



## Compilation and traits of Australian bird species killed by cats



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### ABSTRACT

House cats *Felis catus* have contributed to the extinction of many bird species on islands, but their impact on continental bird faunas is less well resolved. Here, we compile and analyse a comprehensive record of all bird species known to be killed by feral cats at a continental scale. From published studies and unpublished data, we document predation by feral and pet cats on 357 bird species in Australia, including 338 Australian (non-vagrant) native bird species (= 45.6% of the 741 Australian native bird species, excluding vagrants). This tally included 24 species listed as threatened or extinct by the IUCN (40% of the 58 non-vagrant Australian species listed as threatened), and 71 of the 117 bird species (61%) listed as threatened under Australian legislation (or species with one or more subspecies so listed). These tallies are substantially larger than reported in previous reviews. We provide the first continental-scale attempt to model bird species' traits that are associated with likelihood of being killed by cats, and use such modelling to attempt to redress some inevitable biases in compilation of predation records on birds. We conclude that the likelihood of being killed by a cat was highest for bird species that are restricted to islands, are of intermediate body mass (ca. 60–300 g), and nest and forage on the ground, and least likely for bird species occurring mostly in rainforests and wetlands. We also identify a set of bird species most likely to be threatened by cat-predation and hence most likely to benefit from enhanced management of cats. This study does not specifically evaluate the impact of cats on bird populations or on the conservation of Australian birds, but our results suggest that such impact may be much more pervasive than previously documented.

### 1. Introduction

Cats *Felis catus* are versatile predators that largely employ an ‘ambush’ hunting strategy (Bradshaw, 1992; Turner and Meister, 1988) to capture and kill a very wide range of animal species from small invertebrates to vertebrates up to at least 4 kg (Bonnaud et al., 2011; Fancourt, 2015). Predation by introduced cats has been a major cause of extinction for many species, with such impact particularly pronounced for island-endemic vertebrates (Blackburn et al., 2004; Blackburn et al., 2005; Doherty et al., 2016; Medina et al., 2011; Nogales et al., 2013) and for mammals in Australia (Woinarski et al.,

2015). In contrast, the impacts of predation by cats on continental bird faunas is less well resolved, although cats are known to kill hundreds of millions to billions of birds annually in continental settings (Blancher, 2013; Dauphiné and Cooper, 2009; Loss et al., 2013), with such predation shown to be a major source of bird mortality (Loss et al., 2012, 2015).

In a recent paper, Woinarski et al. (2017) concluded that about one million birds are killed in Australia per day by cats. However that study provided no information on the extent to which this toll fell equitably or otherwise across bird species. Here, we complement that previous paper by reporting on the Australian bird species known to be killed by

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cats, and seek to identify bird species, or groupings of species, that are most likely to be subject to cat predation.

First introduced to Australia in the late eighteenth century (Abbott, 2008), cats are now almost ubiquitous across the Australian mainland and also occur on many Australian islands (Legge et al., 2017). There have been two notable listings of Australian bird species known to have been preyed upon by cats. An extensive survey of pet-owners in south-eastern Australia reported records of pet cats killing (or capturing) individuals of 186 bird species (Paton, 1990; Paton, 1991; Paton, 1993), although the full list associated with that study has never been formally published. More recently, Doherty et al. (2015) aggregated information from 70 published and unpublished studies, widely spaced across Australia, of the diet of feral cats. That review compiled cat-predation records for 123 bird species, including 113 native species, of which two species were listed by the IUCN as threatened (Malleefowl *Leipoa ocellata* and Southern Rockhopper Penguin *Eudyptes chrysocome*). Another recent but more speculative compilation relating to the possible detrimental effects of feral cats on Australian biodiversity listed 40 threatened Australian bird taxa (including subspecies) that ‘may be affected by predation by feral cats’, although in many of these cases this implication was not based on any definite records of such predation (Department of the Environment, 2015).

As recognised by their authors, the lists of bird species reported as preyed upon by cats in these previous compilations have some substantial biases and incompleteness (Table 1). Paton's set of studies were based on cat-owners' records in urban and rural areas of south-eastern Australia, and hence bird species that are readily identified by the public were more likely reported by respondents, and bird species that are more common and widespread in this region were likely to have contributed most to the cat-killed tallies. The compilation by Doherty et al. (2015) was more geographically representative, but was also likely to include more common and widespread bird species, and species for which partly-digested prey items are readily identifiable to species. Rare and restricted bird species are less likely to be reported as cat-prey in these data sets, but it is possible that such species have a higher *per capita* rate of being preyed upon by cats, and hence suffer more conservation impact, than those bird species that – because of

their abundance or wide distributions – are more likely to be reported in cat dietary studies.

In the current study, we build on these important preceding compilations through inclusion of records from many additional and more diverse sources in order to provide a continental-scale compilation of bird species for which there are records of individual birds killed by cats, noting also the threatened bird species in this compilation. We then examine, across all Australian bird species, for relationships between records of cat predation and bird species' ecological, morphological and other traits. We then model these relationships to rank species according to their likelihood of being killed by cats, with and without controls for a measure of bird abundance and range. Our modelling at continental scale seeks to diminish the bias due to cat predation being more likely to have been recorded for bird species that are common in areas with higher human population density. This bias may be particularly important to try to redress because a recent continental-scale assessment of predation by feral cats in Australia (Woinarski et al., 2017) reported that the modelled rate of predation of birds (*i.e.* no. individual birds killed  $\text{km}^{-2} \text{y}^{-1}$ ) by cats was highest in arid and semi-arid areas remote from most human population centres, and hence bird species in those relatively under-studied areas may be most at risk from cat predation.

## 2. Methods

### 2.1. Terminology

Note that for convenient shorthand here we use the expression ‘bird species killed by cats’, or variants. We recognise that it is individuals, rather than species, that are killed; but repeated use of that correct wording is unduly cumbersome.

### 2.2. Compilation of cat-predation database

We sought records of birds being killed by cats from many diverse sources. The most notable of these included:

**Table 1**

Real or potential biases in documentation of records of cat predation, and constraints on modelling.

Potential bias	Response in this study to reduce bias
Studies of cat-predation will tend to report records of predation of more common and widespread bird species, and those occurring in areas in and around human population centres	We included information on predation from many diverse sources, including autecological studies of birds, rather than simply collations of cat diet; our modelling includes an offset for abundance, to allow derivation of a <i>per capita</i> estimate of predation risk
Observations of cat predation on birds will be biased towards larger and more distinctive birds	We included information on predation from many diverse sources, including autecological studies of birds, rather than simply collations of cat diet. The bias due to some bird species being more conspicuous or more easily identified mostly relates to the minority of records here that derive from pet-owners' reports
Observations of cat predation on birds will be biased towards bird species that have been the subject of intensive autecological studies	This bias was not entirely circumvented in our compilation or modelling. However, there are relatively few autecological studies of Australian bird species that include documentation of different sources of mortality, and our compilation used very diverse sources in addition to reports from autecological studies.
There have been relatively few studies of birds or cats in mangroves and rainforest habitats.	This bias was not entirely circumvented in our compilation or modelling, but other studies (Legge et al., 2017) indicate that cat density is likely to be relatively low in closed forest habitats.
There will be fewer records of cat predation on birds that became extinct soon after European settlement	This bias was not entirely circumvented in our compilation or modelling, but modelling indicated high predation risk for many extinct bird species anyway
Eggs and nestlings will be under-represented in samples because these may be quickly digested and unidentifiable in cat samples	This bias was not entirely circumvented in our compilation or modelling, but is unlikely to introduce any systematic bias for or against particular bird species
Larger birds may be included in cat samples but these may represent carrion rather than predation	This bias was not circumvented in our compilation or modelling, but our inclusion of predation information arising from assessments of causes of mortality within autecological studies of birds may redress this concern
Cats may kill birds but not consume them ('surplus kill'), and these killed birds will not be present in dietary samples	This factor should not introduce any major bias among bird species – <i>i.e.</i> although colonial bird species may be more likely to be subject to 'surplus killing' this should not affect our analysis, which is based on any records of bird species being killed rather than the tally of numbers of individuals being killed
Consumption of a single individual of a large bird species may satiate cats, whereas it may require many small birds to satiate cats	Not a bias <i>per se</i> – simply recognises that more individuals of smaller bird species may be taken by cats than of larger birds

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