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## Biological Conservation

journal homepage: [www.elsevier.com/locate/biocon](http://www.elsevier.com/locate/biocon)

## How many birds are killed by cats in Australia?



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## ARTICLE INFO

## Keywords:

Conservation

Diet

Introduced predator

Island

Mortality

Predation

## ABSTRACT

From analysis of results from 93 studies on the frequency of occurrence of birds in cat dietary samples, and a recently published assessment of the population size of feral cats in largely natural landscapes, we estimate and map the number of birds killed annually in Australia by feral cats. We show that average rates of predation on birds by cats on islands are ca. 10 times higher than for comparable mainland areas. Predation rates on birds are also relatively high in hot, arid regions. Across Australia's natural landscapes, feral cats typically consume 272 million birds yr<sup>-1</sup> (95% confidence interval [CI]: 169–508 million). However, there is substantial inter-annual variation, depending on changes in the cat population that are driven by rainfall conditions: ranging between 161 million birds yr<sup>-1</sup> (95% CI: 114–284 million) following dry periods and 757 million birds yr<sup>-1</sup> (95% CI: 334–1580 million) following wet periods. On average, feral cats kill 35.6 birds km<sup>-2</sup> yr<sup>-1</sup> (95% CI: 22.2–66.6). About 99% of these mortalities are native bird species. With a much sparser evidence base, we also estimate that a further 44 million birds are killed annually by feral cats in highly modified landscapes, and 61 million birds are killed annually by pet cats, summing to 377 million birds killed yr<sup>-1</sup> (i.e., just over 1 million birds per day) by all cats. Feral cats include a significantly higher proportion of birds in their diet than do other main mammalian predators. The national tally of birds killed by cats in Australia is broadly comparable to recent assessments for Canada, but less than that reported for the United States (because the cat population is much higher there). However, it remains challenging to interpret this mortality tally in terms of population viability or conservation concern for Australian birds.

## 1. Introduction

“Of all bird–mammal interactions, that of the domestic cat catching and killing a bird is probably the most familiar” (Mead, 1982) [p. 183]. Notwithstanding the familiarity of this act, the extent to which cats *Felis catus* present a conservation threat to birds in continental areas is poorly resolved, although it is increasingly apparent that predation by pet and feral cats is a major cause of mortality for bird species in many areas (Loss et al., 2012, 2013, 2015; Marra and Santella, 2016). In Australia, since their first introduction in 1788, feral cats have spread to now occupy the entire continent and most larger islands (Legge et al., 2017), and have been implicated in the decline and extinction of many

native mammal species (Woinarski et al., 2015). The control of feral cats in Australia has recently become a priority for conservation policy and management (Commonwealth of Australia, 2015; Department of the Environment, 2015). Although there have been some general reviews of impacts of cats on Australian wildlife (Abbott et al., 2014; Denny and Dickman, 2010; Dickman, 1996, 2009, 2014; Doherty et al., 2017; Paton, 1993) and a series of important studies of the ecology (including diet) of feral cats (Coman and Brunner, 1972; Doherty et al., 2015; Jones and Coman, 1981; Kutt, 2011; Paltridge, 2002; Pavay et al., 2008; Read and Bowen, 2001; Yip et al., 2014), there has been no assessment of the extent of losses of birds due to cat predation at a continental scale in Australia.

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One of the first dietary studies of cats in Australia concluded that their impacts on birds were likely to be minor:

“The common belief that feral cats are serious predators of birds is apparently without basis. Although birds were common in all sampling areas, they were a relatively minor item in the diet [of feral cats]. Presumably, other factors such as difficulty of capture are responsible for the low intake of birds”

(Coman and Brunner, 1972) [pp. 852–853].

There have been many comparable dietary studies since, such that this interpretation can be re-assessed now with substantially more evidence. In this paper, we collate studies reporting the frequency of occurrence of birds in the diet of feral cats, and combine those data with information from a recent review that estimated the population size of feral cats in Australia (Legge et al., 2017), to derive an estimate of the annual number of birds killed in Australia by feral cats. This approach broadly follows those used to derive national tallies of birds killed by cats in the United States (Dauphiné and Cooper, 2009; Loss et al., 2013; Pimentel et al., 2005) and Canada (Blancher, 2013), although our analysis is based on many more local-scale studies than any previous assessments. Our focus is on the number of individual birds killed, rather than tallies for individual bird species, because many of the studies collated here reported the total frequency of birds in the diet of cats, but did not identify birds to species.

There are several interpretational caveats in our assessment. In Australia, the density of feral cats varies markedly over time, with notable increases in cat density in arid and semi-arid areas after periods of high rainfall and subsequent irruption of key mammalian prey (Dickman et al., 2014; Legge et al., 2017; Read and Bowen, 2001), such that predation pressure (and hence impacts) by feral cats on birds may be highly variable. Predation pressure by feral cats on birds may respond not only to such dynamic variation in the densities of cats and their main prey sources associated with temporal variation in environmental conditions, but may also vary markedly over time and space in response to differing intensities of management of cats (and the often co-occurring introduced red fox *Vulpes vulpes*) and/or to management of some main prey sources (such as rabbits *Oryctolagus cuniculus*) (see also Appendix D) (Bowen and Read, 1998; Courchamp et al., 2000; Holden and Mutze, 2002; Marlow and Croft, 2016; Read and Bowen, 2001). Feral cats are also highly flexible foragers: they readily switch prey types according to the relative abundance of different prey. For example, reptiles feature more prominently (and hence birds less prominently) in the diet of feral cats in Australia during warmer months (Yip et al., 2015). Feral cats may also selectively hunt particular prey species even if rare in the landscape: for example, Spencer et al. (2014) reported that feral cats consumed Forrest's mouse *Leggadina forresti* at a disproportionately high rate relative to their abundance in a study in central Australia. There may also be substantial differences in the hunting behaviour and prey selectivity among individual co-occurring cats, with some individual cats preferentially targeting birds (Dickman and Newsome, 2015; Molsher et al., 1999), and some differences in diet associated with the size of the cat (Kutt, 2012; Moseby et al., 2015).

There have been few previous estimates of the numbers of birds killed by feral cats for any part of Australia. One notable example related to the diet of feral cats on the 131 km<sup>2</sup> sub-Antarctic Macquarie Island (Jones, 1977). Based on an estimated population then of 375 feral cats, dietary analysis and cat metabolic requirements, Jones (1977) estimated that this feral cat population killed 47,000 Antarctic prions *Pachyptila desolata* and 11,000 white-headed petrels *Pterodroma lessonii* per year on Macquarie Island; hence, on average, each cat consumed at least 154 individual birds per year, and the cat population collectively consumed at least 443 birds km<sup>-2</sup> yr<sup>-1</sup>.

For mainland Australia, the most notable assessment of bird mortality rates attributable to feral cats in natural landscapes at any site is that of Read and Bowen (2001) at Roxby Downs in arid South Australia. Their dietary study found an average of 0.21 individual birds in each

cat stomach, and they concluded that each cat consumes at least 0.21 birds per day (assuming that the average passage rate of food in the digestive system of cats is < 1 day). Based on observed densities of 2 cats km<sup>-2</sup>, they estimated that the feral cat population at this site consumed well in excess of 150 birds km<sup>-2</sup> yr<sup>-1</sup>.

Although our primary interest in this paper is predation by feral cats in natural environments, we note that pet cats can also have detrimental impacts on birds in urban and peri-urban areas, and that their impacts may be locally substantial given that cats in such settings often occur in very high densities (Legge et al., 2017; Paton, 1993). So, additional to our assessment of the toll of birds taken by feral cats in largely natural environments, we also estimate the numbers of birds killed by feral cats in highly modified environments (such as around rubbish dumps) and by pet cats. These three segments of the cat population have some notably different characteristics that merit their separate consideration: (i) feral cats in largely natural landscapes generally occur at lower densities but, given that they must hunt their own food, their per capita intake of birds is likely to be far higher than for the other two categories; (ii) feral cats in highly modified landscapes typically occur at very high densities, but derive much of their diet from food sources provided intentionally or unintentionally by humans and hence have lower per capita kill rates of birds than feral cats without such human-provided food sources; and (iii) the number of pet cats in Australia is reasonably well estimated from ownership statistics, but the diet of pet cats is largely provided by their owners, so the pet cat per capita kill rate on birds is likely to be much lower than for feral cats. Note that, as defined by Legge et al. (2017), the total area of natural environments and of highly modified landscapes sums to the total land area of Australia (7.69 million km<sup>2</sup>, including all islands); hence the total population size of feral cats in Australia is the sum of the estimated cat populations for these two landscape components.

Our focus here is on cats as a direct cause of mortality in Australian birds, but we note also that cats may also have indirect impacts on bird populations through competition (with some studies showing large dietary overlaps of feral cats with some Australian raptor species: Pavvey et al., 2008), and indirectly through disease transmission. Notably, the cat is the sole primary host in Australia for toxoplasmosis, demonstrated to be a significant cause of mortality for many bird species (including threatened bird species) in Australia and elsewhere in the world (Dubey, 2002; Hartley and Dubey, 1991; Work et al., 2000).

Our objectives in this study are to: (i) assess the extent of variation in the frequency of birds in cat diet, and the factors associated with such variation; (ii) derive estimates of the average numbers of birds killed in Australia by cats per year and per unit area; and (iii) seek to interpret the conservation significance of such predation rates. In a companion paper (Woinarski et al. submitted), we consider the ecological traits associated with variation among bird species in the likelihood of predation by cats, and collate records of cat predation on Australia's threatened bird species.

## 2. Methods

### 2.1. Feral cats in natural environments

Legge et al. (2017) collated and then modelled 91 site-based estimates of feral cat density to derive an estimate of 2.07 million feral cats in largely natural landscapes of Australia (varying between 1.4 million in drought and average years to 5.6 million after prolonged and extensive wet periods).

For the occurrence of birds in cat diets in Australia, we collated 93 studies (with a minimum of 10 cat dietary samples per study) that provided a quantitative assessment of the frequency of birds in cat stomachs or scats. These studies (Appendix A) were widely spread (Fig. 1) and included a broad representation of Australian natural environments, although we note that some regions (e.g. north-western Australia, and parts of South Australia) had relatively few observations.

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