
<td>(F_{(1, 1123)} = 1.89, \ p = 0.17)</td>
</tr>
<tr>
<td>Cat ownership</td>
<td>(F_{(1, 1123)} = 248.51, \ p &lt; 0.01)</td>
<td>(F_{(1, 1123)} = 16.90, \ p &lt; 0.01)</td>
<td>(F_{(1, 1123)} = 1.20, \ p = 0.27)</td>
<td>(F_{(1, 1123)} = 32.93, \ p &lt; 0.01)</td>
</tr>
<tr>
<td>Gender x ownership</td>
<td>(F_{(1, 1123)} = 1.83, \ p = 0.18)</td>
<td>(F_{(1, 1123)} = 0.10, \ p = 0.75)</td>
<td>(F_{(1, 1123)} = 5.69, \ p = 0.02)</td>
<td>(F_{(1, 1123)} = 8.63, \ p &lt; 0.01)</td>
</tr>
</tbody>
</table>
• Excluding cats that are used for breeding, all cats should be desexed.

There was significant interaction between age and agreement with the statement. Acceptance of this proposal exceeded 80% across all three age groups and increased with each age group (Tables 5.5a and 5.6).

• Would you licence your cat with the council if it became compulsory?

This question was directed solely at cat-owners. There was a high level of acceptance from both female and male cat- owners in regard to licensing their cat. In the absence of significant interactions, agreement with the response significantly exceeded 50% (Tables 5.5a, 5.6).

• The council should have the power to limit the number of cats per household.

Although there was a significant interaction between cat- ownership and agreement with this statement, cat-owners (88%) and non-owners (96%) were both very supportive of this proposal (Tables 5.5b, 5.6).

• Domestic cats killing wildlife in the suburbs is a problem.

The responses showed a strong interaction between cat ownership and the statement. Non-owners (88%) were more supportive than cat-owners (50%) (Tables 5.5b, 5.6).

• To stop cats from attacking wildlife, cats should be kept on their owner’s property.

There was a significant interaction between cat-ownership and agreement with the statement. Non-owners strongly agreed with this statement (87%) whereas cat- owners were more reluctant with their level of agreement running at 48% (Tables 5.5b, 5.6). There was also an interaction between statement and age, with people aged 35-54 less likely to agree with the statement than people older or younger.

• Domestic cats in nature reserves are harmful to wildlife

There was an interaction between cat-ownership and agreement with the statement. Although non-owners were more likely to agree than cat-owners, cat-owners still registered 86% support for this statement compared to 95% of non-owners (Tables 5.5b, 5.6).
Table 5.5a  Responses to four key statements by respondents classified according to their age, gender and cat-ownership.

Statement 1: There is a need for cat legislation
Statement 2: Excluding cats that are used for breeding, all cats should be desexed.
Statement 3: Would you licence your cat if it became compulsory?
Statement 4: The council should have the power to limit the number of cats per household.

<table>
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<th>Age</th>
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<th>Statement 2</th>
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</tr>
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<td>82</td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>Total</td>
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<td>160</td>
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</tr>
<tr>
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<td>7</td>
<td>138</td>
<td>145</td>
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<td>142</td>
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<td>66</td>
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<td>Total</td>
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</table>
Table 5.5b  Responses to four key statements by respondents classified according to their age, gender and cat-ownership.

Statement 5: Domestic cats killing wildlife in the suburbs is a problem.
Statement 6: To stop cats from attacking wildlife, cats should be kept on their owner’s property.
Statement 7: Domestic cats in nature reserves are harmful to wildlife.
Statement 8: The council should have the power to introduce cat free zones in new subdivisions.

<table>
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<th>Age</th>
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<th>Statement 6</th>
<th></th>
<th>Statement 7</th>
<th></th>
<th>Statement 8</th>
<th></th>
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</thead>
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<td>agree</td>
<td>total</td>
<td></td>
</tr>
<tr>
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<td>53</td>
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<td>61</td>
<td>51</td>
<td>112</td>
<td>12</td>
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<td>129</td>
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<td>129</td>
<td>143</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>24</td>
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<td>172</td>
<td>30</td>
<td>147</td>
<td>177</td>
<td>6</td>
<td>166</td>
</tr>
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<td>220</td>
<td>268</td>
<td>19</td>
<td>226</td>
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</tbody>
</table>
Table 5.6  The log-linear models fitted to the responses to each statement. The interaction of ownership x gender x age (design variables) was included in each model so the interaction between these variables did not contribute to the overall lack of model fit. The table shows the chi-square tests for fit of the models (always non-significant) and the significant components of the models.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Model fitted</th>
<th>Significance of model components</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is need for cat legislation.</td>
<td>Ownership x gender x age, Statement x ownership, $\chi^2_{10} = 13.8, \ p = 0.18$</td>
<td>$\chi^2 = 662.7, \ p &lt; 0.001$</td>
</tr>
<tr>
<td>Excluding cats that are used for breeding, all cats should be desexed.</td>
<td>Ownership x gender x age, Statement x age, $\chi^2_{9} = 14.28, \ p = 0.113$</td>
<td>$\chi^2 = 559.07, \ p &lt; 0.001$</td>
</tr>
<tr>
<td>Would you licence your cat with the council if it became compulsory?</td>
<td>Gender x age, Statement, $\chi^2_{5} = 5.4, \ p = 0.37$</td>
<td>$\chi^2 = 26.49, \ p &lt; 0.001$</td>
</tr>
<tr>
<td>The council should have the power to limit the number of cats per household.</td>
<td>Ownership x gender x age, Statement x ownership, $\chi^2_{10} = 12.16, \ p = 0.27$</td>
<td>$\chi^2 = 854.07, \ p &lt; 0.001$</td>
</tr>
<tr>
<td>Domestic cats killing wildlife in the suburbs is a problem.</td>
<td>Ownership x gender x age, Statement x ownership, $\chi^2_{15} = 15.50, \ p = 0.11$</td>
<td>$\chi^2 = 406.79, \ p &lt; 0.001$</td>
</tr>
<tr>
<td>To stop cats from attacking wildlife, cats should be kept on their owner’s property.</td>
<td>Ownership x gender x age, Statement x ownership, $\chi^2_{8} = 1.31, \ p = 0.99$</td>
<td>$\chi^2 = 192.67, \ p &lt; 0.001$</td>
</tr>
<tr>
<td>Domestic cats in nature reserves are harmful to wildlife.</td>
<td>Ownership x gender x age, Statement x ownership, $\chi^2_{10} = 9.16, \ p = 0.52$</td>
<td>$\chi^2 = 12.70, \ p &lt; 0.005$</td>
</tr>
<tr>
<td>Domestic cats in nature reserves are harmful to wildlife.</td>
<td>Ownership x gender x age, Statement x ownership, $\chi^2_{10} = 9.16, \ p = 0.52$</td>
<td>$\chi^2 = 753.33, \ p &lt; 0.001$</td>
</tr>
</tbody>
</table>

- The council should have the power to introduce cat free zones in new subdivisions.

This last statement proved to be the most controversial, generating interactions between gender and agreement with the statement and between cat-ownership and agreement with the statement. Males were more likely to agree than females and non-owners were more strongly supportive than cat-owners. However, all groups, regardless of cat-ownership or gender, showed less than 50% approval for the proposal that there should be cat free zones (Tables 5.5b, 5.6).
5.4 Discussion

Other Australian studies of attitudes pertaining to cat legislation (Paton 1991, REARK 1994b, McHarg et al. 1995, Murray et al. 1999, Perry 1999) have shown strong support by the respondents for the introduction of cat legislation, with concerns focusing on the nuisance caused by roaming cats and perceived threats to wildlife. Non-owners reported problems of nuisance such as attacks on pet birds, digging in the garden and killing wildlife, whereas both cat-owners and non-owners were bothered by cats walking on cars, cat fights and urine spraying. Murray et al. (1999) reported that 38.6% of the respondents on Magnetic Island complained of cats killing wildlife, while 18.9% of the respondents were bothered by roaming cats.

Some studies found roughly half of all pet cats to be hunters (Paton 1991, REARK 1994b, Perry 1999), while other studies which required owners to collect the carcasses of prey killed by their cats reported equal or higher incidences of predation (Paton 1991, Murray & Penridge 1997, Murray et al. 1999). Most mammals and birds killed were introduced species, while lizards comprised the largest group of native species attacked, especially in the warm Queensland climate (Perry 1999). Although complaints about domestic cats tend to be low in communities without relevant legislation, Murray & Penridge (1997) believe that this will increase after legislation has been passed because people feel their complaints will be considered.

Nevertheless, it is important to note that many Australian cat-owners are already highly responsible. For example, Perry (1999) found that 83% of pet cats were sterilised before they were a year old, 93% were sterilised by the age of five years, few owners permitted a cat more than one litter and only 8% of owners had more than one cat. These figures agree closely with estimates of desexing in other Australian surveys (88% to 93%) (REARK 1994a, McHarg et al. 1995, Murray et al. 1999) and are considerably higher than that of 78% reported for the United States by the American Bird Conservancy (2001). Estimates of the proportion of pet cats confined on a national basis were lower, ranging from 39% (REARK 1994b) to 43% (Murray et al. 1999).
Our survey complements these results because of the approach taken in analysis of the data. The use of Rasch, MANOVA and log-linear analysis highlighted attitudes of groups of respondents towards various aspects of cat legislation and cat issues, so that education campaigns can be designed with these groups in mind, for promoting responsible cat-ownership and to help with the acceptance of cat legislation by the general community. Our initial creation of the four scales reflecting knowledge, control, sterilisation and wildlife did reveal a significant relationship with age and gender, but particularly with cat-ownership. Cat-owners were less likely to favour controls and were less concerned about wildlife impacts than non-owners. Predictably, on the knowledge scale, cat-owners knew more about cat issues than non-owners.

The results of specific survey questions (log-linear analysis) followed a similar pattern to the analysis of the scales. There were significant differences between cat-owners and non-owners in their acceptance of the need for cat legislation that covers sterilisation of cats, licensing of pet cats, restrictions on the number of cats per household and restricting cats to their owner’s property. However, cat-owners supported these suggestions at levels of 76% or higher, indicating the high proportion of responsible cat-owners in the community. Thus, there is widespread community support for all these measures, although this is stronger amongst those who do not own cats. Attitudes regarding the impact of cats on wildlife showed a somewhat different pattern. Non-owners were more likely than cat-owners to accept that cats are harmful to wildlife in both nature reserves and the suburbs. While cat-owners still showed 86% acceptance that cats impact wildlife in reserves, they were much less accepting of the impact of cats on wildlife in suburbs (50%). Despite this disagreement between cat-owners and non-owners, less than 50% of all respondents, including non-owners agreed with the concept of cat exclusion zones in new subdivisions to protect wildlife.

These results have important implications for plans to introduce cat control legislation. Firstly, despite the differences between cat-owners and non-owners, the overall acceptance of most aspects of cat control legislation is striking. Non-owners may be more
motivated by wildlife issues while cat-owners could be more concerned about the welfare of their pets, but the end result for both is a high acceptance of most proposals. Secondly, there is considerable community opposition to cat exclusion zones in new subdivisions. Possibly, non-owners see such proposals as infringements of civil liberty despite their concern about wildlife issues.

Levels of acceptance for cat control might be improved by appropriate education campaigns. In the first instance, these could be targeted specifically at cat-owners, perhaps involving the co-operation of veterinarians, using cat welfare to motivate cat-owners. The issue of sterilisation also produced strong gender differences, with males less in favour of sterilisation. This trend has also been noticed in attitudes toward sterilisation of dogs (Blackshaw & Day 1994). Thus male cat-owners could also be an important target group in education campaigns.

Draconian enforcement ordering people to comply with directives is often counterproductive and causes resentment (Mackay 1995). Instead, it is recommended the authorities need to appeal to people’s sense of morality and community justice in achieving compliance in environmentally sensitive areas (Fougere 2000). Legislation gives pet cats a value. Therefore, ownership of the cat is acknowledged and with this comes some level of responsibility. Jennens (1992) reports that the best way to achieve community support is via education and consultation prior to the implementation of legislation.

Educating the community towards responsible pet ownership can never begin too early. The PetPep program has been in schools for some time and, in 2000, the Responsible Pet Ownership Program for Schools was launched with the motto ‘Educating today, taking care of tomorrow’ (Morrice & Soderstrom 2001). Overall, the best opportunity to maximise cat-owners’ compliance with new legislation rests in such an appeal to their sense of natural justice and to their concern for the welfare of their pets. To date, many shires and councils throughout Australia have introduced cat legislation to varying degrees. The Australian Capital Territory (ACT) is the only legislature to introduce legislation that covers the whole territory. The other states have given local councils the option to introduce cat legislation.
Our personal communication with various shire councils and local governments throughout Australia agree with the observation of Kelly (1999), that cat legislation has been accepted relatively well by the community. However, the councils feel that the legislation is almost unenforceable because of limited resources.

To determine the true success of any new legislation, a follow up study is required. This will assess the community’s attitudes and compliance to the new laws, highlighting areas that need more attention via community education to make the new legislation successful. Magnetic Island is the only council to have resurveyed the opinions of the community as to the effectiveness of new cat and dog legislation introduced 14 months before the second survey. The implementation of a ‘pet management plan’ did not discourage members of the community from owning pets. The attitudes of Magnetic Island residents to the cat management did not alter significantly. Residents supported all points of the cat management plan including limiting the number of cats to two; desexing pet cats; identification of owned cats and night confinement (Murray et al. 1999).

The most well-known example of an Australian community that introduced cat legislation is that of the municipality of Sherbrooke in Victoria. Responding to pressure for over four years from groups concerned to protect dwindling lyrebird (Menura novaehollandiae) numbers in Sherbrooke Forest, the council began by implementing: cat registration by marking animals with microchips inserted under the skin, reducing registration fees for desexed animals, controlling pet movement and implementing a night-time curfew. Opposition groups argued that the regulations violated the rights of cat-owners and their pets and were also inhumane (Hartwell 1994), so council officers used education campaigns to change the perception of the community to cat legislation. Council rangers of Sherbrooke believe that the legislation has provided a set of community standards that have educated cat-owners to what is expected of them as responsible pet owners (Pergl 1994). However, education campaigns need to be ongoing to educate new residents as to what is expected of them as cat-owners and prevent existing residents from becoming complacent. Moreover, the effectiveness of the cat curfew is still unclear (Anderson 1994, Pergl 1994).
Chapter V

The lyrebird population is recovering and there is a decrease in the number of lyrebirds brought in with cat related injuries. However, now that the cats are contained at night hunting time is restricted to daylight hours and the prey choice of pet cats has changed to diurnal native animals. Attacks on diurnal native birds have increased from 30 to 53% (Pergl 1994). In 1994, Pergl (1994) proposed a survey of residents’ perceptions of the cat legislation. A survey similar to that conducted by Murray et al. (1999) would enable animal management officers to identify groups within the community that would benefit from further education about responsible pet ownership.

The results of our survey suggest that the growing awareness of the cat issue following the Sherbrooke experience has increased the chance of community acceptance of new cat control measures. For this conclusion to be accepted, the broader applicability of the results of this study must be defended. The study is clearly limited to a suburban community and, as such, may not be applicable to rural areas, or to low density areas on suburban fringes. The response rate exceeded 50%, well above the 20 to 30% de Vaus (1995) believes is sufficient to eliminate bias. In summary, the broad social, age, and residential profile of the study community suggests that these results are likely to be typical of many Australian suburban communities.

Overall, we believe that community attitudes are now generally supportive of cat control measures that will reduce instances of cat nuisance, improve cat welfare by restricting fighting, road accidents and cat stealing, and protect wildlife in remnant suburban bushland. The existing high levels of support from cat-owners could be increased with targeted education campaigns. By emphasising the implications for cat welfare to their clients, veterinarians can play a significant part in this process.
6. General discussion

Superficially, managing pet cats to protect wildlife in suburbia is simple. All that is needed is for people to confine their pets to their properties at all times, preferably within runs so that parts of the garden are free from cat activity. As an added precaution, pet cats could be banned near areas of special environmental sensitivity. In practice, obtaining wide community agreement to such measures is daunting. Here, I overview the contribution of the principal findings of this thesis to the question of managing pet cats to protect wildlife before discussing the key issues of how to obtain compliance, and placing the pet cat question in the wider context of managing wildlife in suburbia.

6.1 Overview of principal findings

In this thesis I set out to apply a precautionary approach to the perceived problem of whether or not predation by pet cats affects species richness and community composition of suburban passerines in the suburbs throughout Perth, Western Australia. The thesis had four broad aims and the findings in relation to them were as follows.

Aim 1: Justify a case for applying the precautionary principle to this problem

The precautionary principle argues that uncertainty over the real extent of a possible environmental impact should not rule out protective action (Deville & Harding 1997). Thus for precaution to apply, there should be a reasonable, but uncertain, belief that a significant environmental impact could occur (Deville & Harding 1997). My reviews of the literature regarding the predatory impacts of pet cats and the application of the precautionary principle in Chapters I and II led to this justification for applying the precautionary principle in the specific case of predation on passerines by pet cats in Perth:

- Numerous international and Australian (including Western Australian) studies document the number and range of prey taken by pet cats and, in some cases, quantify
predation rates. While prey species include vermin (both native and exotic), they also include native species of conservation concern.

- Only some pet cats hunt and the type of prey taken varies with local availability.
- Despite the undeniable evidence for hunting, the evidence for significant effects on urban wildlife populations is weak. Critics argue that cats primarily kill prey from abundant local species and that prey populations are not endangered.

Overall, these findings indicate the likelihood that pet cats in Perth could have a significant impact on populations of suburban passerines because of the extent of predation, but definitive evidence of impacts on prey populations is sparse. Therefore the application of the precautionary principle is justified.

Aim 2: Reduce uncertainty regarding the impacts of pet cats in this environment by testing for relationships between cat density and bird species richness and community structure.

In Chapter III I described Perth’s bird fauna and, in Chapter IV, examined eight factors that might influence passerine species richness or community structure in Perth suburbs. Using data on birds occurring in yards across the metropolitan area provided by the Birds Australia Suburban Birds Survey and my own surveys of dog density, cat density, housing density, age of suburb, distance to and size of nearest bushland and garden vegetation composition, I found:

- Cat density did not predict the species richness or community composition of passerines. With the possible exception of the Western Spinebill, cat density was not a significant predictor of the presence/absence of 15 selected passerines.
- Housing density and distance to and size of nearest bushland were the main predictors of passerine species richness and community composition, primarily through their impact on the abundance of small and medium-sized insectivores.
These results support the view that high residential densities, inappropriate landscaping at a range of scales or poor conservation of remnant bushland determine the passerine species found in suburban Perth. Such conclusions are consistent with the studies of Evans et al. (2009a) in the UK, Evans et al. (2015) in the USA and van Heezik & Adams (2014) in New Zealand.

Aim 3: Consult with citizens to determine a range of acceptable precautionary measures that could be applied

Consultation is one of the precautionary principle’s greatest strengths. If a range of stakeholders have an input into choosing precautionary actions, then there may be a greater chance of compliance than if arbitrary methods are enforced. In my survey of attitudes and practices within the City of Melville, specific measures that met with 65% or greater approval from owners and non-owners alike included:

- There is a need for cat legislation.
- Excluding cats that are kept by licensed breeders, all cats should be desexed.
- Local councils should be empowered to restrict the maximum number of cats that can be owned per household.

A further 63% of owners answered yes to:

- Would you license your cat with the council if it became compulsory?

Nevertheless, owners and non-owners differed sharply in their assessments of the impact of pet cats on wildlife. While both owners (86%) and non-owners (95%) agreed strongly that cats in nature reserves are harmful to wildlife, only 50% of owners believed that predation by cats was a problem for wildlife in the suburbs, compared to 88% of non-owners. Therefore owners and non-owners may have different motivations for accepting various precautionary actions, with owners much less likely to be motivated by concerns for wildlife.
Aim 4: Recommend a precautionary strategy that could be applied in Perth while awaiting the results of future research on the extent of impacts

Ideally, precautionary actions are an interim measure adopted until uncertainty over the real nature of putative impacts is resolved. If impacts are found to be benign, precautionary actions can be relaxed, whereas if they are found to be serious, measures should be continued. If the potential for serious impacts is established, these measures become preventive (negating a known risk) rather than precautionary (taking care in the case of lack of information) (Deville & Harding 1997).

Despite my findings that the density of pet cats does not impact suburban passerines, there is no reason yet to disregard the need for measures to reduce predation by pet cats on wildlife. To begin with, my study was restricted to passerines and so the findings that cat densities are a lesser issue than housing densities and the size and distribution of remnant bushland will not necessarily apply to non-passerine birds, herpetofauna, mammals or invertebrates. Also, this study did not take into account the potential for pet cats to spread disease to wildlife (Fitzgerald 1990), which is an important area of potential impact distinct from predation. Nor did the study specifically test for the sublethal effects of pet cats on wildlife (Bonninorton et al. 2013).

In common with many other correlation based studies in animal ecology, my study suffered from potential bias in interpreting a key variable – in this case, cat density. It could be argued that cat densities may not correlate strongly with predation. For example, cats in higher density areas may hunt less because they roam less widely or spend more of their time in intraspecific interactions. Conversely, cats at lower densities may hunt more, leading to a higher rate of predation/cat that offsets the lower densities. The overall effect would be a similar predation pressure across a range of cat densities, with the only real effect to be considered a binary variable of ‘cat’ versus ‘no cat’ (assuming ‘no cat’ areas could be established).
The published empirical data on whether the predation rates of individual pet cats are density-dependent are contradictory and therefore inconclusive (Table 6.1).

Table 6.1  Impact of cat density on predation rates from a range of international and national studies

<table>
<thead>
<tr>
<th>Author</th>
<th>Location</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paton (1991)</td>
<td>Australia</td>
<td>Rural cats caught more than double the prey of suburban cats. Cat density greater in suburban areas.</td>
</tr>
<tr>
<td>Lepczyk et al. (2003)</td>
<td>USA</td>
<td>Positive relationship between cat density and total predation by cats. Predation rate per individual cat did not vary between rural and suburban cats. Cat density was significantly different across the rural/urban gradient.</td>
</tr>
<tr>
<td>Kays &amp; DeWan (2004)</td>
<td>USA</td>
<td>Cat activity did not affect small mammal populations in the area.</td>
</tr>
<tr>
<td>Sims et al. (2008)</td>
<td>UK</td>
<td>Inverse correlation between the number of bird species richness and cat density, but cannot conclude this relationship is causal.</td>
</tr>
<tr>
<td>Lilith et al. (2010)</td>
<td>Australia</td>
<td>No relationship between cat density or regulations on cat movement and presence of prey species in remnant vegetation.</td>
</tr>
<tr>
<td>van Heezik et al. (2010)</td>
<td>New Zealand</td>
<td>Cats in gardens that were larger and more structured bought back more prey than cats in small gardens with minimal vegetation structure.</td>
</tr>
<tr>
<td>Thomas et al. (2012)</td>
<td>UK</td>
<td>Inverse relationship between predation rates and cat density.</td>
</tr>
</tbody>
</table>

Problems of regional variation and unsubstantiated assumptions in reaching conclusions are a major problem in assessing predation by pet cats. On balance, I consider my conclusion that cat density (and, by extension, predation by pet cats) is not a significant determinant of passerine species richness or community structure in Perth is justified, but others may not be convinced. The correct response is to continue precautionary measures while seeking to resolve the uncertainty to the satisfaction of all parties.

I suggest that these issues can be dealt with by a continuation of a precautionary approach with specific attention to three areas: further research to reduce uncertainty; a stringent evaluation of the likely effectiveness of the precautionary measures identified as having widespread community acceptability and increased emphasis on responding to the
measures, independent of the question of predation by cats, that are established strongly as threats to suburban wildlife.

6.2 Reducing uncertainty - research issues and priorities

6.2.1 What research issues are important?

During the 1980’s and 1990’s a strong view developed in ecology and wildlife biology that research should move beyond description of phenomena to testing predictions about the system under study. An emphasis on predictions links cause and effect explicitly, developing strong theory and offering unambiguous advice to management (e.g. Bergerud 1974, Hairston 1989, Caughley & Gunn 1996, Ratti & Garton 1996, Ford et al. 2000). In this context, there are now ample studies documenting the types of prey taken by pet cats in a wide range of international settings (e.g. Churcher & Lawton 1987, Barratt 1998, Gillies & Clout 2003, Lepczyk et al. 2003, Woods et al. 2003). Such descriptive work established the potential for impacts but not their real extent, so more recent work is shifting to testing explicit predictions about changes in wildlife populations in response to cat predation (e.g. Baker et al. 2005, Sims et al. 2008, van Heezik et al. 2010). Ecological theory offers several theoretically interesting and practically important hypotheses relevant to this case. These are the ‘doomed surplus’ hypothesis, the possibility of sub-lethal effects and mesopredator release.

Table 6.2  Studies of the effects of doomed surplus

<table>
<thead>
<tr>
<th>Author</th>
<th>Location</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baker et al. (2008)</td>
<td>UK</td>
<td>Birds killed by cats were in poorer condition than birds in the general population.</td>
</tr>
<tr>
<td>Banks (1999)</td>
<td>Australia</td>
<td>Predator removal (fox) did not alter prey population numbers. N.B. removal of foxes may have allowed a release of mesopredators which continued to suppress target population.</td>
</tr>
<tr>
<td>Risbey et al. (2000)</td>
<td>Australia</td>
<td>Prey population increased after the removal of feral cats.</td>
</tr>
<tr>
<td>van Heezik et al. (2008)</td>
<td>New Zealand</td>
<td>Populations of focal species such as Blackbird and Fantail would not persist in the presence of cats, but Silvereyes may survive if cat predation were halved.</td>
</tr>
</tbody>
</table>
The ‘doomed surplus’ hypothesis suggests that losses to predation do not cause declines in wildlife populations because the prey taken were weak and would have died from other causes (Park et al. 2002). Predictions arising from this hypothesis are that birds killed by cats should be in poorer condition than birds in the general population, indicating that those taken by predators were ailing, and that prey populations should not increase following predator control. However, results vary (Table 6.2).

Beckerman et al. (2007) proposed that cats exert a ‘sub-lethal’ effect on prey populations. In their desire to avoid cats prey may alter their foraging behaviour or their use of specific habitats and these changes may, in turn, influence survivorship and fecundity. With regard to bird populations in the United Kingdom, the authors used a modelling approach to demonstrate that, in areas of high cat density, even small declines of one offspring per year per cat could lead to marked declines of up to 95% in bird abundance. Such modelling outcomes are strong support for precautionary action to mitigate the proposed impacts, but they require empirical verification.

Finally, the hypothesis of mesopredator release predicts that removing a top predator from an ecosystem may cause increases the numbers of predators lower down the food chain (mesopredators), actually increasing the predatory pressure on smaller prey (Medina & Nogales 2009, Ritchie & Johnson 2009). In the suburban context, pet cats may be regarded as the top predator and rodents as mesopredators. While cats undeniably hunt and kill a range of birds, they also take rodents and thereby reduce the rodents’ predatory pressure on bird eggs and nestlings (Banks 1999, Courchamp et al. 1999, Matthews et al. 1999, Davey et al. 2006, van Heezik et al. 2010). Under this hypothesis, it is plausible that reductions in predatory pressures on rodents by excluding cats from certain areas or confining them so they cannot hunt could actually increase mortality of bird species.

In considering all these hypotheses, it will be very important to allow for regional differences in fauna responses. This point can be seen most clearly in the case of the Common Starling, which is declining in the United Kingdom and is regarded as being potentially at risk from predation by cats (Beckerman et al. 2007). By contrast, it is well
established in suburban eastern Australia despite being common prey for pet cats (Barratt 1998). This example illustrates how the same prey species may respond differently in different localities, presumably in response to local conditions. It is a particularly interesting case, because explanation of the reasons for the varied responses may help reach generalisations about how prey species may respond in different circumstances.

6.2.2 What research techniques could be applied?

Predictions from the hypotheses listed above could be tested using a range of methods, each with its specific potential and problems. The earliest approaches used descriptive methods recording the prey taken by cats and extrapolating from these and data on regional or national cat populations to estimate annual predation rates (e.g. Churcher & Lawton 1987, Paton 1991). The validity of such extrapolations (but not the value of the comprehensive observational data) has been criticised and emphasis has shifted to new approaches.

One option is collecting data on more geographically constrained populations of cats and their prey to determine patterns of mortality and recruitment in the face of varying levels of cat predation (e.g. Loyd et al. 2013). Data from studies can then feed into models exploring the effects of changes in predation rates on prey far more quickly and comprehensively than could be done in a series of empirical field studies (Lepczyk et al. 2003). Models can test hypotheses regarding changes in prey population sizes, identify characteristics that lead some species to decline while enabling others to persist over long periods, assess complex interactions (notoriously difficult to do otherwise) and provide objective guidelines for decision making (Lindenmayer & Possingham 1994, van Heezik et al. 2010). They are only as good as the data available for input, but that can actually be an advantage in highlighting the information needed to build a useful model (Anderies et al. 2007). Nevertheless, models may be misleading if based on unfounded or poorly stated assumptions (Abbott & Christensen 1996) and the strongest inference comes when their
predictions are tested empirically. Cases in point are the retrospective validation of the predictions of population viability models (Brook et al. 2000, Ball et al. 2003).

A second option lies with manipulative experiments. These have been used effectively to resolve questions of predatory impacts for feral cats (Risbey et al. 2000). Logistically, this was an achievable experiment because there were no pet-owners involved although there were other constraints of time and scale. Currently, there are new subdivisions that do not permit pet cats and these areas could be used to test variables including species richness and community composition (see Chapters III and IV and Grayson et al. (2007)) or detailed studies of particular species covering life history data such as clutch size changes (Lima 1987 and references therein), behavioural/foraging changes (Lima 1998, Hodgson et al. 2006) and population trends (Ruxton 1995, Ruxton & Lima 1997, Lima 1998, Chamberlain et al. 2009 and references therein). These experiments would also need to monitor fluctuations of exotic mammal populations (Mathews et al. 1999, Dickman 2007, Salo et al. 2010).

Meta-analysis of predator manipulation studies has shown that predators do limit their prey, however, one in six experiments showed no effect of predator manipulation (Salo et al. 2010). Implementation and interpretation of such exclusion experiments are difficult. For example, manipulation experiments need to: (i) extend over several breeding seasons to allow for unusual temporal effects, (ii) ensure that other possible predators and competitors of the prey are taken into consideration, (iii) attempt to quantify emigration from experimental areas, (iv) assess the possibility of mesopredator release concurrently with changes in the responses of birds and (v) account for an increase in resource availability for the prey in question that could account for a sudden increase in prey numbers (Salo et al. 2010).

Opportunities for implementation may come through using the cat ownership regulations imposed or planned by local municipalities as experimental treatments in an adaptive management approach to assessing the impact of pet cats on wildlife. This treats different management actions in space and time as experimental treatments, increasing
understanding of the system being managed (Stankey & Allan 2009 and references therein). Thus management and research unite in a feedback loop, with the results of the trials informing management and changes in management policy subject to on-going testing. Involvement of scientists in planning the interventions may also maximise the benefits by planning the design well and avoiding some of the problems of confounding that can arise when well-meaning regulators implement several measures simultaneously, preventing a meaningful assessment of any one of them alone. The case of the effectiveness of collar-worn anti-predator deterrents in reducing successful hunting is an important lesson here. Anecdotal opinions of the ineffectiveness of bells in reducing hunting abound on the internet and these appeared confirmed by Paton’s (1991) survey based study of the prey caught by pet cats. However, subsequent controlled experimental studies revealed that bells and other collar mounted devices reduce prey captures by 34 - 54% (Ruxton et al. 2002, Woods et al. 2003, Nelson et al. 2005, Calver et al. 2007, Calver & Thomas 2010, Gordon et al. 2010, Hall et al. 2015, Willson et al. 2015), indicating the importance of controlled experimental studies for evaluation of hypotheses.

6.3 An overview and evaluation of acceptable precautionary measures

Possible precautionary measures include: the introduction of cat legislation which includes mandatory sterilisation to reduce the oversupply of cats, the possibility of limiting the number of cats per household to two, containing owned cats to their property for varying amounts of acceptable time and encouraging cat owners in the use of cat bibs/collar-mounted devices for their cats when they are not contained or if contained to a garden.

6.3.1 Mandatory sterilisation

In all surveys (Grayson et al. 2002, Van de Kuyt 2004, Lilith et al. 2006, Toukhsati et al. 2012), respondents are highly supportive of mandatory sterilisation of pet cats. The main motivation for cat owners is to minimise the effects of having pets that want to mate and the disposal of kittens. However, the general public are becoming more educated and
appear to understand the importance of reducing the supply of kittens and reducing the number of cats entering shelters (Van de Kuyt 2004, Toukhsati et al. 2012). The sterilisation of female cats is a more difficult procedure than males and wasn’t common place until surgical techniques and the use of anaesthetics were refined and deemed safe. Until then, kittens were either dumped, given away as pets, or disposed of – often by drowning. Drowning was deemed to be painless due to a rise in carbon dioxide levels that rendered the cat unconscious, but this was challenged and drowning is not considered to be euthanasia (Ludders et al. 1999).

In Australia, the sterilisation rate is high (91%) (Animal Health Alliance 2013). Although this appears to be a reasonable rate, the climate in Australia provides ideal conditions for an extended breeding season for female cats (Webb 2008). To compensate for the environmental conditions, sterilisation rates of owned cats in Australia need to be more towards 98% (Webb 2008). Furthermore, many cats are sterilised after reproductive maturity and have had an opportunity to breed (Johnson & Calver 2014). Sterilisation rates in other countries are reported as much lower (e.g. 80% in the USA (Chu et al. 2009) and 43% in Teramo, Italy (Slater et al. 2008)). In these instances, increases in the sterilisation rates and early age sterilisation (Johnson & Calver 2014) for pet cats is likely to significantly reduce the dumping of unwanted kittens and protect wildlife.

The management of stray cats, or in many cases, semi-owned cats is another important precautionary measure. By encouraging feeders of stray cats to either take responsibility for the cats they feed by having them sterilized and being responsible owners, or surrendering them to a cat management facility, reduces the number of kittens born/contributing to the feral/stray cat continuum (Webb 2008), ultimately impacting on suburban wildlife (Toukhsati et al. 2007, Zito et al. 2015). Further, reducing the availability of kittens in turn increases the value of a cat as a pet and only people who really want a cat will actively seek out a cat as a pet, rather than the current trend of passive acquisition (Webb 2008).

It is important to note, though, that the rates of sterilisation of pet cats are essen-
tially self-reported. Respondents aren’t always completely honest when it comes to divulging what they really do as the respondent’s answer can be influenced by how they feel the researcher views them, also known as social desirability bias (Mirzaee 2013). However, I do believe that the vast majority of cat owners recognise that sterilisation of pet cats is the right thing to do and most owners would sterilise their pet cat for the benefit of the cat and to make the cat easier to manage.

6.3.2 Limiting the number of pet cats per household

In areas not in an exclusion area or with 24 hour confinement or even night time confinement, residents could reduce the impact of pet cats by restricting ownership to two cats. In Western Australia, such reductions are likely to be modest as it is reported that there is an average of 1.4 cats per household (Department of Local Government WA 2011). However, the number of 1.4 cats per household could be inflated by some households having more than the average number of pet cats. International studies reporting means of over two cats/household, e.g. 2.24 in the US study by Chu et al. (2009), are also difficult to interpret because they could well be biased by a small number of households with large numbers of cats and medians or frequency distributions are not presented.

6.3.3 Containment

Containment of cats is a potentially divisive issue – particularly between cat owners and non-owners. Historically, cats are perceived as animals that need to roam and containment of cats is cruel (Grayson et al. 2002). However, the impact of cats, particularly in Australia, is widely represented in the media (i.e. Millman 2015) and this factor plus the nuisance caused to neighbours now outweighs the reluctance to oppose the containment of pet cats by non-owners (Grayson et al. 2002, Van de Kuyt 2004, Lilith et al. 2006, Toukhsati et al. 2012). From the cat owner’s perspective, the value of cats as pets has increased and cat owners are more inclined to contain their cat for its welfare (to reduce the incidence of road trauma and cat fights (Gunaseelan et al. 2013) and protection against top order predators (Kays & DeWan 2004). Cat owners are, however, concerned about the
impact of their cat on wildlife, but this is secondary to the welfare of their cat (Van de Kuyt 2004, Toukhsati et al. 2012).

6.3.4 How to get compliance

The Department of Local Government WA (2015) implemented the Cat Act of 2011 in Western Australia. Local councils and shires within Western Australia are required to enact and enforce this Act to reduce the number of negative impacts of cats in both the community and environment, including the high numbers of unwanted cats from being euthanized and to encourage responsible cat ownership (Department of Local Government WA 2015). The Cat Act became effective as of November 1st, 2013, and requires all cats to be sterilised, microchipped and registered. Local councils may introduce further laws such as restricting the number of cats in a household, containment of cats and determining where cats can be prohibited. Other states around Australia also have legislation pertaining to cats. Some legislation that has been in for some time enforces just the registration of cats and trespassing, while the newer legislation enforces sterilisation of cats, registration, microchipping and sometimes restricting the number of cats per household. Each act also allows for local municipalities to enact local laws that may include curfews and prohibited/sensitive areas (Table 6.3).

Table 6.3 Cat legislation throughout Australia as of 2015

<table>
<thead>
<tr>
<th>State</th>
<th>Name</th>
<th>What’s involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Victoria</td>
<td>The Domestic Animals Act 1994</td>
<td>Registration, microchipping. Adequately contain pet cats at all times. Cats at large can be trapped and owners of identified cats can be fined (Parliament of Victoria 2014).</td>
</tr>
<tr>
<td>South Australia</td>
<td>The Dog and Cat Management Act 1995</td>
<td>Currently under review (previously Government of South Australia 2010).</td>
</tr>
<tr>
<td>Northern Territory</td>
<td>Animal Management Plan 2008</td>
<td>Registration, microchipping, licence required if you want to keep more than two cats. Adequately contain pet cats at all times. Cats at large can be trapped and owners of identified cats can be fined (City of Darwin 2014).</td>
</tr>
</tbody>
</table>
Although respondents may support the ideal of cat legislation (Grayson et al. 2002), achieving compliance is the tricky part. For example, in Fremantle, Western Australia, 600 cat owners have registered their cats since the inception of the legislation in 2013 (City of Fremantle, pers. comm.), constituting only 12.9% of the cat population (Table 6.4). There is a higher rate in the City of Melville with 20.0% (City of Melville, pers. comm.) (Table 6.4). In Victoria, registration rates are a little higher at 24.4% (Table 6.4). However, respondents in Van de Kuyt (2004) self-reported registration rates of 88% in her Melbourne survey (n = 320).

Table 6.4 Percentage of cats registered with their relevant council

<table>
<thead>
<tr>
<th>Location</th>
<th>Proportion of cats (a)</th>
<th>Population of location (b)</th>
<th>How many cats in the location (c) = (a.b)</th>
<th>How many cats registered (d)</th>
<th>% of cats currently registered (d/c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>City of Fremantle</td>
<td>0.15</td>
<td>31,000</td>
<td>4,650</td>
<td>600 (Anon. 2015, pers. comm. 1)</td>
<td>12.9</td>
</tr>
<tr>
<td>City of Melville</td>
<td>0.15</td>
<td>107,239</td>
<td>16,086</td>
<td>3,288 (Carrie 2015, pers. comm. 2)</td>
<td>20.4</td>
</tr>
<tr>
<td>State of Victoria</td>
<td>0.15</td>
<td>58,864,000</td>
<td>8,829,000</td>
<td>215,482 (Van de Kuyt 2015, pers. comm. 3)</td>
<td>24.4</td>
</tr>
</tbody>
</table>

To convert the support for cat legislation (Grayson et al. 2002) to actual compliance, the key appears to be making responsible cat ownership easier and attainable (Gunaseelan et al. 2013). Local councils (e.g. City of Stirling 2015) and the Department of Local Government WA (2015) have a wealth of information regarding the Cat Legislation

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1 Anonymous (2015). Number of cats registered in the City of Fremantle. Personal communication. Author address: Ranger, City of Fremantle, Town Hall Centre, 8 William Street, Fremantle, ph. 08 9432 9905. Access Date: 9th September, 2015.

2 Carrie, Peter (2015). Number of cats registered in the City of Melville. Personal communication. Author address: Coordinator Neighbourhood Amenity, Peter.Carrie@melville .wa.gov.au; ph. 08 9364 0647. Access Date: 9th September, 2015.

Act and Responsible Cat Ownership, however this information needs be disseminated into the community as only those searching will find it on the websites. Veterinarians have been identified as a group likely to be listened to by owners (McDonald et al. 2015). Veterinarians are already responsible for sterilisation and microchipping and can take the opportunity to introduce the other aspect of responsible cat ownership to cat owners, reaching some of the target audience (McDonald et al. 2015). However, the remainder of cat owners who do not take their cat to the vet will need to be reached in another way.

Cat owners who are not regular visitors to veterinary practices could be approached initially by leaflets in letter boxes informing cat owners of the benefits of responsible cat ownership, including the reasons for cat legislation and their obligations. The leaflets could include examples set by other cat owners in their vicinity (McHarg et al. 1995, McDonald et al. 2015) and information about care/surrendering of stray cats. This initial approach could be followed by a higher presence of rangers in the street (Van de Kuyt 2004). The initial approach will be intensive and costly, but without it, the existing cat legislation is ineffective.

In this study (Grayson et al. 2002), all measures of cat legislation enjoyed 66% or better support from all categories of the community (including owners), but owners in particular were much less enthusiastic about options for confinement of pet cats or establishment of restricted areas where they could not be owned. These controversial suggestions may nevertheless be the most effective measures for protecting wildlife because they keep cats and wildlife from interacting. For example, confining cats at night should reduce predation on nocturnal fauna, although birds and many lizards would be vulnerable by day.

Total confinement would broaden protection to all categories of fauna. Furthermore, the self-reported incidence of total confinement of pet cats in Australia is estimated at less than 10% and nocturnal confinement at up to 80% (with large variation within and between cities) (REARK 1994a, b, McHarg et al. 1995, Perry 1999, Lilith et al. 2006, Toukhsati et al. 2012), so there is considerable scope for increases in this practice. This is also likely to
be the case in many other countries (for example, over 90% of pet cats in the United Kingdom are estimated to have regular outdoor access, Sims et al. (2008)). Whereas in areas where there is a top order predator, owners are more likely to keep their cats contained (Kelly 1999, Kays & DeWan 2004).

For owners, cat welfare is the key to improving containment (Van de Kuyt 2004, Toukhsati et al. 2012, Gunaseelan et al. 2013). At the time of writing, impacts by feral cats on Australian threatened species has rated highly in the news (Lauder 2015) and could be linked to anecdotal increases in cruelty to pet cats. As found in Kays & DeWan (2004), owners are more inclined to contain their cat for the cat’s safety and this could be motivation for some owners to contain their cat/s.

Historically, law has dictated night time containment of cats in suburbia (Incoll, J. pers. comm. 2006). The introduction of this law/legislation was initially viewed as draconian and was poorly received by cat owners (Pergl 1994). However, a law and/or legislation that is supported by the community and is enforced is more likely to be successful (Vago 2009). Community support for containment laws can come from groups such as veterinarians and cat-owning neighbours who already contain their cat (for example, see the ‘I Immunize Campaign (I Immune 2015)). Generally, neighbours are keen to ‘do the right thing’ in their community (McDonald et al. 2015), and if supported by providing cat owners with the knowledge on how to contain their cats, acceptance and compliance is likely to be greater. Further, community education of the benefits of cat containment, incorporating behaviour enrichment will also aid in changing the general public perception that containment is cruel (Department of Agriculture - Government of Victoria 2015).

Evidence of the effectiveness of restrictions accompanied by education campaigns is available, although the information is generally qualitative, anecdotal or opportunistic (Anderson 1994, Penson 1995, Kelly 1999, Baker 2001, Buttriss 2001, Moore 2001, Thistleton 2015). The case of the lyrebird population in Sherbrooke Forest, Victoria, is the best documented example, although definitive interpretation is difficult because multiple
measures were implemented simultaneously (unfortunately, a common problem with *ad hoc* community responses). The population of lyrebirds in 1975 (100 to 120) was halved by 1983, with predation by pet cats implicated as a significant factor on the basis of lyrebirds injured by cats presented to wildlife carers. Following the introduction of cat curfews and other strategies such as fox control, the population has more than doubled and no lyrebird deaths have been related to cat activity (Incoll, J. pers. comm. 2006). The concurrent implementation of fox control and cat curfews confounded the interpretation of the relative importance of foxes or pet cats in the decline, although reported reductions in the number of lyrebirds presented to wildlife carers following cat attacks suggested that cats were an important part of the problem. With night time containment, hunting time is restricted to daylight hours and the prey choice of pet cats has changed to diurnal native birds. From 1988 to 1994, the numbers of diurnal native birds bought into the Sherbrooke Wildlife Shelter with cat related injuries increased from 30 to 53% (Pergl 1994). The Yarra Ranges Shire has since introduced 24 hour cat containment to further reduce the impact of pet cats on native fauna (Yarra Ranges Council 2015).

Cat containment was introduced into some new suburbs in the ACT that were in close proximity to remnant vegetation (ACT Government 2015). Acceptance by residents in the new subdivisions appear to be successful as people living outside of the cat containment areas are five times more likely to encounter problems with cats. The long term plan for the ACT is to have 24 hour containment throughout the whole territory (Thistleton 2015). At the time of the survey (2011), cat owners (25% of households) were significantly less supportive of lifetime registration, cat containment in new subdivisions and throughout the ACT, whereas the rest of the community gave a high level of support for these issues (Micromex Research 2011).

Other local councils claim to have successfully implemented more stringent restrictions such as a requirement to keep pet cats on their owners’ properties at all times (Baker 2001), declaring new sub-divisions ‘cat free’ (Buttriss 2001) and impounding cats trespassing in conservation reserves (Moore 2001). Such ‘self-reporting’ of success may be
biased by self-interest and a consequent lack of rigor in data collection or analysis, especially if a high rating is given in anecdotal reports. Nevertheless, some reports acknowledge concerns about compliance (Pert 2001, Scheele 2001) and enforcement (Pert 2001), suggesting a critical examination of relevant issues. At the least, these reports offer two practical considerations for further investigation: (i) that cat-free zones are more acceptable if enforced when a new subdivision is released (Buttriss 2001) and (ii) that a key element of success is equal emphasis on the welfare of wildlife and pet cats (Pergl 1994).

Confinement by way of devices such as cat runs and the ‘cat proof prowler’ (Bock 2015) prevents cats from wandering, keeps them safe from roads and cat fights (Rochlitz 2003a, b, 2004) and protects wildlife in remnant bushland. However, it does not remove the problem of sub-lethal effect of cats on backyard wildlife (Beckerman et al. 2007), only containment within the house, or no cat at all, will achieve this. These comments are not necessarily applicable elsewhere in Australia or internationally, where people may have different views and practices and implementation of mandatory sterilisation and caps on numbers of owned cats may not necessarily be acceptable, or might have a more substantial effect if implemented.

6.3.5 Complementing the measures: Predator deterrents, exclusion devices and alternative pets

If owners are prepared to neuter their pet cats, keep no more than two cats and licence those cats with the local council, but not to confine their cats to their property at all times, then cats and wildlife will still be in contact and hunting may still result. If legislation does not extend to compulsory confinement, then other husbandry measures that are more acceptable to owners but may reduce predation could be promoted. These include collar-worn predation deterrents, electronic devices to exclude cats from sensitive areas (or non-owners’ properties) and the promotion of alternative pets.

Recent controlled experimental studies investigating the efficacy of collar mounted
devices such as bells (Ruxton et al. 2002, Gordon et al. 2010), electronic warning systems (Nelson et al. 2005) and pounce protectors (with and without bells) (Calver et al. 2007), and Birds Be Safe (Hall et al. 2015) have shown a significant reduction in the number of prey caught by cats. Use of devices such as these may help improve the profile of free ranging pet cats, alleviate guilt of owners as well as reduce predation rates. Ruxton et al. (2002) also believe that such devices can aid in the welfare of the cat because it allows the cat freedom instead of being confined. This avoids health problems such as a documented increase in the incidence of diabetes in under-exercised and over-fed confined cats (Slingerland et al. 2009). However, this does not eliminate the problem of nuisance caused by wandering cats and the possible sub-lethal effect of cats (Beckerman et al. 2007).

For those who are bothered by trespassing cats, there are products and devices that will deter unwanted cats from entering gardens. Using the term ‘cat deterrent’ in a ‘Google’ search, several alternatives are available such as chemical sprays, motion sensors utilising water or high frequency to deter. These devices are primarily directed toward cats, but may also deter native fauna. Further, some councils allow the loan of cat traps for residents to trap ‘problem cats’ (i.e. Yarra Ranges Council 2015). However this practice is not supported by all councils (City of Stirling 2015) as it could be deemed an offence (Government of Western Australia 2002).

Alternatively, Archer (2002) and Hopwood (2002) believe that the public should have a wider choice of pet animals, including native fauna, to satisfy the need for pets, reduce the impact caused by some of the common household pets such as cats and increase conservation awareness. Hopwood (2002) argued that it is better for an individual to be kept as a pet and have life than not to live at all. In contrast, Viggers & Lindenmayer (2002) believes that using native fauna as pets is not in the best interests of native fauna on the whole. Their concerns include: transfer of zoonotic diseases, disease transfer from selectively bred animals to wild populations, interbreeding between these two groups reducing genetic fitness of species and creating a homogenous species by interbreeding of clines, and introduction of species into areas where they would not normally occur causing
problems for existing species. They are also concerned about the ability of native species to tolerate stress in captivity, especially if kept in inappropriate enclosures or social groups, and the lack of knowledge of the general public about how to look after native animals (Viggers & Lindenmayer 2002).

On balance, I feel that few, if any, Australian native animals are good matches for cats as potential pets. They would need to be playful, sufficiently independent to tolerate long daily absences of their owners and adaptable to a range of environments including confined suburban yards and possibly life indoors in apartments. If they were allowed to roam freely, nuisance problems such as fouling neighbours’ yards would still continue. Predatory animals such as quolls would still be likely to attack wildlife so the wildlife protection problem would persist. For these reasons I believe that Australian native animals are unlikely to supplant cats as favoured household pets and that predatory pressures on other wildlife might not be reduced if they did so.

6.4 Beyond cats – other issues in managing suburban wildlife

6.4.1 Scape-cat!

Stigmatising cats as the cause of wildlife decline in suburbia is attractive for several reasons. The majority of households do not own a cat, the predatory behaviour of cats is conspicuous and persecution of cats does not involve major lifestyle changes or urban planning changes for non-owners. This attitude is encouraged by the popular media. For example, in 1992 the popular Australian television program Burke’s Backyard described the pet cat as an ‘urban terrorist’ (Department of Conservation and Natural Resources Victoria 1992) and more recently the Threatened Species Strategy claimed feral cats are wholly responsible for the extinction of native marsupials and not habitat loss ‘Their threat factor was more than double that of red foxes, the next highest threat, and triple that of habitat loss and fragmentation’ (Department of the Environment 2015). Although this is aimed at feral cats, anecdotal evidence exists that the general public extrapolate the damage
caused by feral cats to domestic cats (see extreme comments arising from Doherty & Calver 2014).

6.4.2 Hard issues of urban planning

In this study, cat predation was not a significant predictor of passerine species richness or passerine community composition. Instead, sites with low housing density and areas of remnant bushland greater than five hectares in size in the vicinity supported greater species richness of passerines. This suggests that the superficial attractiveness of blaming cats detracts from other potentially significant issues that are harder to manage but are probably more important. The comprehensive literature on the effects of urbanisation on birds (Chamberlain et al. 2009 identified nearly 1,000 relevant references) and the more recent studies on the influences of garden design on bird species richness and community composition support a strong focus on issues of habitat fragmentation (especially as influenced by housing density and reserve planning) and garden design in conserving birds in suburban settings.

Careful design of cities, including urban areas is crucial to minimising their ecological impact. In Perth, the urbanisation is low grade, but its impact is spread along the Swan Coastal Plain for 150 km, resulting in isolated fragments of remnant bushland of varying sizes. In the majority of other areas, urbanisation occurs on land previously used for agriculture (Seto et al. 2010), whereas development in Perth, a global hotspot for biodiversity (Hopper & Gioia 2004), has mainly occurred in bushland that has been fully cleared. The size of remnants has been proven to be of importance to conserving biodiversity, but so too is the length of time and the history of the remnant since isolation (Hahs et al. 2009). For example, in Perth, Western Australia, species richness in small remnants of Banksia woodland was halved in less than a few decades since isolation with the species richness of the herbaceous layer in these smaller remnants being mostly affected (Ramalho et al. 2014). Structural complexity of vegetation is essential for maintaining the
species richness of avifauna (Hodgson et al. 2006, Ashley et al. 2009), hence the importance of long term planning and management of remnants.

Small remnants, with complex structural vegetation can still provide significant benefits for many species of avifauna (Hodgson et al. 2006). However, some of the smaller avian insectivores are either absent or in very small numbers (Piper & Catterall 2003, Hodgson et al. 2006). Factors such as roads (Wood & Recher 2004, Tremblay & St Clair 2009), use of pesticides/insecticides (Mitra et al. 2011), (but the use of pesticides may be beneficial for some species by reducing the incidence of nest parasites, see Evans et al. 2009b), food availability (Gibb & Hochuli 2002), predators (Matthews et al. 1999), competitors (Kath et al. 2009), lack of refuge for protection (Kath et al. 2009) and nesting opportunities (Rayner et al. 2015) do play roles in bird species’ life histories that cause them to be sensitive to urbanisation. Many of these factors can be accommodated for in urban areas, which leads us to look at gardens throughout suburban areas.

Loss of natural vegetation in countries such as the UK (and probably much of Europe as well) has been a gradual process over centuries and biodiversity has decreased over this time too, but a tenuous balance has been reached with species utilising remnant woodland, hedgerows, fields and suburban gardens. Thus English and European urban gardens provide refuges, food and other resources for birds, including threatened and red listed avifauna (Cannon 1999, Ruxton et al. 2002). Davies et al. (2009) observed that 87% of UK homes have a garden of an average size of 190 m². These gardens provide up to 3.5 million ponds and 287 million trees, representing approximately 25% of trees in the UK outside woodlands. Furthermore, residents have installed an estimated 4.7 million nest boxes and approximately half of all households (including those without gardens) provide supplementary feed for birds. Supplementary feeding, especially when coupled with gardens of higher structural complexity, promote complexity in bird assemblages within the UK. But further clearing, increased housing density and the shift to smaller gardens is further impacting biodiversity by leading to fewer, smaller gardens supporting fewer landscape elements, especially trees and vegetation contributing to canopies above 2 m high (Gaston et al. 2007, Loram et al. 2011).
In Australia, where less of the total landscape is intensively modified by humans (Dunn et al. 2006), suburbia is described not as a resource but as a ‘sink’, where mortality exceeds recruitment for some forms of wildlife (Recher 2004), but a source for others (Evans et al. 2015). Variation in garden characteristics and local habitat does substantially affect the nature of garden bird assemblages (Daniels & Kirkpatrick 2006). For example, Parsons et al. (2009) identified characteristics of suburban vegetation that supported populations of the Superb Fairy-wren (*Malurus cyaneus*) in New South Wales. Thus gardens could be planned to favour desired species and species assemblages and gardeners can contribute significantly to conserving birds in suburbia (Burghardt et al. 2009, Evans et al. 2015). However, the current trend in Australia and the UK is for reduced lot size in new subdivisions and subdivision in established suburbs resulting in an increase in impermeable surfaces and reduction in garden vegetation and structural complexity (Hall 2010).

Aside from the impact to biodiversity, this loss of vegetation has implications including temperature control, carbon storage, filtering of pollutants, minimising storm water run-off, and erosion and provision of refuge for native fauna etc. (Hall 2010). To help combat this, initiatives such as the Urban Forest Strategy (Department of Planning and Infrastructure WA 2014) are being implemented to map and monitor the canopy coverage throughout suburban Australia, including road verges, parks, private lands and remnant bushland. This initiative encourages developers to preserve existing trees and plant new mature trees. However, trees alone do not add to the structural complexity required for many species to survive in suburbia. Also, the choice of trees recommended by the Urban Forest Management include exotic species that do not support native arthropods and hence provide food for avian insectivores (Burghardt et al. 2009, but see Waite et al. 2013 for species that can adapt to incorporate the arthropods found in exotic trees).

Collaboration is needed between urban planners and urban ecologists to identify focal species that can realistically survive in urban environments and plan for these species. It must be acknowledged that not all native avifauna can be accommodated in the urban environment because of their inability to adapt or cope with urbanisation, but the species that can adapt/survive could be provided for in terms of provision of structurally and species rich vegetation that provides refuge, food and nesting requirements. Additionally,
work by researchers such as Dunn et al. (2006), Kirkpatrick et al. (2007), Luck et al. (2009), and van Heezik et al. (2013) provide insight into the individual traits of gardeners to determine the best way to approach the community to aid in conserving urban biodiversity. Strategies to conserve urban biodiversity may include: containment of introduced predators such as cats in cat runs and managing aggressive avian exotic species and avian native urban colonists by manipulating habitat – i.e. planting of complex vegetation to reduce their preferred habitat such as the Noisy Miner in eastern states of Australia (Ashley et al. 2009).

6.5 Concluding remarks

Burgin (2004) proposed a ‘year 2020 vision’ where Australian urban gardens are transformed into a refuge for fauna. These gardens would contain indigenous vegetation including native grasses that do not require mowing, pesticide or fertilisers, contributing to the flow on effects of reducing carbon emissions, reducing the pollution of ground water and water runoff and greatly reducing the use of scheme water and groundwater for thirsty alien vegetation. It is a wonderful vision, but attaining it will involve far more effort and changes in attitudes than regulating cat ownership.

Habitat variables are the key to conserving suburban passerines. Educating residents and local governments respectively as to the benefits of revegetation and conservation of land ranging from local, through to patch and landscape level, will allow suburbia to act as corridors for many species to move between remnants and reduce the ‘sink effect’ of suburbia. Although this study found that cats did not impact suburban passerines it also found that a substantial majority of Perth suburban residents, including cat owners, desired cat regulations enforcing sterilisation and restrictions on the number of cats/household. If such regulations were enforced, cat densities could be contained and predatory pressures reduced. Compulsory containment of cats on their owners’ properties was not supported widely across the community. However, education of cat owners and the general community that 24 hour containment improves cat welfare by reducing the incidence of injury from fighting, road trauma and cat cruelty is the way to change behaviours of the cat owning community.
List of Appendices

Appendix A: An information-theoretic approach to factors determining the species richness of passerines in Perth suburban gardens

Appendix B: Responses to specific queries related to data chapters

Appendix C: The full survey used in Chapter V
An information-theoretic approach to factors determining the species richness of passerines in Perth suburban gardens

Introduction

The setwise regression approach used in chapter IV to explore relationships between environmental variables and the species richness of birds observed in suburban Perth domestic gardens has now fallen from favour compared to model-testing approaches based on the Akaike Information Criterion (AIC) (see Burnham & Anderson 2002 for a detailed exposition, Stephens et al. 2007 for ecological applications, and Garamszegi 2011 for an account applicable to behavioural ecology). Rather than attempt to identify a ‘best model’ through regression approaches, AIC simultaneously tests several alternative models, ranking them in terms of explanatory power in relation to the dependent variable under investigation. Inferences are based on the model set rather than just one model, which is valuable when the comparison of competing models does not show one to be clearly superior. The explanatory power of each model in the set is indicated by its AIC value, so ranking the AIC values indicates the relative explanatory power of the models. The model with the lowest AIC value has the best explanatory power within the model set, although models differing only slightly in AIC should not be discounted. Without reference to other models in the set, a single AIC value is uninterpretable (Symonds & Moussalli 2011).

The term AIC is often used generically to embrace either the AIC itself or a derivation to correct for an issue in a particular analysis. For example, the AICc correction is recommended for small sample sizes (a rule of thumb is that the AICc is appropriate where the sample size divided by the number of parameters in the largest model is less than 40). Another common correction is the QAIC, which corrects for problems of severe over dispersion in data (for example, as can occur in count data where many observations are zero). This can also be corrected for small sample sizes to give the QAICc (Symonds and Moussalli 2011).
As well as the AIC or $AIC_c$, reporting the results of AIC analyses commonly includes:

- $AIC_c$ differences ($\Delta i$) – (the difference between any particular $AIC_c$ and the smallest $AIC_c$ observed)
- Akaike weights – the relative likelihood of a model or, to put it another way, the probability that the model would come out with the smallest $AIC_c$ if the study was repeated with an equal sample size
- Cumulative Akaike weights – the sum of the Akaike weight for a particular model and all models above it
- Odds ratios – the Akaike weight for the best model divided by the Akaike weight for another specified model, thus indicating the relative likelihood of different models occurring
- Parameter weights – the sum of the Akaike weights for all models in the analysis that include a particular parameter (predictor).

When interpreting models there is considerable debate over whether or not particular models can be discounted altogether as having too little explanatory power to warrant further consideration. Rules of thumb proposed for decision making focus on AIC differences, with values less than 2 being considered as valid as the top ranked model and those greater than 10 implausible relative to the top ranked model (Burnham & Anderson 2002). Between those extremes, Richards (2005) suggests that models with AIC differences up to 6 should be considered seriously. Alternatively, Burnham & Anderson (2002) propose ranking models in order of increasing AIC and including those models with cumulative Akaike weights of 0.95 or less (effectively, a 95% confidence limit for the best model).

A common approach in behavioural ecology is to take an all-subset approach (Symonds & Moussalli 2011), also called a best subsets approach (Statsoft Inc 2013), in which an AIC is calculated for all possible combinations of variables and the intercept, as opposed to explicitly testing a priori choices. The all-subset approach is discouraged
Appendix A

by some as “data dredging” (e.g., Burnham & Anderson 2002), but accepted by others as an exploratory or hypothesis-generating approach (Symonds & Moussalli 2011).

When multiple models are plausible, a model averaging approach may be employed to derive weighted averages of parameters and their error estimates across several models (Burnham & Anderson 2002). Natural averaging is appropriate where the case for one model is strong but a little uncertain, while full-model averaging is best suited to situations where the best model(s) selection is unclear (Symonds & Moussalli 2011).

Given the increasing use of AIC approaches in behavioural ecology, in this appendix I revisit the analyses reported in chapter IV using AIC. My aim was to determine if the original conclusions were robust following AIC analysis. To do so I used an all-subset approach, treating the analysis as exploratory and stopping short of model averaging given that my objective was to indicate the relative likelihood of plausible predictors as being strong explanations for bird species richness in suburban Perth.

Methods

This was an exploratory analysis with no specific hypotheses, in which each of the predictor variables log$_{10}$ housing density, log$_{10}$ distance to nearest bushland greater than 5 ha, suburb age, log$_{10}$ dog density and cat density could reasonably be expected to influence the species richness of birds observed in suburban gardens. Therefore I used an all-subset approach based on the AIC$_c$ (allowing for small sample sizes) to determine which predictors or combination of predictors best explained the dependent variable of bird species richness. I checked for multicollinearity involving predictor variables using the Variance Inflation Factor (VIF), adopting the rule of thumb recommended by Zuur et al. (2007, p. 570) that values greater than five were problematic. Models based on the normal distribution and the identity link function gave the best model fit and these are reported. I report AIC$_c$, AIC$_c$ differences, Akaike weights, and odds ratios for the 95% confidence set of best-ranked models (the models whose cumulative Akaike weight
≤ 0.95), as well as parameter weights, estimates (with standard errors) and Wald statistics for each predictor. All analyses used the Statistica software (Statsoft 1999).

**Results**

Bird species richness was predicted most strongly by housing density. This variable featured in all models in the 95% confidence set of best-ranked models in each case (Table A4.1) and gave the largest parameter weight (Table A4.2). The estimate was negative, indicating that bird species richness increased as housing density fell (Table A4.2). The next most influential predictor, judged by parameter weight, was distance to nearest bushland. The estimate was negative, so bird species richness fell with increasing distance to nearest bushland (Table A4.2). However, this predictor also had the greatest standard error on its estimate (Table A4.2). Cat density did not occur in any model with an AIC<sub>c</sub> difference of less than 2 (Table A4.1), although it did occur in some models with an AIC<sub>c</sub> difference between 2 and 10 (Table A4.2). Its parameter weight was negative, low relative to other predictors. VIF values for predictor variables ranged from 1.12 – 1.41, so no adjustments for multicollinearity were required.

**Discussion**

The setwise regression approach reported in the main chapter identified housing density, distance to nearest bushland, and the size of nearest bushland as the main predictors of bird species richness in suburban Perth. Cat density was not a significant predictor. The all-subsets approach using AIC<sub>c</sub> employed in this appendix supports key elements of those conclusions. Housing density and distance to nearest bushland emerged as important predictors, while cat density was not a strong predictor. Contrary to the results in the main chapter, size of the nearest bushland was not a major factor. Overall, I conclude that the key findings of no strong relationship between cat density and bird species richness in the gardens of suburban Perth and bird species richness declining with distance to nearest bushland are valid.
Appendix A

Table A4.1  95% confidence set of best-ranked models (the models whose cumulative Akaike weight, \( acc w_i \leq 0.95 \)) examining relationships between environmental variables and the species richness of birds found in suburban gardens in Perth.

<table>
<thead>
<tr>
<th>Candidate models</th>
<th>( k )</th>
<th>( \text{AIC}_c )</th>
<th>( \Delta i )</th>
<th>( w_i )</th>
<th>( acc w_i )</th>
<th>Odds</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNB + HD</td>
<td>4</td>
<td>314.75</td>
<td>0.00</td>
<td>0.25</td>
<td>0.25</td>
<td>1.00</td>
</tr>
<tr>
<td>DNB + SNB + HD</td>
<td>5</td>
<td>315.45</td>
<td>0.70</td>
<td>0.18</td>
<td>0.43</td>
<td>1.42</td>
</tr>
<tr>
<td>DNB + HD + AS</td>
<td>5</td>
<td>316.76</td>
<td>2.01</td>
<td>0.09</td>
<td>0.52</td>
<td>2.73</td>
</tr>
<tr>
<td>CD + DNB + HD</td>
<td>5</td>
<td>316.99</td>
<td>2.24</td>
<td>0.08</td>
<td>0.60</td>
<td>3.07</td>
</tr>
<tr>
<td>DD + DNB + HD</td>
<td>5</td>
<td>317.13</td>
<td>2.37</td>
<td>0.08</td>
<td>0.68</td>
<td>3.28</td>
</tr>
<tr>
<td>DNB + SNB + HD + AS</td>
<td>6</td>
<td>317.64</td>
<td>2.89</td>
<td>0.06</td>
<td>0.74</td>
<td>4.23</td>
</tr>
<tr>
<td>CD + DNB + SNB + HD</td>
<td>6</td>
<td>317.91</td>
<td>3.16</td>
<td>0.05</td>
<td>0.79</td>
<td>4.86</td>
</tr>
<tr>
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<td>6</td>
<td>317.95</td>
<td>3.20</td>
<td>0.05</td>
<td>0.84</td>
<td>4.95</td>
</tr>
<tr>
<td>CD + DNB + HD + AS</td>
<td>6</td>
<td>319.06</td>
<td>4.31</td>
<td>0.03</td>
<td>0.87</td>
<td>8.64</td>
</tr>
<tr>
<td>DD + DNB + HD + AS</td>
<td>6</td>
<td>319.26</td>
<td>4.51</td>
<td>0.03</td>
<td>0.90</td>
<td>9.52</td>
</tr>
<tr>
<td>CD + DD + DNB + HD</td>
<td>6</td>
<td>319.43</td>
<td>4.68</td>
<td>0.02</td>
<td>0.92</td>
<td>10.38</td>
</tr>
<tr>
<td>CD + DNB + SNB + HD</td>
<td>7</td>
<td>320.18</td>
<td>5.43</td>
<td>0.02</td>
<td>0.94</td>
<td>15.09</td>
</tr>
</tbody>
</table>

HD = \( \log_{10} \) housing density, DNB = \( \log_{10} \) of distance to nearest bushland, SNB = \( \log_{10} \) size of nearest bushland > 5 ha, AS = age of suburb, DD = \( \log_{10} \) dog density, CD = cat density

Table A4.2  Parameter weights and estimates examining relationships between environmental variables and the species richness of birds found in suburban gardens in Perth.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter weight</th>
<th>Estimate</th>
<th>Standard error</th>
<th>Wald statistic</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td></td>
<td>25.578</td>
<td>2.927</td>
<td>88.770</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>HD</td>
<td>1.00</td>
<td>-7.046</td>
<td>1.542</td>
<td>20.865</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>DNB</td>
<td>0.98</td>
<td>-11.473</td>
<td>3.332</td>
<td>11.850</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>SNB</td>
<td>0.40</td>
<td>-1.313</td>
<td>1.077</td>
<td>1.487</td>
<td>0.222</td>
</tr>
<tr>
<td>AS</td>
<td>0.37</td>
<td>-0.013</td>
<td>0.022</td>
<td>0.325</td>
<td>0.568</td>
</tr>
<tr>
<td>DD</td>
<td>0.23</td>
<td>0.094</td>
<td>1.579</td>
<td>0.004</td>
<td>0.952</td>
</tr>
<tr>
<td>CD</td>
<td>0.23</td>
<td>-0.049</td>
<td>0.190</td>
<td>0.067</td>
<td>0.800</td>
</tr>
</tbody>
</table>
Responses to specific queries related to data chapters

Some statistical or interpretation queries were raised regarding published chapters of the thesis. To keep the text of the thesis identical to the published chapters, those queries are dealt with separately here. Each query is presented, together with a response.

Chapter V

Query 1

I would like to see more explanation here of what was done to obtain the rho value reported in the results. For example, I’m not sure how matrices based on Euclidean distances could be calculated for all the environmental variables combined.

Response

A series of analyses was performed: (i) the similarity of sites was determined based on their bird community composition, (ii) the similarity of sites was determined based on the environmental variables measured at each site, and (iii) the similarities in (i) and (ii) were then compared to give the Rho value reported. My co-authors and I reasoned that, if bird community composition responded to a complex of interactions involving the environmental variables, then Rho would be significant. It was not. However, as explained in the chapter, when sites grouped by each individual environmental variable were compared to bird community composition, then four environmental variables were found to be significant.

Query 2

The bird species have been divided into functional groups, but there is nothing in the chapter to indicate how you expected the different functional groups to fare. Also, what about cat home ranges?

Response

Functional groups: Functional groups as defined were not expected to respond strongly to cat predation, because the dominant reasons for their local persistence or decline in suburbia are believed to be related to availability of food and breeding
resources, which cannot be provided sufficiently by small suburban lots (Freudenberger et al. 1997, Watson et al. 2001). Individual species were expected to respond more strongly, based mainly on the extent to which they foraged on the ground.

Cat home ranges: Home ranges were not measured in this study, so speculation on them has been kept to a minimum. It is difficult to assess individual hunting behaviours and tease out impacts of cats in suburbia, including cat density and home ranges, leading to the conclusion that cats should be restricted to their owner’s property to reduce the possible impact and to eliminate the sub lethal effect cats may exert.

Query 3

The caption of Table 4.3 requires more explanation of the contents of the table: it is rather difficult to interpret.

Response

A revised legend is:

Table 4.3 Results of setwise regression and simple linear regression for predicting bird species richness from the eight core predictor variables. The simple linear regressions test for the significance of a single independent variable. The first setwise column shows all four independent variables included in the best fitting multiple regression, each with a separate test of significance. These values are based on the complete data set. The second setwise column gives the results of separate t-tests for the significance of each variable based in each of two subsets produced by randomly splitting the original data file.

Chapter V

Query 1

I’m not convinced about the validity of removing the 37 outliers exhibiting extreme values. In fact I think it is interesting that they were almost all non-owners of cats. I could imagine, and it is my experience, that some people feel very strongly about cats and their habit of preying on wildlife, and these people do not own cats. If the
answers they made were consistent, then it would be wrong to describe their responses as frivolous and exclude them from the survey.

**Response**

The cases were removed because examination of the individual surveys indicated selection of extreme cases (either all strongly agree or all strongly disagree) for a particular section or, in some cases, across the entire survey. Given that some items were reversed within a section (*i.e.* to be consistent in opinion, one would expect a ‘strongly agree’ for one item and a ‘strongly disagree’ for the reversed partner) the patterns were unlikely to be a considered response to items by someone with extreme views.

However, as a test of the effect of excluding these values the analysis was rerun with the extreme values included. The conclusions were unchanged: Age, Gender, Cat Ownership and the Gender x Ownership interaction remained significant in the MANOVA (compare the Table below with Table 4.3 in the main text).

<table>
<thead>
<tr>
<th>Effect</th>
<th>Rao’s R (df1, df2)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>2.26 (8, 2314)</td>
<td>0.021</td>
</tr>
<tr>
<td>Gender</td>
<td>3.28 (4, 1157)</td>
<td>0.011</td>
</tr>
<tr>
<td>Cat ownership</td>
<td>70.60 (4, 1157)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age x gender</td>
<td>0.70 (8, 2314)</td>
<td>0.692</td>
</tr>
<tr>
<td>Age x ownership</td>
<td>0.44 (8, 2314)</td>
<td>0.895</td>
</tr>
<tr>
<td>Gender x ownership</td>
<td>3.11 (4, 1157)</td>
<td>0.014</td>
</tr>
<tr>
<td>Age x gender x ownership</td>
<td>0.67 (8, 2314)</td>
<td>0.714</td>
</tr>
</tbody>
</table>

Examination of the univariate tests showed that Age was significant for attitudes to control, Gender was significant for attitudes to control and sterilisation, Cat Ownership was significant for attitudes to control, wildlife and knowledge, and the Gender x Ownership interaction was significant for sterilisation and knowledge.

Thus irrespective of views on the validity of excluding the extreme cases, the conclusions remain unchanged either way.
Appendix C

The full survey used in Chapter V

INSTRUCTIONS
- At the beginning of each section, a brief explanation has been provided as to the reasons behind each heading.
- When answering the questions below, please give YOUR INITIAL REACTION and circle the most appropriate answer.
- Please use “I don’t know” ONLY when you have no opinion on the issue.
- At the end of each section, a space has been provided should you wish to make any comments.

RESTRICTIONS TOWARDS CATS

Some people feel that restrictions should be placed on cat ownership to prevent cats being a nuisance to neighbours and wildlife. The restrictions may also help to protect cats from fighting or being run over. Other people feel that such restrictions are inhumane, unnecessary and difficult to enforce. Please give us your opinion by answering the questions below.

1. There is a need for cat legislation.
   a) strongly disagree    b) disagree    c) agree    d) strongly agree    e) I don’t know

2. Are you aware of any areas within Australia where cats must be licensed.
   a) yes    b) no    c) I don’t know

3. Cats can be kept within the boundaries of their owner’s property.
   a) yes    b) no    c) I don’t know

4. All cats should be kept in at night time (curfewed).
   a) strongly disagree    b) disagree    c) agree    d) strongly agree    e) I don’t know

5. Cats should be kept on their owner’s property or, if on a farm, to the area immediately around the house at all times.
   a) strongly disagree    b) disagree    c) agree    d) strongly agree    e) I don’t know

6. To stop cats from attacking wildlife, cats should be kept on their owner’s property or, if on a farm, to the area immediately around the house at all times.
   a) strongly disagree    b) disagree    c) agree    d) strongly agree    e) I don’t know

7. To reduce the number of cats being hit by cars, cats should be kept on their owner’s property or, if on a farm, to the area immediately around the house at all times.
   a) strongly disagree    b) disagree    c) agree    d) strongly agree    e) I don’t know

8. All cats should be licensed with the council in the same way as dogs are.
   a) strongly disagree    b) disagree    c) agree    d) strongly agree    e) I don’t know

9. People that breed and sell cats should be licensed.
   a) strongly disagree    b) disagree    c) agree    d) strongly agree    e) I don’t know
10. Local governments should be responsible for enforcing cat control.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

11. The increased costs for cat control should be covered by increasing council rates/taxes.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

12. Authorised enforcement officers (rangers) should have the power to impound nuisance cats.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

13. Rangers should have the authority to pick up and impound any cats seen roaming on the streets.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

14. Rangers should have the power to put to sleep (euthanase) impounded and unclaimed cats.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

15. Local governments should have the power to limit the number of cats per household.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

16. The maximum number of cats per household should be
   a) unlimited  b) one to two cats  c) no cats  d) don’t know

17. Local governments should have the power to establish cat free zones in new subdivisions.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

18. Owners of pet cats have:
   a) a higher risk of heart attack compared to the general population
   b) a moderate risk of heart attack compared to the general population
   c) just as much at risk of a heart attack as the general population
   d) less risk of heart attack compared to the general population
   e) much reduced risk of heart attack compared to the general population

19. How do you feel about pet cats?
   a) cats are a wonderful animal
   b) cats are okay
   c) I don’t like cats
   d) cats should be prohibited as pets

COMMENTS

WILDLIFE

Many people believe that cats are one of the major contributors to the decline of wildlife (i.e. furred animals such as possums, birds, lizards, frogs etc.) in the rural towns and on farms. Others feel that the real problems are elsewhere and cats are being used as a scapegoat. Please tell us your views by answering the following questions.
20. It is important to have wildlife (i.e., furred animals, birds, lizards, frogs, etc.) in rural towns and around your farm house.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

21. Domestic cats killing wildlife in rural towns is a serious problem.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

22. Domestic cats on farms are harmful to wildlife.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

23. Domestic cats in nature reserves are harmful to wildlife.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

24. Do you think that cats hunt more during the daytime or nighttime?
   a) daytime  b) nighttime  c) I don’t know

25. Domestic cats hunt less if they are well fed.
   a) yes  b) no  c) I don’t know

26. A desexed cat is less likely to hunt than a cat which has not been desexed.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

27. It should be illegal to keep a cat as a pet in Australia.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

28. A bell worn by a cat is effective in alerting prey.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  I don’t know

29. In Western Australia, diseases transmitted from cats to people and animals occurs
   a) very commonly  b) commonly  c) rarely  d) very rarely  e) not at all  f) I don’t know

30. All pet cats should be declawed (have their claws removed).
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

COMMENTS

_____________________________________________________________________

_____________________________________________________________________

STERILISATION

Some believe that by sterilising all pet cats, the impact to wildlife will be lessened, there will be fewer unwanted cats/kittens and pet cats will be less of a nuisance to neighbours. Others feel that unwanted sterilisation may be inhumane and could change the value of cats as pets. Please tell me how you feel about this issue by answering the questions below.
31. Excluding a cat/s that is owned by a breeder, all cats should be desexed.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

32. Only male cats should be desexed.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

33. Only female cats should be desexed.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

34. Female cats should be allowed to have a litter of kittens before they are desexed.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

35. Female kittens can first reproduce at:
   a) 0 - 3 months of age  b) 4 - 7 months of age  c) 8 - 10 months of age  d) 11 months and over  e) I don’t know

36. The cost of desexing a female cat is:
   a) $20.00 to $40.00  b) $41.00 to $60.00  c) $61.00 to $90.00  d) $91.00 or more? e) I don’t know

37. The cost of desexing a male cat is:
   a) $20.00 to $40.00  b) $41.00 to $60.00  c) $61.00 to $90.00  d) $91.00 or more? e) I don’t know

38. The cost of having a cat desexed is reasonable.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

39. Only a registered veterinarian should desex cats.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

40. Desexed cats fight less.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

41. Desexed cats are less likely to wail.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

42. Desexed cats are less likely to roam.
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know

43. Desexed male cats are less likely to spray (territory marking).
   a) strongly disagree  b) disagree  c) agree  d) strongly agree  e) I don’t know
Appendix C

COMMENTS


AND NOW FOR SOME QUESTIONS ABOUT YOU.

People’s experience and attitudes towards cats varies with their upbringing, occupation, age and other factors within their lives. Please answer the following questions by circling the appropriate answer.

44. How old were you when you or your family first owned a cat?
   (if you or your family have never owned a cat, please write “never”)_____

45. Which age group do you fit in?
   a) 18 - 34 years
   b) 35-54 years
   b) over 54 years

46. Does your current occupation involve working with animals (eg. farming, vet, breeding, training/handling/ranger etc.)
   a) yes  b) no

47. What is your current occupation?
   a) clerical worker
   b) crafts-worker
   c) farmer, farm manager or farm labourer
   d) home-maker
   e) machine operator or labourer
   f) manager or administrator
   g) military/armed forces
   h) professional or technical
   i) retired
   j) service worker or private household worker
   k) sales worker
   l) student
   m) unemployed/looking for work
   n) other, please specify______________________________

48. Have you ever taken, or are you undertaking, any courses which involve topics such as environmental issues, animal studies etc?
   a) yes  b) no

49. Which of the following best describes your highest educational level?
   a) completed Year 10 at high school
   b) completed Year 12 at high school
   c) completed/completing diploma at TAFE
   d) completed/completing degree at university
   e) post graduate studies at university
   f) other, please specify______________________________

50. Has your own opinion toward cats altered in any way in the last 10 years?
   (if yes, how?)________________________________
Appendix C

51. Are you
   a) male   b) female

52. What is your postcode? __________

53. Do you live in a rural town or on a farm? __________

54. Do you live in
   a) close proximity to natural bushland
   b) a suburban area removed from bushland
   c) intensive farmland
      removed from bushland
   d) other, please specify __________

55. How many cats do you have?
   a) none   b) one   c) two   d) three   e) four or more

If you don’t own a cat, there is no need for you to continue with the survey. Thank you very much for your valuable assistance. The time that you have taken is most appreciated. Please place the survey in the self addressed envelope and post.

COMMENTS (if more room is required, please do not hesitate to attach another sheet of paper). ____________________________

If you own a cat/s, please complete the rest of the survey.

If you own more than one cat, please answer each question for each cat. For example, in the following question: “has your cat been desexed?”, if one cat is desexed and the other is not, then circle both yes and no for the following question.

56. Has your cat/s been desexed?
   a) yes (please go to Q 59)
   b) no  (please go to Q 57)

57. If not, what was the reason?
   a) you don’t see the reason
   b) you want to, or do breed from your cat/s
   c) you haven’t gotten around to it
   d) it is too expensive
   e) you are worried that your cat’s personality may change and it may get fat.
   f) other ____________________________

58. If it became compulsory to have pet cats desexed, would you have your cat desexed?
   a) yes
   b) no
   c) unsure, if so why? ____________________________

59. If your cat/s has been desexed, about what age was he/she when the operation was performed?
   (if you have more than one cat and they were desexed at different ages, circle all the appropriate age groups.)
   a) 6 to 10 months
   b) 11 to 15 months
   c) more than 15 months
   d) my cat was already desexed when I got him/her
   e) I don’t know
Appendix C

60. Does your cat/s live:
   a) solely inside
   b) solely outside and free roaming
   c) solely inside during the night, but free roaming during the day
d) inside and outside, but restricted to my property
   e) inside and outside, but free roaming.

61. I would be happy to keep my cat/s confined (either indoors or in a run) between sunset to sunrise?
   a) yes   b) no   c) I don’t know

62. I would be happy to keep my cat/s confined (either indoors or in a run) at all times?
   a) yes   b) no   c) I don’t know

63. Would you keep your cat/s in at night time if it became compulsory?
   a) yes   b) no   c) I don’t know

64. Would you license your cat/s with the council if it became compulsory?
   a) yes   b) no   c) I don’t know

65. Does your cat/s wear any identification on his/her collar?
   a) yes   b) no   c) sometimes

66. Has your cat/s had his/her yearly vaccinations?
   a) yes   b) no   c) I don’t know

67. Does your cat/s wear a bell on his/her collar?
   a) yes   b) no   c) sometimes

68. Do you use any methods of flea control on your cat/s (ie. flea collar, flea powder, herbal flea repellent etc.)?
   a) yes   b) no   c) sometimes

69. When you last went away on holiday, what arrangements did you make for your cat?
   a) a friend or neighbour comes in to feed my cat.
   b) I leave food out for my cat.
   c) the situation has never arisen.
   d) I take my cat with me on holiday.
   e) my cat goes to a cattery (boarding kennel for cats).
   f) I had someone stay in the house to look after my cat and the house.
   g) other ________________________________

70. Has your cat/s caught any
   a) mice or rats
   b) other furred animals
   c) birds
   d) lizards or snakes (you may circle more than one choice)

(if you answered “yes” to any of these animals, please continue with Q 71, if you answered “no”, the please go to Q 75)

71. If your cat/s has caught any mice or rats during the last two weeks, how many might that be? __________________________ (per cat)
72. If your cat/s has caught any *other mammals* during the two weeks, how many might that be? ___________ (per cat).

   Do you know what species were caught – possums, phascogale, native mice or others?

   ____________________________________________

73. If your cat/s has caught any *birds* during the last two weeks, how many might that be? ___________ (per cat)

   Do you know what species were caught or whether native or introduced?

   ____________________________________________

74. If your cat/s has caught any *lizards or snakes* during the last two weeks, how many might that be? ___________ (per cat)

75. What type of food do you mainly feed your cat/s?
   a) fresh food (ie. fish, chicken)
   b) tinned cat food
   c) scraps
   d) dried food
   e) other, please state ________________________________

76. What is your major reason for owning a cat?
   a) companion animal
   b) vermin control
   c) it was given to me or I inherited it from someone else
   d) commercial breeder
   e) other, please state ________________________________

   COMMENTS (if more room is required, please do not hesitate to attach another sheet of paper).

   ____________________________________________

   ____________________________________________

   ____________________________________________
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