Birds are Still Singing in Our Suburbs: Contemporary Hunting Data for Pet Cats in Urban Australia

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Posted Date: 18 September 2026

doi: 10.20944/preprints202609.1612.v1

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 doi:10.20944/preprints202609.1612.v1

Article

Birds are Still Singing in Our Suburbs: Contemporary Hunting Data for Pet Cats in Urban Australia

Jacquie Rand [1,2,*], Karthick Sharma [1,3], Hung Hei Ng [2] and Kate J. Dutton-Regester [1,2]

[1] Australian Pet Welfare Foundation, Kenmore, QLD 4069, Australia
[2] School of Veterinary Science, The University of Queensland, Gatton, QLD 4343, Australia
[3] School of Public Health and Social Work, Queensland University of Technology, Kelvin Grove, QLD 4059
* Correspondence: jacquie@petwelfare.org.au

Simple Summary

Hunting of wildlife by pet cats is an important concern in Australia, resulting in claims pet cats are "sending our suburbs silent". National estimates of predation by pet cats are limited and depend on assumptions about how many cats hunt, how much prey they catch, and how much prey is not observed by owners. This study examined 2,405 owned and semi-owned cats from lower-income suburbs in Ipswich, Queensland, whose carers enrolled them in a free sterilization program and were required to complete a questionnaire. Most cats were not reported to hunt: 77% were reported never to hunt, and even among cats with outdoor access, 58% were not reported to hunt. Among cats reported to catch prey, insects and rodents were most common, while birds were least commonly reported and were usually caught in low numbers. When the observed hunting frequency and number of prey observed to be caught in this population were used to generate national predation estimates, the resulting totals were substantially lower than previously published Australian estimates. For birds, our estimated annual mortality of 0.38 million was 161- to 311-fold lower than the widely cited estimates of 61–118 million birds killed each year by pet cats and was more consistent with estimates of Australia's total urban bird population of 11 million. Our findings show that hunting varies greatly among pet cats and that national estimates depend strongly on the data and assumptions used to calculate them.

Abstract

Published estimates of predation by pet cats have led to claims that pet cats are having a devastating effect on native wildlife". This is based on data collected 32-37 years ago, that reported pet cats in Australia caught an estimated 61 to 118 million birds a year, with every pet cat, regardless of age or containment catching an average of 15.6 to 31.2 birds per year. However, reliable contemporary data on hunting by pet cats in urban Australia remain limited, and national predation estimates are sensitive to assumptions about how many cats hunt, how much prey they catch, and how much prey is not observed by carers. Our study analyzed questionnaire data from 2,405 owned and semi-owned cats enrolled in a community sterilization program in lower-income suburbs of Ipswich, Queensland, between 2022 and 2025. Questionnaire completion was required for enrolment, reducing self-selection based specifically on an interest in cat hunting or wildlife. Of 2,392 cats with hunting information, 77% were reported never to hunt and 23% to hunt sometimes or often. Even among cats with outdoor access, 58% were not reported to hunt. Among cats reported to catch prey, insects and rodents were most common, while bird captures were least common and generally low in number. National predation estimates were calculated using observed hunting prevalence, prey composition and prey counts observed in this study population, with published correction factors applied for prey not observed by owners. Median-based estimates were 0.38 million birds, 3.29 million mammals and 4.07 million reptiles annually, and for birds, the estimated rate averaged across all cats (hunters and non-hunters) was 0.10 birds per cat per year. Our estimates for birds were 161 to 311 times lower than

 doi:10.20944/preprints202609.1612.v1

previously published Australian estimates, which exceed the estimated urban bird population of 11 million and annual turnover of approximately 3.6 million birds. These findings demonstrate substantial variation in hunting behavior among pet cats, and show that national predation estimates are strongly influenced by the underlying data and assumptions used in extrapolation.

Keywords: domestic cats; pet cats; urban ecology; predation; prey capture; owner-reported hunting; wildlife; extrapolation

1. Introduction

Domestic cats (*Felis catus*) live in a range of circumstances in urban areas. Some are owned pets, some are semi-owned cats that are fed or cared for by people who do not consider themselves the owner, and some are unowned free-roaming cats that rely partly or largely on human food sources [1–3]. In Australia, cats are among the most popular companion animals, with approximately 5.8 million owned cats nationwide [4]. However, concern about their roaming and hunting behavior has generated substantial debate, particularly regarding their potential effects on native wildlife.

Important distinctions exist between feral cats living independently of people and pet cats living in urban environments, including differences in food availability, ecology and opportunities to hunt. Feral cats have been linked to declines in native species in Australia and elsewhere, particularly in natural and island ecosystems [5], but the population-level ecological effects of pet cats in urban areas are less clear. Published estimates of pet-cat predation have been widely cited leading to claims that Australia's pet cats "wreak environmental havoc"and are "sending our suburbs silent", resulting in demands that cat containment be mandated [6–9].

Published Australian estimates of predation by pet cats have used several approaches. Earlier estimates of bird, mammal and reptile predation used the average number of prey observed by owners to be caught or brought home by pet cats in a small number of Australian studies, then adjusted these rates to account for prey not observed by owners, and extrapolated them to the national pet-cat population [10–12]. A later estimate also accounted for the proportions of pet cats that roamed and hunted before estimating national predation rates [13]. The resulting estimates are therefore sensitive to the data and assumptions used, including the number of prey reported, the correction applied for prey not observed by owners, estimates of roaming and hunting, and how representative the source studies are of the wider Australian pet cat population.

Much of the Australian data underpinning these widely-cited estimates were collected approximately three decades ago [10–12,14–19]. Since then, patterns of cat ownership and containment have changed [4,20,21], alongside substantial urban development, habitat modification and shifts in wildlife communities that may alter prey availability [22–24]. Thus, these source studies may not be representative of contemporary pet-cat predation patterns.

Importantly, hunting behavior and prey capture vary substantially among individual pet cats. Previous studies have reported that a relatively small proportion of cats account for a large proportion of prey caught [25,26]. Additionally, the types of prey caught by pet cats also varies among individual cats and is influenced by the surrounding environment. This variation is important when interpreting the potential effects of pet-cat predation on wildlife. Studies of pet cats have reported capture of introduced species, common native species, as well as some less common native prey [25,27]. The ecological significance of prey captured, therefore depends on the type and population size of native prey: capture of an introduced rodent or common native vertebrate cannot be assumed to have the same population-level consequence as capture of a native species with a small or declining population. Urban wildlife populations are also influenced by habitat availability and quality, vegetation structure, connectivity, surrounding land use and the extent of urban development [28,29]. For example, passerine bird density and species diversity in suburban Perth was negatively associated with increasing housing density, and distance to nearby bushland as well as decreasing size of the bushland, and not density of pet cats [28]. These findings indicate that the

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number and composition of prey caught by pet cats, variation in hunting among individual cats and the broader urban environment all need to be considered when assessing potential wildlife effects.

Important knowledge gaps therefore remain. Contemporary Australian data describing how frequently pet cats hunt, the types and numbers of prey they catch, and variation among individual cats are limited. Widely-cited national estimates draw substantially on earlier Australian studies of prey observed by cat owners and subsequent extrapolation to the national pet-cat population [10–13]. Contemporary Australian data from lower-income urban communities are also limited, despite differences in resources to contain pet cats and access to veterinary care, which may influence cat ownership and management [30,31]. Notably, cat-related complaints and cat admissions to shelters and municipal facilities are highest from the most disadvantaged suburbs [32].

In 2020, the Australian Pet Welfare Foundation established the Community Cat Program in collaboration with the City of Ipswich, RSPCA Queensland and Animal Welfare League Queensland, providing free sterilization for owned and semi-owned cats in selected lower-income suburbs of Ipswich, Queensland. Participants enrolling a cat are required to complete a questionnaire, providing a large contemporary dataset on cat characteristics, care and hunting behavior. The aim of our study was to collect contemporary data on the frequency of reported hunting, the types and numbers of prey caught, and factors associated with hunting. Using the data observed in our population, predation by pet cats at the national level was estimated for comparison with previously published data.

2. Materials and Methods

2.1. Community Cat Program and Permit Approvals

This study used data from participants in the Australian Pet Welfare Foundation's Community Cat Program, run in partnership with RSPCA Queensland and Animal Welfare League Queensland. Multiple organizations provided funding and in-kind support, including the Fondation Brigitte Bardot (Paris, France) for sterilizations, MSD Animal Health (Macquarie Park, NSW, Australia) for vaccinations and parasite control, Central Animal Records (Keysborough, Australia) for microchip registration of cats, and Neighborhood Cats (New York, NY, USA) for cat traps and expert advice.

The program provides free sterilization, microchipping and basic veterinary care to owned and semi-owned domestic cats in selected suburbs of Ipswich, Queensland. All participants included in this analysis were required to complete an online questionnaire before an appointment could be made. People caring for a semi-owned cat were required to agree to take ownership of the cat as part of enrolment in the program. Carers who were unable to take ownership, usually because they were caring for multiple cats, were booked in separately in the program.

Participants answered compulsory questions about owner details and the cat's health, diet, outdoor access and hunting behavior, as well as optional questions about ownership practices. Full program details, including the handling of semi-owned cats, permit procedures and collaborating organizations, have been described previously [30,31]. Ethics approval was obtained from the University of Queensland's Research Ethics and Integrity Unit (Human Ethics 2019/HE002153; Animal Ethics 2019/AE000207).

2.2. Study Area, Participant Eligibility and Recruitment

The study was conducted in Ipswich, a local government area in southeast Queensland, Australia (Figure 1). Ipswich has a humid subtropical climate with mean maximum and minimum temperatures of 32.0°C and 20.0°C in January, and 21.1°C and 7.0°C in July, and mean annual rainfall of approximately 878 mm [33]. Residents of Rosewood, Redbank Plains, and Goodna in the city of Ipswich, Queensland who identified as cat owners or semi-owners were invited to participate in the Community Cat Program. These suburbs were chosen because they had high rates of cat admissions (> 20 cats/1000 residents) to shelters and pounds compared to the average for Ipswich (15 cats/1000 residents) and for Queensland (7 cats/1000 residents) [31,34]. The SEIFA index of relative

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socioeconomic advantage and disadvantage (IRSAD) scores of residents in these suburbs were 892, 906 and 868 respectively [35]. The average SEIFA score across the three suburbs was 888, which was lower than both the Ipswich local government area score of 948 and the national baseline of 1000 [35]. In February 2023, the eligibility criteria were expanded to include Bundamba, Dinmore, Ebbw Vale, Gailes, New Chum, Riverview, and surrounding suburbs.

Figure 1. Map of Ipswich Local Government Area where the study was conducted. Points represent the approximate location of each questionnaire participant.

Residents were informed about the program through advertisements on the Australian Pet Welfare Foundation website and Facebook page [36]. Interested participants joined a waiting list through BookitLive [37]. As part of the screening process, they provided their residential postcode to confirm that they lived in an eligible suburb. Eligible participants were then sent a booking link to schedule an appointment at the RSPCA's domestic-animal clinic at Wacol. To use the online booking system, participants had to be willing to take ownership of the cat or cats being enrolled. Each cat required a separate booking, although one person could enroll more than one cat. After booking, participants were required to complete the questionnaire for each cat enrolled.

2.3. Questionnaire Design

The questions used in this study formed part of a larger longitudinal study that began in 2020 (Appendix A). Data included in the present analysis were collected between February 2022 and December 2025 and focused on hunting behavior, prey capture and diet. Participants provided information about each cat, including sex and age, and were asked whether the cat had outdoor access and whether it hunted. More detailed information on containment practices is reported separately in a companion paper [38]. Respondents were asked whether they had ever seen their cat catch prey. Those answering "yes" were asked which types of prey they had seen their cat catch: insects, slugs and snails, lizards and geckos, rodents, birds or other prey. For each prey type selected, respondents were asked, "On average, how many [prey type] does your cat catch in 6 months?" and whether they had seen their cat eat that prey. The questionnaire included an "other prey" category but did not require respondents to identify the prey type. Ownership status before enrolment in the program was classified from a compulsory questionnaire question asking whether the respondent considered themselves the owner of the cat or was feeding or caring for it. Detailed analyses of cat caring behaviors and ownership status of 1094 cat owners and semi-owners have previously been reported from a smaller and earlier component of the same dataset [31].

2.4. Data Cleaning

During the study period, 2,597 questionnaire responses were received. Of these, 125 duplicate entries were identified and removed. Where duplicates occurred, the entry with the most complete

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information or the most recent booking date was retained, as this was assumed to be the most up to date. Forty-three responses from outside the eligible suburbs were removed, along with one response that contained inconsistent information. The final dataset included 2,405 unique records. Where responses included numerical values, such as cat age or duration of ownership, these were converted to months. One respondent reported owning the cat "since kitten"; which was assumed to have been acquired at four weeks of age. One respondent recorded "flies" under "other prey" and was recoded as insects. Where "other prey" was selected but did not have any further details on the type of prey, this was not classified as either vertebrate or invertebrate.

2.5. Statistical Analysis

Questionnaire responses were exported to Microsoft Excel® and analyzed using R (version 4.5.1). Data were cleaned and recoded to ensure consistency. Where possible, responses for number of prey caught were converted to numbers, and ambiguous responses (e.g., 'a few every now and then') were treated as missing values. Descriptive statistics, including mean, median, standard deviation, minimum, and maximum, were calculated for the number of prey caught in five categories: insects, lizards/geckos, rodents, birds, and other prey. These were summarized separately for vertebrates (birds, rodents, lizards and geckos) and invertebrates (insects, slugs and snails) so that vertebrate results could be compared with previously published Australian estimates of vertebrate prey caught by pet cats.

Further prey analyses focused on 523 cats whose owners answered Yes to "Does your cat hunt" and indicated frequency as "sometimes" or "often", and then also answered Yes to "Have you ever seen your cat catch prey" and answered Yes or No for each prey category information (Figure 2). Of these, 269 cats were seen by owners to have caught at least one specified prey type, while 254 were not seen to have caught any of the specified prey types despite owners stating their cat hunted. Cats could be observed to catch more than one prey type.

Owners were then asked to estimate how many of each prey type they were seen to catch in the last 6 months. Mean and median prey counts were calculated only for cats reported to catch the relevant prey type and for which a usable numerical six-month count was provided. In 116 instances, a respondent reported having seen the cat catch a particular prey type, but did not provide a numerical estimate of how many were caught in the last six months; no respondent recorded an explicit zero. Because the first question asked whether that prey type had ever been observed, while the second requested a numerical six-month estimate, a blank numerical response could not be assumed to represent zero prey caught. These instances were therefore excluded from calculations of mean and median prey counts, but the cat was retained as having been reported to catch that prey type.

Cats were classified as having outdoor access if owners reported access as 'More indoors than outdoors', '50/50', 'More outdoors than indoors', or 'Outdoors only'. Associations between categorical variables were assessed using chi-squared tests of independence, including associations between raw meat feeding and reported hunting, ownership status and outdoor access, ownership status and reported hunting, and ownership status and reported prey type. Statistical significance was assessed at $\alpha = 0.05$.

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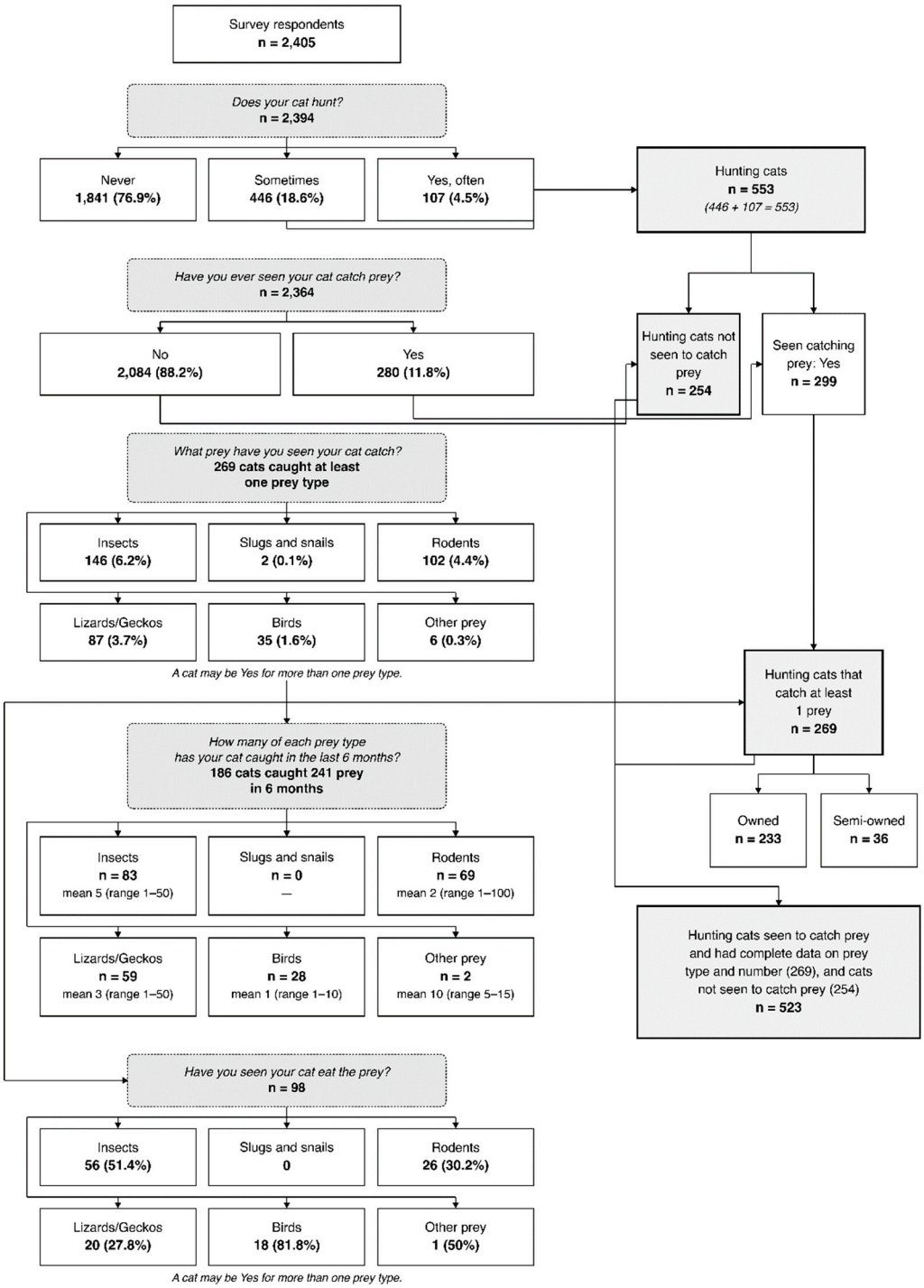

Figure 2. Responses to predation-specific questions in the cat questionnaire showing selection criteria for inclusion in the analysis of cats that hunted and were observed to catch prey. Respondents enrolling more than one cat in the sterilization program had to complete the questionnaire separately for each cat, thus representing two or more respondents and responses. See Appendix A for full questionnaire design. Answers for prey type are not mutually exclusive. A single cat could catch or eat multiple types of prey.

2.6. Predation Estimates

To compare our results with previous national estimates, we examined birds, mammals and reptiles separately from insects, slugs and snails. For each prey category included in reported national estimates of prey caught by pet cats [10–13,39], the number of prey reported over six months in our cohort was doubled to estimate how many were caught in a full year. Because owners do not see

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every prey animal their cat catches, these annual vertebrate totals were adjusted using published estimates of how often owners notice prey caught by their cats (birds 29%, mammals 20%, reptiles 22%. [10–12]. Insects, slugs and snails were summarized separately and were not included in the main comparisons because similar published correction factors were not available.

We then estimated the average number of prey caught each year for each prey type using cats whose carers reported that their cat caught that prey and provided a usable count. The results of our cohort were compared with previously reported estimates of prey captured across the total owned cat population using population estimates in Woinarski et al. [10,11] and Murphy et al. [12] of 3.88 million, and in Legge et al. [13] of 3.77 million. For this comparison, our estimates were adjusted using three factors: firstly, the proportion of the 523 cats with complete data that were reported to hunt and hunted at least one vertebrate prey in 6 months in at least one prey category - 174 (33.3%) of the 523 cats hunted vertebrate prey; 349 (66.7%) were not reported to hunt vertebrate prey or only hunted invertebrates, and, secondly, among those cats, the proportion reported to hunt each specific category of vertebrate prey, and thirdly, the median number of prey observed to be caught in that category. The adjusted per-cat estimates were then applied to the Australian owned-cat population used previously (3.88 million and 3.77 million [10,13,40]) to estimate national totals. Birds, mammals and reptiles were reported separately from insects, slugs and snails so that the results could be compared with previous Australian estimates.

For each prey type, the median number reported during the previous six months among cats with a usable numerical count was doubled to obtain an annualized value. This assumes that prey capture during the reported six-month period was representative of the remainder of the year. Rodents were treated as mammals and lizards/geckos as reptiles for comparison with previous national estimates.

To allow comparison with previous Australian estimates, annualized vertebrate counts were adjusted using the published correction factors used in those studies for prey killed but not returned to or detected by owners: 29% for birds, 20% for mammals and 22% for reptiles [10–12]. No comparable correction factor was available for insects, so insect counts were annualized without adjustment.

For each prey type, the proportion of the study population (hunters and non-hunters) estimated to catch that prey was calculated by multiplying the overall proportion of cats reported to hunt by the proportion of reported hunters with complete prey information that caught the relevant prey type. This proportion was then multiplied by the adjusted median annual prey count among cats reported to catch that prey type to obtain an average annual predation rate per cat for that prey. A second calculation was performed using owned cats only, using the hunting prevalence and proportions of prey seen to be caught for owned cats and excluding cats classified as semi-owned before enrolment.

The average annual number of prey estimated to be caught per cat for all cats (hunters and non-hunters) was multiplied by 3.88 million owned cats, the Australian pet-cat population estimate used by Woinarski et al. [10,11] and Murphy et al. [12], to obtain national totals. Estimates reported by Legge et al. [9], which used a population estimate of 3.77 million pet cats, were compared with our estimates. Birds, mammals and reptiles were reported separately to facilitate comparison with previous Australian estimates; insects were reported separately.

3. Results

3.1. Questionnaire Response Rate and Demographics

All cat owners and semi-owners who were willing to take ownership of cats in the free sterilization program had to complete the questionnaire to participate. This gave a 100% response rate among participants. After data cleaning, the final dataset included 2,405 responses (Table 1). Not every participant answered every question, so the number of responses for each question is shown in the relevant tables. Of the 2,405 respondents, 1,360 (56.5%) came from four suburbs: Redbank

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Plains (*n* = 610 [25.4%]; population = 24,349), Goodna (*n* = 394 [16.4%]; population = 10,391), Brassall (*n* = 210 [8.7%]; population = 12,115), and Rosewood (*n* = 146 [6.1%]; population = 3,263) [41–44]. Together, these suburbs had a combined population of 49,929 according to the 2021 Australian Census, representing 22% of the city of Ipswich population [45]. Another 799 respondents (33.2%) came from 26 other suburbs across the Ipswich region.

3.2. Cat Characteristics and Ownership Status

Cat age was available for 2,207 cats, and 80% were in the age range reported to be the most prolific hunters (4 months to 5 years [46]) and only a small proportion (2.6%) were over 5 years old (Table 2).

Table 2. Age, breed and ownership characteristics of cats reported in the questionnaire.

Age (*n* = 2,207)		**Breed (*n* = 2,342)**		**Ownership (*n* = 2,401)**	
Category	**Cats, % (*n*)**	**Category**	**Cats, % (*n*)**	**Category**	**Cats, % (*n*)**
< 8 weeks	1.3% (29)	Domestic Short Hair	60.4% (1,414)	Owned	87.8% (2,109)
2 to <3 months	6.7% (147)	Domestic Medium Hair	24.8% (581)	Semi-owned	12.2% (292)
3 to <4 months	9.7% (213)	Domestic Long Hair	7.5% (175)		
4 to <6 months	22.7% (500)	Other	7.3% (172)		
6 to 12 months	29.2% (645)				
13 months to 5 years	27.9% (615)				
>5 to 12 years	2.6% (58)				

Most cats (60.4%) were domestic short-hair cat (Table 2). Based on responses to the question "Prior to when you heard about the free desexing program, did you consider that you were the owner of this cat, or were you just feeding or caring for this cat?", most cats (88%) were reported as owned by the respondent, while 12% were reported as semi-owned.

3.3. Prey Type and Frequency

Of the cat owners and carers (n=2,394), who answered the question, "does your cat hunt?" only 23% said yes (sometimes or often), and 77% said no, while an even smaller proportion of cats were seen to catch prey (12%) (Figure 2). Of cats that hunted (*n* = 553) and had information on the type of prey seen to be caught, over 21% (*n* = 120) were reported to catch only vertebrates and over 16% caught only invertebrates (Table 3). Of the whole questionnaire population of 2392 cats including hunters and non-hunters (excluding 2 who had no data on ownership), 11% cats caught vertebrates, invertebrates or both, while only 5% caught only vertebrates and 4% caught only invertebrates.

Of the 553 cats that hunted, 299 were seen catching prey but for only 269 cats (48.6% of 553 cats) was at least one kind of prey reported to be caught, and 254 of the cats that hunted were not seen catching any prey. Prey analyses were based on cats that hunted (*n* = 553), were not *n* = (254) or were seen to catch prey (*n* = 299) and also had complete data on prey type (269) and provided the number seen caught in the previous 6 months for at least one type of prey (186 cats) (Figure 2).

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Table 3. Types of prey reported among cats reported to hunt sometimes or often (n = 553), calculated using data for 269 cats seen to catch at least one prey type and where prey type was reported (Figure 2). They are shown as a percentage of cats that owners said hunted (n = 553), and as a percentage of all 2,392 cats with hunting and ownership data available (2 cats with hunting data but no ownership data were excluded). Prey-type categories are mutually exclusive.

Prey category*	Cats, % (n) of hunting cats (n = 553)	% of all cats (2,392 with ownership data)
Vertebrates only	21.7% (120)	5.0%
Invertebrates only	16.8% (93)	3.9%
Both vertebrates and invertebrates	9.8% (54)	2.3%
Other prey only	0.4% (2)	0.1%
Not recorded	51.4% (284)	11.9%
Total	**100% (553)**	**23.1%**

* Combining the 'Vertebrates only' and 'Both vertebrates and invertebrates' categories, 174 cats (31.5% of hunting cats; 7.3% of all 2,392 cats) caught at least one vertebrate, regardless of whether they also caught invertebrates.".

Of the 269 cats seen catching at least one kind of prey, 54% (145 cats) were reported to catch insects and 65% (174/269) caught at least one vertebrate. Of the 174 cats catching vertebrates, 55% caught rodents (96 cats), 50% lizards and geckos (87 cats), 18% birds (32 cats), and 1% other prey (2 cats).

When calculated over the whole cohort of 523 cats reported to hunt and information on whether (n = 269) or not (254) they were seen to catch prey, and if seen, type and numbers of prey, 28% were reported to catch insects, 18% rodents, 17% lizards and geckos, 6% birds, and 1% other prey (Table 4).

Semi-owned cats accounted for only 12% of cats but accounted for 18.4% (n = 16) of cats reported to catch lizards and geckos, 18.8% (n = 6) of cats reported to catch birds, and 9.6% (n = 14) of cats reported to catch insects (Table 4).

The proportion of cats reported to eat the prey they caught also differed between prey groups. About half of the cats that caught birds were reported to eat them, compared with about 20–30% of cats that caught most other kinds of prey (Table 4).

Table 4. Kinds of prey reported among the 269 cats respondents said hunted and they saw the cat catch prey and they provided information on at least one kind of prey (Figure 2). For each prey type, the proportion of owned cats and the proportion of semi-owned cats reported to catch that prey did not differ significantly (χ^2, all $p > 0.05$).

	Cats reported to catch this prey				
		% of all cats, and owned or semi-owned cats that hunted with complete data on prey type including 254 cats not seen to catch prey and 269 seen catching at least one prey type (n = 523)			Cats reported to eat this prey
Prey type	**% (n) of cats that hunted & caught at least one prey type (n = 269)**	**% of all cats (owned & semi-owned) (n = 523)**	**% (n) of owned cats (n = 448)**	**% (n) of semi-owned cats (n = 75)**	**% of cats reported to catch this prey that ate it (n)**
Insects	54.3 (146)	27.9	29.5 (132)	18.7 (14)	34.2 (50)
Lizards and geckos	32.3 (87)	16.6	15.8 (71)	21.3 (16)	25.3 (22)
Rodents	35.7 (96)	18.4	17.9 (80)	21.3 (16)	28.1 (27)
Birds	11.9 (32)	6.1	5.8 (26)	8.0 (6)	56.3 (18)
Other prey	2.2 (6)	1.1	1.3 (6)	0 (0)	16.7 (1)

 doi:10.20944/preprints202609.1612.v1

On a per-cat basis, insects had the highest number of captures, and with some cats reported to catch up to 50 insects in a six-month period (Table 5, Figure 3). Birds were captured least often, with a median of 1 bird per cat over six months and a maximum of 10 birds caught by one cat. Six cats were reported to catch other prey, but only two owners provided a count, so this category was not interpreted further.

Table 5. Median and mean of each prey type caught by owned and semi-owned cats in the six months prior to the questionnaire being completed.

	Number of prey caught in previous 6 months			
	Owned cats		Semi-owned cats	
Prey type	Median (Range)	Mean ± SD	Median (Range)	Mean ± SD
Insects	5 (1-50)	9.0 ± 10.4	3.5 (1-50)	8.9 ± 14.8
Lizards and geckos	3 (1-50)	4.6 ± 7.3	4 (1-24)	5.6 ± 6.7
Rodents	2 (1-100)	4.6 ± 13.7	3 (1-6)	2.8 ± 1.3
Birds	1 (1-10)	1.8 ± 1.9	1 (1-5)	1.8 ± 1.8
Other prey	10 (5-15)	10.0 ± 7.1	-	-

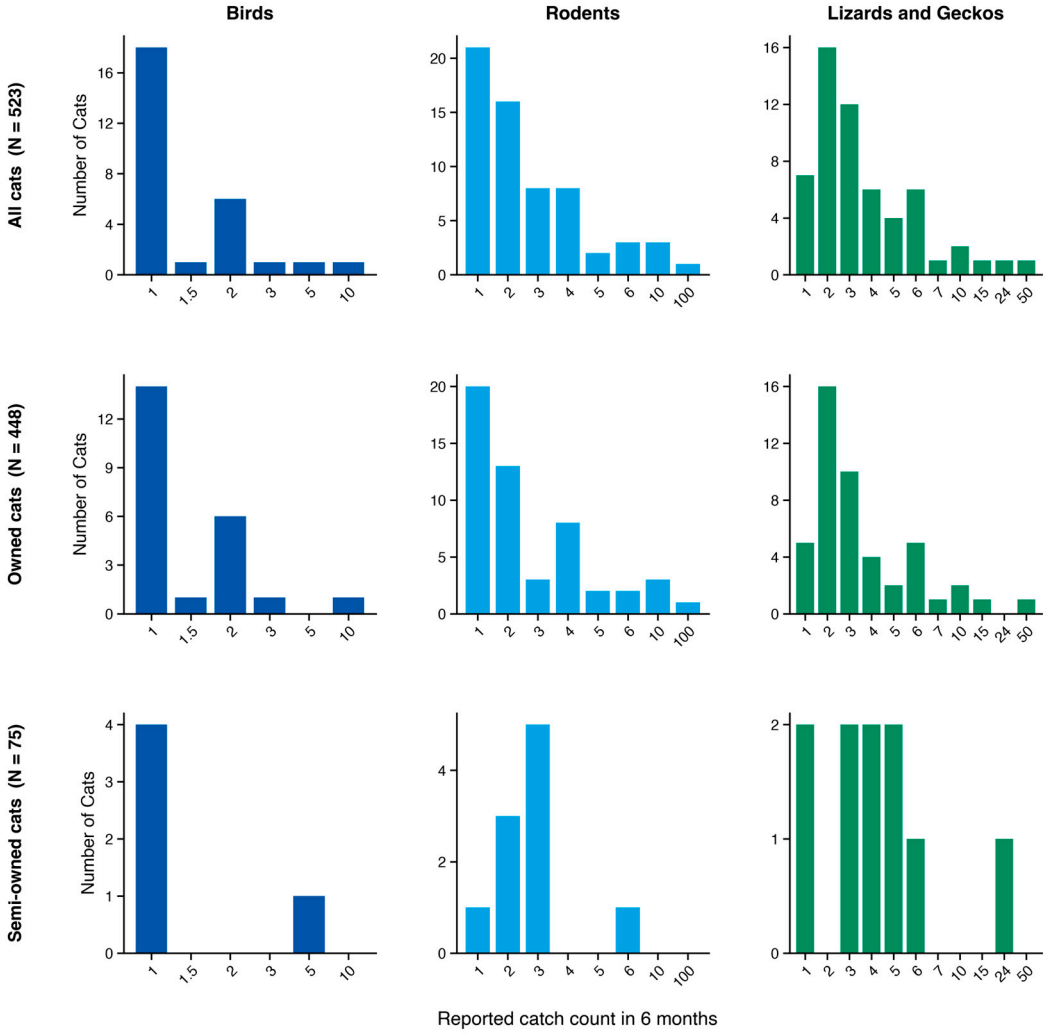

Figure 3. Reported number of vertebrate prey caught by cats in the six months prior to the questionnaire being completed, separated by ownership type.

Prey captured also differed between containment groups (Figure 4). Among cats reported to catch insects, about half were kept indoors only. Among cats reported to catch birds, almost half were

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in the 50/50 indoors and outdoors category, while 28 % (n = 8) were reported as spending more time outdoors than indoors and two indoor-only cats were reported to catch birds. It is unknown if they were pet birds, or wild birds that accidentally entered the house through an open window or door, or intentionally entered looking for food, or it was a reporting error. Cats reported catching lizards or geckos and rodents were more evenly distributed across containment categories, although relatively few were in the more outdoors than indoors category.

Although containment differed significantly between owned and semi-owned cats (χ^2, $p < 0.001$), with semi-owned cats less likely to be kept indoors, there were no significant differences between owned and semi-owned cats in the proportion reported to hunt ($p > 0.5$) or in the kinds of prey caught (all $p > 0.05$).

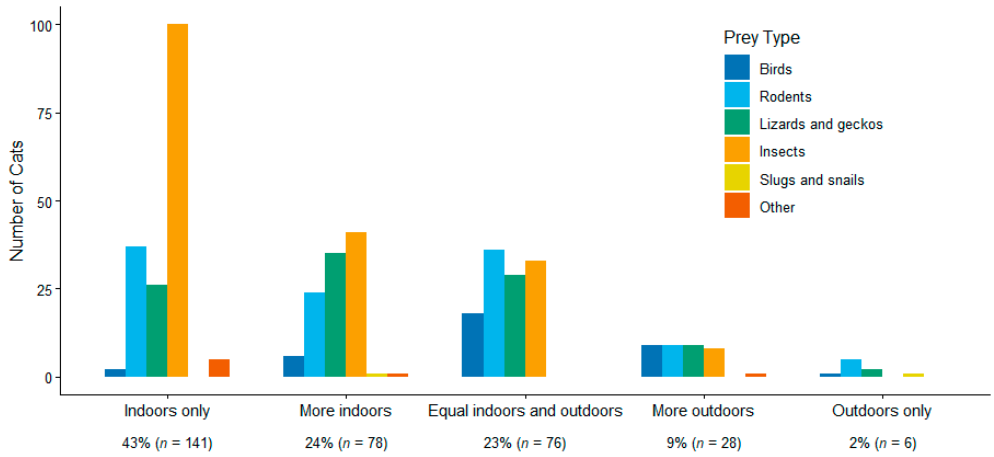

Figure 4. Predation by category of outdoor access for the 329 cats with containment information and reported to catch at least one prey type. n is the number of cats per containment category, with an individual cat able to be reported to catch more than one type of prey. Percentages are calculated for each containment category based on the number of individual cats in each category out of all 329 cats.

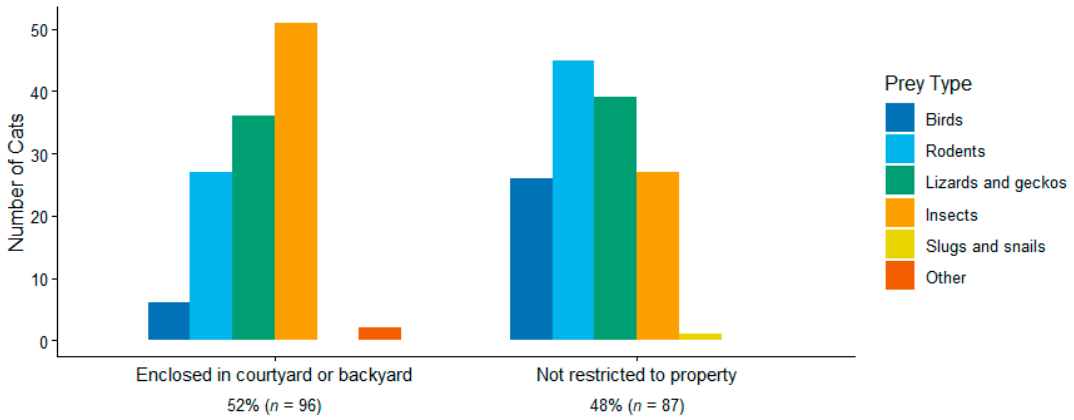

Figure 5. Types of prey seen to be caught by 183 cats with outdoor access and information about the extent of their outdoor access and types of prey caught. n is the number of cats in the two categories of outdoor access that also had information on type of prey caught. An individual cat could catch more than one type of prey.

3.4. Estimated Population-Wide and National Predation Totals

Of the 523 cats with complete hunting and prey information, 6.1% were reported to catch birds, 18.4% mammals, 16.6% reptiles, 27.9% insects, and 1.1% other prey (Table 4). These proportions were used in the predation calculations (Appendix B). Insects were summarized separately and are shown for completeness, but the main comparisons with previously published Australian estimates focused

 doi:10.20944/preprints202609.1612.v1

on vertebrates. To compare our national estimates for the cats in our study with reported estimates, we used the same number for the national owned cat population used in Woinarski et al. [10,11] of 3.88 million pet cats and Legge et al. [13] of 3.77 million pet cats.

After adjusting for the fact that owners do not see all prey their cats catch and using proportions used in previously published estimates, the median number of prey caught each year among cats reported to catch each prey type was 6.9 birds, 20.0 mammals, 27.3 reptiles. For insects (median 10.0 insects/year) no adjustment was made because none was available, (Table 8). We then applied these rates to the proportion of the 523-cat cohort that caught each prey type, along with two estimates of hunting prevalence – one for all owned and semi-owned cats together, and one for owned cats.

Among all 2,392 owned and semi-owned cats with complete diet and hunting data whose owners answered the question "Does your cat hunt?", 553 said yes (either sometimes or often), giving an overall hunting prevalence of 23.1%. This gave estimated median annual rates across all owned cats of 0.10 birds, 0.85 mammals, 1.05 reptiles, and 0.65 insects per cat per year, and, scaled to an Australian owned-cat population of 3.88 million (Animal Medicines Australia, 2022), estimated national totals of 0.38 million birds, 3.29 million mammals (rodents), 4.07 million reptiles, and 2.50 million insects per year (Table 8). When semi-owned cats were excluded from the calculation, the national estimate of birds caught by pets each year was 0.35 million, and the estimates for mammals and reptiles were also lower than when semi-owned cats were included.

Table 6. Estimated annual prey captured per cat, scaled up to the Australian owned-cat population, based on owner-reported six-month prey counts that were doubled to estimate annual values. All "per year" values are calculated only among cats reported to catch that specific prey type and with a usable numeric count. **For birds, mammals, and reptiles, values were adjusted using published estimates of how often owners notice prey their cat catches [10–12]; no equivalent estimate existed for insects, so no correction was applied. #This estimated per-cat rate was then multiplied by the Australian owned-cat population (3.88 million [40]) to produce the final national estimates.

Prey type	% (*n*) of cats that caught this prey type shown for all 523* cats that hunted and had information on prey caught in the last 6 months. Included cats not seen to catch prey (*n*=254) or were seen to catch prey and prey type reported (*n*=269)	Median prey caught/cat that caught this prey/year, adjusted for return rate**	Median prey caught/cat/year, averaged across all 2,109 owned cats (hunters and non-hunters)^	Estimated national rate of prey capture for all pet cats (excluding semi-owned) in Australia (million/year)#
Birds	6.12 % (32)	6.90	0.09	0.35
Mammals (rodents)	18.36 % (96)	20	0.81	3.13
Reptiles (lizards/geckos)	16.63 % (87)	27.27	0.98	3.79
Insects	27.92 % (146)	10	0.67	2.59

* 174 cats were seen to catch at least one vertebrate, and 349 that did not. ^The estimated proportion of all owned cats seen catching each prey type was calculated by multiplying the proportion of the 523 cats that hunted (Figure 2).

Among the 2,109 owned cats only, whose owners answered the same question, 477 said yes, giving a hunting prevalence of 22.6%. Applying this to the proportion of the 448 owned cats within the 523-cat cohort reported to catch each prey type gave median annual rates of 0.09 birds, 0.81 mammals, 0.98 reptiles, and 0.67 insects per owned cat per year, and estimated national totals of 0.35 million birds, 3.13 million mammals, 3.79 million reptiles, and 2.59 million insects per year (Table 6).

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3.5. Diet and Predation

Most cats (94%) were fed mainly commercial food, with more than 80% receiving both wet and dry food. Smaller proportions were fed raw meat or cooked meat along with commercial food (Table 7). Chicken (73%) and beef (56%) were the most common types of raw meat, although many cats were fed more than one type (Table 7).

Table 7. Diet type among cats with diet data (n = 2,400 cats) and raw meat types reported among cats fed raw meat. Raw meat categories are not mutually exclusive because cats could be fed more than one type of raw meat; therefore, percentages for raw meat types may sum to more than 100%.

Category	Cats, % (*n*)
Diet type (*n* = 2,400)	
Commercial food	94.2% (2,261)
Wet and dry food	81.6% (1,958)
Wet food only	1.7% (40)
Dry food only	9.3% (222)
Raw meat and commercial food	5.8% (139)
Cooked meat and commercial food	1.7% (41)
Raw meat types reported for cats fed raw meat	
Chicken	73.0% (445)
Beef	55.6% (335)
Lamb	16.9% (100)
Pork	15.2% (90)
Rabbit	2.9% (17)
Kangaroo	21.1% (124)
Other	5.8% (34)

Cats fed raw meat were more likely to be reported as hunters: 31% were reported to have caught prey in the previous six months, compared with 21% of cats that were not fed raw meat. This difference was statistically significant ($\chi^2 = 25.91$, df = 1, $p < 0.001$) (Table 8).

Table 8. Raw meat feeding and reported hunting behavior among cats with complete diet and hunting data (n = 2,392 cats). Percentages in the "No hunting behavior" and "Hunting behavior reported" columns are calculated within each raw meat feeding group.

Diet	No observed hunting behavior, % (*n*)	Hunting behavior, % (*n*)
Not fed raw meat	79.5 (1415)	20.5 (365)
Fed raw meat	69.4 (425)	30.6 (187)

4. Discussion

This study provides a large contemporary dataset on reported hunting behavior and prey captured in Australia, covering more than 2,400 cats from predominantly socioeconomically disadvantaged suburbs in Ipswich, Queensland. An important strength was that questionnaire completion was required for all cats enrolled in the free sterilization program, reducing the voluntary participation bias that can occur when studies specifically recruit owners interested in cat hunting or wildlife. A key finding was that most cats (77%) in this study were not reported to hunt. Importantly, when the proportion of cats that hunted and the type and numbers of prey observed to be captured were used to generate national estimates, they were substantially lower than previously published Australian estimates. For example, our estimate of bird predation was 161 to 311 times lower than previous national estimates and was more consistent with estimates of the total urban bird population and annual turnover.

 doi:10.20944/preprints202609.1612.v1

4.1. Reported Hunting Frequency

Only a minority (23%) of the 2,392 cats in our study were reported to hunt sometimes or often, and less than half (42%) of cats with outdoor access were reported to hunt. This is consistent with two United Kingdom studies showing that prey capture is concentrated among a relatively small proportion of cats [26,47]. In one study, 60% of cats were not observed to bring birds home over 12 months [26]. Similarly, in Dunedin, New Zealand, 25% of cats returned no prey over 12 months, while a small proportion of prolific hunters accounted for much of the predation [25]. These findings reinforce that hunting and prey capture vary substantially among individual pet cats. Because prey counts are strongly right-skewed, mean prey counts can be heavily influenced by a few prolific hunters, whereas medians better represent the typical individual cat.

4.2. Prey Composition in Urban Areas

An important question is what pet cats in urban areas actually catch. Of the 269 cats reported to have caught at least one prey type, 54% were reported to catch insects and 65% caught at least one vertebrate. Among the 174 cats reported to catch vertebrates, 55% caught rodents, 50% lizards or geckos, and 18% birds. Our questionnaire recorded broad prey categories rather than individual species, limiting our ability to determine whether vertebrate prey were native or introduced.

4.2.1. Insects

The prominence of insects in our study is consistent with a study of 37 pet cats in Auckland, New Zealand using cat-borne cameras [46]. Predation events included stalking, pursuing, or seizing prey. Of the 121 recorded events, cats successfully captured prey in only 33% [46]. Prey type could be identified in 64 of the 121 events; 46% involved invertebrates and 7.4% involved vertebrates, all of which were skinks [46].

Invertebrates are also regularly recorded in Australian diets of feral cats. Across 87 Australian studies, invertebrates occurred in 39% of diet samples from cats in largely natural environments and 28% from highly modified environments, with grasshoppers, crickets and related insects the most frequently recorded [48]. These estimates for feral cats are only approximately half the proportion of cats in our study that hunted invertebrates. However, direct comparison is difficult for several reasons. First, the feral-cat studies largely examined stomach contents or scats, whereas our data relied on prey observed and reported by carers. Second, unlike the cats in our study, feral cats must consume sufficient prey to meet their nutritional requirements; because insects provide less biomass than vertebrate prey, this may require a greater number of predation events and greater energy expenditure. Third, 65% of the cats in our study were confined entirely indoors, which would limit their access to vertebrate prey. Nevertheless, these findings demonstrate that invertebrates form a substantial component of cat hunting.

4.2.2. Rodents

Rodents were the most commonly reported vertebrate prey in our study and were likely to have been predominantly introduced species. In a national survey of Australian pet owners, 97% of 1,523 mammal prey that could be classified were introduced; 53% were mice, 28% were rats and 12% were rabbits [27]. In a Canberra study, mammals comprised approximately 65% of prey brought home by pet cats and approximately 98% of mammal prey were introduced species [14]. Similarly, an analysis of stomach contents from 25 trapped urban cats in Brisbane identified only one prey species, the introduced black rat (*Rattus rattus*) [27,49].

In an Australian study of pet cats and unowned cats in highly modified environments, including around tip sites and urban parks, introduced mammals were nearly eight times more frequent than native mammals (46% of diet samples compared with 6% for native mammals) [12]. Collectively, these findings suggest that the majority of rodents reported in our study were likely to have been

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introduced mice or rats, particularly given the well-established, low-density urban setting of the study area in Ipswich.

4.2.3. Small Lizards and Geckos

Small lizards and geckos were the second most commonly reported vertebrate prey. Similarly, among Australian pet cats reported to catch prey, 36% caught reptiles. Of these, 97% of reptile prey were small lizards, skinks and the introduced Asian house gecko (*Hemidactylus frenatus)*. Native skinks and small native lizards comprised 70% of reptiles caught, while 30% were introduced [27]. Although many reptile prey caught by urban cats are native, the significance of this at a population level is uncertain because population sizes are unknown for many reptile species and their ability to withstand predation is likely to differ among species [27].

The occurrence of small reptiles in modified environments is also species and habitat specific. In 59 urban habitat remnants in Brisbane, garden skinks and fence skinks were the most frequently detected reptiles, with each occurring at nearly half of the sites [50]. However, that Brisbane study is nearly 20 years old, and since the introduced Asian house gecko was first noted in Brisbane in 1983, it has continued to invade suitable habitat and is now one of Australia's most abundant urban reptiles. The Asian house gecko is widely distributed across northern and eastern Australia and is reported to negatively affect some native insects and spiders, and compete with native geckos for resources [51–53]. Because Asian house geckos are suited to tropical and subtropical areas, they are absent in cooler climates, and so the proportion of reptile prey caught by cats that are introduced or native will vary by location. Our study was conducted in Ipswich, adjacent to Brisbane, and the introduced Asian house gecko may therefore have comprised some of the lizards and geckos reported by participants. Asian house geckos are commonly found around buildings and homes, including on illuminated walls, both outside and inside buildings and houses, and may therefore have been caught by some of the 9% of indoor-only cats that caught lizards and geckos. However, because respondents were not asked to identify reptile prey to species, we cannot determine what proportion of the lizards and geckos caught were Asian house geckos or native reptiles.

4.2.4. Birds

Birds were the least commonly reported vertebrate prey in our study and were reported for only 6% of the 523 cats with detailed prey analysis (hunters and non-hunters). Among cats in our study reported to catch vertebrate prey, 18% caught birds, compared with 35% reported in an Australia-wide survey [27]. However, unlike our study, potential respondents to the Australia-wide study were informed that it was investigating predation by pets, which may have overrepresented cats that hunted. That study aimed to estimate the number and relative proportions of prey caught and did not estimate the proportion of pet cats that hunted versus did not hunt.

In contrast, a New Zealand study of 37 pet cats using cat-borne cameras recorded no successful bird captures, although one dead bird was scavenged and brought home [46]. Differences among studies are likely to reflect variations in cat populations, prey availability, observation periods and methods used to detect and report hunting.

In the Australia-wide study, 14% of cats caught native birds and 10% introduced birds [27]. Commonly identifiable birds included passerines such as introduced sparrows, Indian mynas, and starlings as well as native noisy miners, and fairy-wrens [27]. However, birds caught in our study were not identified to species-level, so these findings provide context for possible prey composition rather than evidence of the species caught by cats in Ipswich. However, camera trap images from the same suburbs in Ipswich showed that frequently recorded bird species included common species such as ravens, crows, Australian magpies, noisy miners, Indian mynas, pied currawongs and crested pigeons.

The abundance of individual bird species depends on location. The composition and abundance of urban bird communities vary geographically, and introduced species that are common prey in one location may be less prevalent in other regions. For example, starlings and house sparrows are more

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common in southern states than in Ipswich [54]. Loss of shrub and understory vegetation can reduce populations of smaller native birds such as superb fairywrens, scrubwrens and silvereyes [55]. Noisy miners (*Manorina melanocephala*) are native honeyeaters that are highly abundant in many urban environments. Loss of protective habitat may also increase exposure of smaller native birds to noisy miners, which live in large colonies and aggressively defend their territory [55]. This interaction, together with habitat modification, has contributed to conservation concern regarding declines in some small woodland birds, which has resulted in culling of noisy miners in some areas [56]. In Brisbane, which is adjacent to Ipswich, noisy minors are highly abundant and have been reported to comprise up to 50% of the urban bird community [57]. Previous Australian research has found that the composition of bird prey caught by cats reflects the common species in the local environment [14].

The importance of predation at the population level depends on more than the number of birds killed. Average longevity of banded Australian bird species known to be preyed upon by cats has been reported to be approximately 2–4 years, indicating that approximately 25–50% of individuals in these populations would be expected to die each year [27,58]. However, because of continuous reproduction and, in some cases, immigration from other locations, bird populations can remain relatively stable despite substantial turnover of individuals, with population size regulated by factors including resource availability, habitat, and density-dependent survival [59].

Evidence from European studies suggests that, on average, birds killed by cats were in poorer health and condition than birds dying from collisions with windows or cars. In Bristol, United Kingdom, birds killed by pet cats had lower fat reserves and reduced pectoral muscle mass than birds killed in collisions with windows or vehicles [47]. Similarly, a study of dead passerines collected by members of the public found that birds killed by cats had significantly smaller spleens than birds killed by collisions with windows or vehicles [60]. Spleen size was almost one-third smaller in birds killed by cats, which is consistent with lower immunocompetence, given the reported association between spleen size and both humoral and cell-mediated immune responses [60,61]. This difference was also evident among juveniles, with spleen size averaging 48% smaller in juvenile birds killed by cats [60].

These findings suggest that birds killed by cats may be disproportionately drawn from individuals in poorer health or condition. Cat predation may therefore represent, at least in some circumstances, compensatory rather than wholly additive mortality; that is, cats may remove some birds that were already less likely to survive and reproduce. Consequently, the extent to which urban cat predation increases overall mortality or reduces native bird populations cannot be inferred from numbers killed alone. Where predation disproportionately removes compromised individuals that might otherwise die from other causes, the number of birds killed will overstate the number of additional deaths attributable to cats.

Similarly, in a study of wildlife rescued in New South Wales, most of the cat-related rescues of threatened and endangered mammals involved smaller tree-dwelling and flying species, including gliders, microbats, and small possums which are primarily arboreal and do not usually spend time on the ground [62,63]. When they are found on the ground, it is often because they are injured, sick, dehydrated, or are displaced juveniles, or because they are moving between disconnected trees in fragmented landscapes.

Natural turnover contributes to the process commonly described as “survival of the fittest”. Individuals better suited to prevailing environmental conditions are more likely to reproduce, and individuals in poorer health or condition, or with inferior genetic variants, are removed. This increases the representation of superior genetic traits in subsequent generations and contributes to long-term survival of the population as a whole [64,65].

Overall, our findings are consistent with previous evidence that urban pet cats catch a broad range of prey, including insects, rodents, small reptiles and birds, with birds the least commonly reported prey. Importantly, prey captures are not ecologically equivalent: capture of an introduced mouse or common or sick native vertebrate cannot be assumed to have the same population consequence as capture of a healthy native species with a small or declining population. Because

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respondents were not asked to identify prey to species level and we did not measure local prey abundance, survival, reproduction or recruitment, our data describe the composition of prey reported by owners but cannot determine the population-level effect on native wildlife.

4.3. Comparison with Predation Estimates

Our estimates were substantially lower than those widely quoted in the media for pet cats in Australia [10–12]. For example, widely cited estimates suggest that pet cats kill approximately 61 million birds annually [10], 53 million reptiles [11], and 180 million mammals [12]. A subsequent study using some of the same datasets as earlier studies, estimated annual totals of approximately 117.6 million birds, 189.6 million mammals and 82.9 million reptiles killed by pet cats in Australia [13]. In contrast, our annual predation estimates were 0.38 million birds, 3.29 million mammals and 4.07 million reptiles. Like ours, these previous estimates include both native and introduced prey.

Several characteristics of our study population and estimation approach may have influenced our national estimates, and suggest actual figures might even be lower. Cats in our study were younger than the broader Australian pet-cat population, and younger cats have been reported to hunt more frequently than older cats [15]. Our estimate of 0.38 million birds also included the 12% of cats that were not considered owned before their carers heard about the free sterilization program. These cats had greater outdoor access and a higher proportion were reported to hunt; when they were excluded, the estimated annual number of birds caught decreased from 0.38 million to 0.35 million. Finally, because there were no published Australian data, we used the same published correction factors for prey not observed by owners as those used in the national estimates published between 2017 and 2019. These correction factors were derived from three US studies conducted approximately 15 to 50 years ago, involving cat populations that differed from ours in patterns of outdoor access, containment, and prey type. Their applicability to contemporary Australian urban cats is therefore uncertain, particularly because few cats in our study could leave the property, and those that were outside were contained. Consequently, prey such as birds may have been more likely to be observed by owners, even if they were left where they were killed.

4.3.1. Comparison with Published National Estimates

For birds, Woinarski et al. [10] derived a population-average estimate of 15.6 birds caught annually by each pet cat by combining Australian data on the number of birds observed to be caught by pet cats, with a correction for birds killed but not observed by owners, and applying the resulting rate to the estimated national population of pet cats. Legge et al. [13] subsequently used a more detailed modelling approach that accounted for the proportions of pet cats that roamed and hunted, resulting in an average estimate over the whole cat population of 31.2 birds killed per cat per year, regardless of containment or age. In our analysis, the estimated average rate was 0.10 birds caught per cat per year when owned and previously semi-owned cats were included, and 0.09 birds per cat when previously semi-owned cats were excluded. These rates already incorporate the published correction for birds predated but not observed by owners. The approaches by Woinarski et al. (61 million birds) [10] and Legge et al. (118 million birds) [13] produced national estimates approximately 161 and 311 times higher, respectively, than our estimate of 0.38 million birds per year.

For additional context, the published national estimates of 61–118 million birds killed annually substantially exceed estimates of approximately 11 million birds present in Australian urban areas at any one time [57,66]. A study across 72 urban neighborhoods in 18 south-eastern Australian towns found mean densities of 9.3 birds per hectare (4.9 native and 4.4 introduced birds/ha) with individual neighborhood estimates ranging up to 15 native and 13 introduced birds/ha [66]. Applying the estimate of 9.3 birds per hectare to the estimated urban area of 1.19 million hectare in Australia in 2015 would result in an estimated 11 million birds in urban areas of Australia [66,67]. In the Australian study, richness and diversity of urban bird communities were strongly influenced by vegetation characteristics of household gardens, along streetscapes and in urban parklands. The

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density of native and introduced birds varied primarily in response to changes in the built environment, measured through impervious surface cover.

Average lifespan of several banded Australian bird species susceptible to cat predation has been reported to be approximately 2–4 years [27,58]. Therefore, approximately 25% to 50% of the total bird population would die annually from a multitude of causes. These include degenerative, congenital, metabolic, neoplastic, nutritional, physical (extreme weather events, etc.), environmental (including loss of habitat), infection (viral, bacterial, protozoan, fungal, parasitic, etc.), immune, toxic or traumatic, including collisions with motor vehicles and windows, and attacks from dogs, other birds and cats. Despite this annual turnover of birds, reproduction and immigration generally maintain the total population size at a relatively stable level determined by food availability and suitable habitat [68,69]. However, based on an annual turnover of 33% (average of 25% - 50% turnover) of the 11 million birds in urban areas of Australia, it would be expected that 3.6 million (2.75 to 5.5 million) of a total population of would die from various causes each year. Hence, our estimate of 0.38 million birds predated by cats is far more realistic than the 61 to 118 million bird deaths from pet cats claimed by the earlier studies. Similarly, a New Zealand study using predation estimates from 37 pet cats with cat-worn videos found that calculations of the city-wide catch over the 12-month period for six of the bird species evaluated, were either close to or greater than the assumed total urban bird populations for those species, which the authors noted may have been implausible [46]. The comparison nevertheless illustrates the uncertainty that can arise when individual hunting observations are scaled to larger populations, and highlights the importance of testing national predation estimates against independent information on prey abundance, survival, reproduction and migration.

In Australia, each cat-owning household owns approximately 1.3–1.5 cats [4]. To illustrate the scale of the previously published estimates, if the population-average estimates of 15.6–31.2 birds killed annually per cat were applied to a household with two cats, and 29% of killed birds were observed by owners, this would equate to an average of approximately 0.75–1.5 birds observed per month regardless of containment or age. This should not be interpreted as an expectation for every two-cat household, because hunting varies substantially among individual cats, so some owners would observe more and others less. Nevertheless, this frequency is substantially higher than that observed in our study and highlights the difference between the national modelled estimates and the hunting patterns observed in our population. Our study reflected contemporary cat containment practices and was designed to more accurately determine the proportion of pet cats that hunted versus those that do not [15,27].

4.3.2. Similarities in Study Design, Assumptions and Extrapolations

Our study differed from these widely cited studies in data collection, recency and the calculations used for extrapolation, but there were also important similarities. Both approaches used owner observations of prey caught and adjustments for prey not observed by owners. We adjusted our counts for prey caught, in the absence of Australian data, using the published estimates that cats brought home 29% of birds killed [10], 20% of mammals killed (rounded from the 18.6% estimate used by Murphy et al. [12]), and 22% of reptiles killed [11].

The applicability of these correction factors to our study population is uncertain. These correction factors were derived from three studies conducted in the USA. One involved data collected more than 50 years ago, based on personal observations of three pet cats in rural USA with 24/7 indoor-outdoor access, with an estimated 50% of prey observed; however, fetuses from pregnant prey were also included in the total prey count [70]. A second study reported owner observations collected approximately 25 years ago from pet cats living adjacent to a bush reserve; cats roamed freely during the day, but were mostly contained at night [71]. The study reported observations of 12 cats and compared these observations with video recordings from a different group of 12 cats to estimate the proportion of prey observed, and assumed both groups hunted and brought home prey similarly (30% of total prey caught was observed) [71]. The third study reported that 23% of captured prey were returned home based on data collected 15 years ago using video recordings from 50 cats

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living in suburban and rural areas of Georgia; the cats were free-roaming during the day, with 75% contained at night [72]. These three studies were used to derive the 29% bird return rate, which was then used to extrapolate the mean of 4.6 birds observed by owners to be an average of 15.6 birds caught annually be each pet cat. These differences illustrate the uncertainty involved in correcting owner-observed prey counts to estimate total predation. Differences in location, period, outdoor access and observation methods introduce uncertainty when these correction factors are applied to contemporary Australian urban cats. Future studies should obtain Australia data that reflect contemporary containment practices and the types of wildlife preyed upon by pet cats, to improve the accuracy of extrapolations.

4.3.3. Key Differences Between Studies – Mean Versus Median for Numbers of Prey Caught

When prey-count data are strongly right-skewed, the mean and median describe different aspects of the distribution. The median is less influenced by extreme values and better describes the typical individual cat, whereas the mean incorporates the contribution of prolific hunters and is more relevant when the sum of individual population counts from multiple smaller groups is combined into a single, overall estimate described by a mean value. National estimates can therefore differ substantially depending on which summary measure is used [73].

Many studies confirm that the number of prey caught by pet cats is highly skewed. For example, cats residing in Canberra suburbs bordering bushland, approximately 70% of cats caught fewer than 10 prey animals over 12 months, while 6% caught more than 50 [15]. Similarly, in an Australia-wide study of 445 cats reported to have caught prey, the median number of prey observed over six months was 4, compared with a mean of 8.7, with individual estimates ranging from 1 to 155 prey [27]. Similarly, in Dunedin, New Zealand, predation was highly skewed with a small proportion of prolific hunters contributing disproportionally; the median was only 4 prey caught per cat over 12 months compared with the mean of 13.4 prey [25]. Individual cats may also specialize in particular prey. Among 26 cats that returned at least 10 prey items in a Sydney study, 8 cats specialized in small birds, 5 in lizards, 4 in black rats and 3 in larger birds, while 6 cats returned a broader range of prey [74]. This strongly skewed distribution of prey capture has important implications when individual hunting rates are extrapolated to a national population. We therefore present median-based estimates as the more relevant analytical scenario, but highlight the sensitivity of national estimates to the summary statistic used.

Just three Australian datasets were used to determine the type and average number of prey caught by pet cats, which was then used to estimate that pet cats caught 61 million birds a year, and only one of the three was peer-reviewed [10,15–17]. All three studies used owner observations of birds caught by pet cats. In the only peer-reviewed study [15], approximately 70% of cats caught fewer than 10 prey animals during 12 months, while 6% caught more than 50, producing a strongly right-skewed distribution. Barratt [15] reported both the median (1.25 birds per cat per year) and mean (2.3 birds per cat per year), and cautioned that the mean was strongly influenced by a small number of prolific hunters, and recommended the median as a better representation of the average predation by pet cats. However, the mean value was subsequently used in the national extrapolation by Woinarski et al. [10]. In the two non-peer-reviewed publications, a two-page article in Birds Observer from 1990 reported an average of 8.0 birds returned per cat per year in Adelaide, and an unpublished honors thesis from Hobart reported 3.3 birds/year per cat. The three reported mean values of 2.3, 8.0 and 3.3 birds per cat per year were combined as an unweighted mean of approximately 4.53 birds per cat per year. This value was then adjusted using the estimate that 29% of killed birds were returned or otherwise observed by owners, producing a population-average estimate of 15.6 birds killed per pet cat per year [10].

4.3.4. Key Differences Between Studies – Proportion of Cats That Hunt

Because completion of the hunting questionnaire was required for cats enrolled in the free-sterilization program, we were able to estimate the prevalence of reported hunting in the study

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population. Overall, 23% of 2,392 cats were reported to hunt sometimes or often. Among the 523 cats reported to hunt sometimes or often and whose owners said they saw their cat catch prey and with complete information on prey categories, 6% were reported to catch birds. In contrast, the three Australian prey-capture datasets used in the national estimate by Woinarski et al. [10] primarily quantified the number and types of prey observed or returned by participating cats, rather than separately estimating the prevalence of hunting in their cohort of pet cats. The resulting mean estimate of 15.6 birds killed per pet cat per year, after adjustment for birds not observed by owners, was applied as a population-average rate across the estimated 3.88 million Australian pet cat population, producing an estimate of approximately 60.6 million birds killed annually [10]. Much of the Australian prey-return information contributing to this calculation was collected during the 1990s [15–17] and therefore may not reflect contemporary patterns of cat ownership, outdoor access or containment. These studies were also not designed to determine the proportion of cats that were hunters versus non-hunters.

4.3.5. Comparisons for Mammals and Reptiles

Murphy et al.'s [12] estimate of 180 million mammals was approximately 55 times higher than our median-based estimate of 3.29 million mammals. Previous Australian studies have reported that 97–98% of identifiable mammalian prey caught by pet cats were introduced species, particularly mice, rats and rabbits [15,27]. However, mammalian prey in our study were not identified to species, so we cannot determine what proportion were native or introduced. National estimates that combine native and introduced mammalian prey should therefore be interpreted cautiously when they are used to imply impacts specifically on native wildlife.

Woinarski et al.'s [11] estimate of 53 million reptiles was approximately 13 times higher than ours (4.07 million). The introduced Asian house gecko is abundant in urban areas of subtropical southeast Queensland and may have comprised some of the lizards and geckos reported in our study. Because reptile prey were not identified to species, the proportion of native and introduced lizards and geckos could not be determined. The proportion of reptile prey caught by cats that is introduced versus native will vary markedly by location, particularly with regard to the distribution of Asian house geckos in tropical and subtropical humid climates relative to cooler southern climates.

Although snakes were not included as a separate prey category in our questionnaire, previous Australian studies suggest they comprise a small proportion of reptile prey caught by pet cats [15,27]. In an Australia-wide survey, snakes comprised just 1% (21) of the 1,691 reptiles caught by 445 cats [27]. Carpet pythons (*Morelia spilota)* are the most frequently encountered snake species in urban and suburban Ipswich [75,76]. They are non-venomous, often exceed 2 to 3 meters in length, and are regularly found in backyards, roof spaces, and garages as they hunt for rodents and possums [76]. Because of their size, they are more likely to prey on pet cats than to be preyed upon by them. In a study of 258 'nuisance' pythons from Brisbane and Ipswich, most were reported after the snakes had consumed domestic pets or cage-birds [77]. Mature pythons have been reported to consume domestic cats, poultry, and sometimes small dogs. Notably, none of the snakes caught by cats in the Australia-wide study were carpet pythons [27]. Thus, interactions between pet cats and larger reptiles in urban environments are not necessarily unidirectional.

4.3.6. Key Differences Between Studies – Legge et al. (2020)

Legge et al. [13] subsequently used a more detailed model that explicitly accounted for contained cats and cats that roamed but did not hunt. Across six Australian studies, they estimated that 71.1% of pet cats roamed outside; across 10 studies, 78.4% of roaming cats hunted; and across 12 Australian studies, roaming cats that hunted brought home an average of 28.1 vertebrate prey per cat per year. Seven non-Australian studies were then used to estimate that, across prey types, approximately 15.1% of killed prey were brought home. Applying this correction to the 28.1 vertebrate prey per cat per year brought home annually produced an estimated 186 vertebrates killed per year by each roaming cat that hunted [13]. When contained cats and roaming cats that did not hunt were

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incorporated into the model, the resulting population-average estimate was 103 vertebrates per pet cat per year across the estimated population of 3.77 million pet cats: 50.3 mammals, 31.2 birds and 22 reptiles per cat. This produced national estimates of approximately 189 million mammals, 118 million birds and 82.9 million reptiles annually [13]. Thus, the estimate of 31.2 birds per pet cat is a modelled population average resulting from several sequential adjustments rather than a direct observation of the average number killed by pet cats in Australia. This modelled rate is approximately 311 times higher than our estimate of 0.10 birds/year.

4.3.7. Impact of Assumptions and Extrapolations

These calculations demonstrate why national predation estimates are highly sensitive to the assumptions used. The resulting totals depend on the estimated pet cat population, the proportion of cats allowed outdoors, the proportion of roaming cats that hunt, the number of prey recorded for hunting cats, the correction applied for prey killed but not returned or observed, the relative occurrence of different prey types, and whether mean or median prey counts are used. Even relatively small differences at several stages of extrapolation can compound when estimates are applied to millions of cats. This does not mean that national extrapolation is inappropriate, but it does mean that estimates should be interpreted in the context of the populations sampled and the assumptions required to scale those observations to the national population of pet cats.

Our results show that estimates of predation by pet cats vary markedly according to the proportion of cats that hunt, prey composition, variation among individual cats and the correction applied for unobserved prey. Nevertheless, both our median- and mean-based estimates were substantially lower than previous national estimates. This contrast demonstrates that national predation totals are strongly influenced by the underlying data, the population to which those data are applied, and the assumptions used in extrapolation.

4.4. Distinguishing Predation by Feral and Pet Cats

Feral cat predation estimates are often conflated with those of pet cats and cats in highly disturbed environments e.g., stray cats, cats living around farm buildings, mining sites and indigenous communities. However, because the estimated number of pet cat numbers (currently approximately 5.8 million) exceeds estimates of feral cat abundance (2.1–6.3 million) [13,78], it is frequently claimed that pet cats represent a greater predation risk to native wildlife than feral cats [79]. National studies have estimated that an individual feral cat in natural landscapes kills approximately 129 birds, 225 reptiles and 390 mammals each year [10–12]. Feral cats in these environments depend on hunting and scavenging for food to meet their nutritional needs, whereas pet cats are fed and vary greatly in their access to the outdoors and propensity to hunt. The two groups also occupy environments with different prey communities, cat densities and food availability.

These ecological differences are also reflected in prey composition. Previous Australian studies of pet cats in urban environments have reported that a high proportion of identifiable mammalian prey were introduced species, particularly mice, rats and rabbits [14,27]. In contrast, feral cats in natural environments prey on a broad range of native mammals, including species of conservation concern and, depending on location, some introduced species [12,80]. In the Australia-wide survey, it was estimated that ratio of 1.4 native to 1 introduced bird caught by pet cats [27]. A similar ratio of 1.1 native to 1 introduced (4/9/ha to 4.4/ha) was reported for urban abundance of birds [66]. As part of our study, camera traps are being used to estimate cat numbers and wildlife abundance and composition within about 1 meter of ground level. The birds most frequently observed include common birds such as ravens, crows, Australian magpies, noisy miners, Indian mynas (introduced), pied currawong and crested pigeons. Among mammals of a size potentially susceptible to cat predation, most were introduced rabbits, hares, rats, mice and common species like brushtail possums. Pet cats in urban areas should therefore be distinguished from feral cats living in largely natural environments when predation estimates are interpreted. Estimates of the numbers and type

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of prey caught by feral cats should not be assumed to apply directly to pet cats living in urban environments without accounting for differences in food availability, outdoor access, hunting behavior and prey communities.

4.5. Feeding Practices and Predation

In our study, cats that were fed raw meat were more likely to be reported to hunt than cats that were not fed raw meat (30.6% versus 20.5%). The same pattern was evident when prey were separated into broad groups: cats fed raw meat were more often reported to catch insects (12% versus 6%) and vertebrates (10% versus 5%). However, this association does not demonstrate that feeding raw meat caused cats to hunt. Most cats fed raw meat (69%) were not reported to hunt and, among the 552 hunting cats for which raw meat feeding information was available, 66% were not fed raw meat. Differences in diet, outdoor access, reproductive status or other characteristics of the cats may therefore contribute to the observed association.

4.5.1. Consideration of Nutritional Inadequacies in Raw Food Diets

The questionnaire did not record how much raw meat cats received, how frequently it was fed, or whether it represented an occasional supplement or a major component of the diet. Cats classified as being fed raw meat may also have received a complete and balanced commercial diet. However, meat alone, whether raw or cooked, does not constitute a complete and balanced feline diet unless appropriately formulated and supplemented to meet cats' nutrient requirements. Studies evaluating home-prepared diets for cats have commonly identified nutritional deficiencies or imbalances [81,82]. In one study, none of the 25 home-prepared cat diets analysed met all recommended requirements for protein, fat, essential amino acids and minerals, and all contained at least three nutrients below recommended levels [81]. However, our data do not allow us to determine whether cats fed raw meat received nutritionally inadequate diets, experienced hunger, or hunted because their nutritional requirements were not being met.

4.5.2. Impact of Reproductive Status on Nutritional Requirements

Reproductive status may also be relevant to energy requirements. All cats in our study were unsterilized when carers completed the questionnaire because they were being enrolled in a free sterilization program, and we could not determine whether hunting behavior changed following sterilization. Studies have demonstrated reduced energy requirements following sterilization [83–85]. In young adult cats, energy requirements decreased by 18% following sterilization [84]. Conversely, energy requirements increase substantially during reproduction. Pregnant cats consumed approximately 1.8 times their maintenance energy requirement during the fourth week of pregnancy and twice the maintenance requirement during the seventh week, with energy requirements increasing further during lactation [86]. Because we did not record the quantity of food consumed, whether individual cats' diets met their energy requirements, nor did we match surgical records with our dataset (many female cats in the program were pregnant or lactating during spring and summer), we cannot determine whether differences in energy balance contributed to hunting behavior.

4.5.3. Impact of Feeding and Sterilizing Cats on Predation

Potential relationships between the provision of commercial cat food and dietary reliance on wild prey have also been reported from a study of 122 cats involved in a sterilization and feeding program on a rural property in British Columbia, Canada [87]. A subset of 17 cats was sampled using stable-isotope analysis of fur samples before sterilization and again after sterilization and regular provision of commercial cat food. Their isotope profiles shifted away from patterns associated with consumption of wild prey and resembled those of indoor cats consuming commercial dry cat food.

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However, sterilization, regular provision of cat food and other changes occurred over the same period, so the contribution of individual factors to the dietary shift could not be determined [87].

4.5.4. Impact of Feeding and Behavioral Enrichment on Predation

Experimental research also indicates that feeding and behavioral enrichment can influence prey capture. In a controlled trial in the United Kingdom, providing a nutritionally complete commercial food high in meat-derived protein reduced the number of animals captured and brought home by 36%, while introducing 5–10 minutes of daily object play reduced captures by 25% relative to controls and the pre-intervention period [88]. The food used in that study was a commercially formulated, grain-free food rather than raw meat, so the finding should not be interpreted as evidence that raw feeding reduces hunting. Instead, the study provides evidence that changes in diet and opportunities to express components of predatory behavior through play can influence predation.

Overall, our findings demonstrate an association between raw meat feeding and reported hunting, including both insect and vertebrate prey, but do not establish the mechanism underlying that association. In particular, they do not demonstrate that raw meat caused hunting, that raw-fed cats were nutritionally deficient, or that they hunted because their energy requirements were not being met. The available literature indicates that nutritional adequacy, food provision, reproductive status, sterilization and behavioral enrichment may all influence energy balance, diet and hunting behavior [83,85–88]. More detailed information on the quantity and nutritional composition of food provided, outdoor access, reproductive status and changes in hunting before and after sterilization would be required to determine why raw meat feeding was associated with hunting in our population.

4.6. Broader Ecological Context and Implications

Our results should also be considered alongside the multiple factors that influence wildlife populations in urban areas. More broadly, urban green spaces can make an important contribution to biodiversity conservation, although their value depends on factors including size of remnant natural habitat, connectivity with other suitable habitat, surrounding land use, vegetation structure and management [29].

4.6.1. Population Studies of Wildlife and Cats in Urban Areas

At 57 sites across suburban Perth, pet cat density was not significantly associated with passerine bird species richness or diversity [28]. Bird species richness was negatively associated with increasing housing density and distance from remnant bushland and positively associated with the size of nearby bushland.

Similar patterns have been reported for small and medium-sized mammals [89]. No significant differences in mammal diversity or abundance were found among remnant bushland sites in Perth that were subject to three different cat-management approaches for approximately 10 years prior to the study: strict prohibition of cat ownership; nighttime curfews with a requirement to wear a collar with a bell; and no cat restrictions. Brushtail possums and southern brown bandicoots were the most abundant medium-sized mammals present, and occurred at similar levels across the sites. Total mammal abundance at the unregulated sites exceeded that at the two sites with cat restrictions, but these unregulated sites also had denser vegetation. The smaller mardo (*Antechinus flavipes),* which the authors suggested could be regarded as the most susceptible to cat predation of all the native species because of its size, was found predominantly at an unregulated site. However, these sites also had denser vegetation, and vegetation density was positively associated with mammal numbers [89]. Denser vegetation provides greater shelter from predators and often richer food resources [89].

Responses to highly modified habitats also differ among wildlife species. The abundance of southern brown bandicoots in Melbourne was significantly higher at the most highly urbanized sites where cats were most frequent and lower in the remnant natural sites where cats were rare [90]. The

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findings demonstrate that highly modified urban habitats can support resident and breeding populations of some adaptable native species.

Collectively, these studies indicate that urban wildlife occurrence and abundance reflect interacting influences including vegetation structure, habitat size and quality, connectivity, surrounding land use and urban landscape management, as well as predation [28,29,90,91].

4.6.2. Human Associated Risks to Wildlife in Highly Disturbed Environments

Urban wildlife is also exposed to habitat clearing and fragmentation, altered vegetation, road traffic, human-made materials, unsuitable environmental conditions, severe weather, disease, toxins and other predators. Vehicle collisions are an important recorded cause of wildlife injury and mortality in Australian urban and peri-urban environments [62,92–94]. In a New South Wales dataset of rescues involving threatened species, rescues attributed to cat attacks accounted for 0.6% of recorded rescues, while rescues associated with human-made materials, weather-related events, unsuitable environmental conditions and vehicle collisions were recorded more frequently [62]. Rescue datasets capture only animals that are found, reported and admitted to care and therefore cannot provide complete estimates of cause-specific mortality or population-level impact. Nevertheless, these data illustrate that wildlife in human-modified environments is exposed to multiple threats, and management needs to address the preventable causes of injury and mortality that pose the greatest threats.

Overall, the available evidence does not indicate that pet cats have no effect on urban wildlife. Rather, the magnitude and ecological significance of their effects are likely to vary among individual cats, prey species, locations and habitat conditions. A prolific hunting cat could have a meaningful local effect, particularly where prey populations are small, isolated or vulnerable. At broader urban scales, however, wildlife occurrence, abundance and persistence are also influenced by habitat availability and quality, vegetation structure, connectivity, road mortality and other features of the human-modified environment. Urban wildlife management should therefore consider these interacting pressures, including habitat protection and restoration, reduction of road- and infrastructure-related mortality, and practical measures to reduce hunting by pet cats known to prey on wildlife, rather than assuming that a single cat management response such as mandated containment will measurably reduce the threats to urban wildlife populations.

4.7. Limitations

This study has several important limitations. Although completing the questionnaire was required for enrolment in the free sterilization program, the sample was limited to cats from selected lower-income suburbs of Ipswich. Requiring questionnaire completion reduced voluntary participation bias among program participants, but it did not remove selection bias associated with participation in the program itself. Participants were owners and carers seeking free sterilization for an unsterilized cat, and the findings therefore cannot be assumed to represent all cat owners or pet cats in Ipswich or Australia, particularly those in higher-income households, rural areas, higher-density housing including inner-city areas with high-rise apartments, or in regions with different cat-management practices and access to veterinary care.

4.7.1. Age

The age distribution of cats in the study also differed from that expected for the broader Australian pet-cat population. Approximately 80% of cats in our cohort were aged from four months to five years, while only 2.6% were older than five years. A small proportion (1.3%) was recorded as younger than eight weeks, which may reflect inaccurate owner-reported ages or cats booked into the program before reaching the minimum weight required for sterilization ($\geq$ 1 kg). By comparison, Animal Medicines Australia [95] reported that 63% of Australian pet cats were younger than six years

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and 34% were younger than two years, indicating a substantially larger representation of older cats in the general pet-cat population than in our cohort.

Age is relevant because multiple studies from Australia, the United Kingdom and New Zealand have reported declining predation with increasing cats age [15,25,26,46,96–99]. However, there is no single age at which cats can be considered to cease hunting. The underrepresentation of older cats in our cohort likely overestimated their hunting rates relative to the national population of pet cats, although the magnitude of any such bias cannot be quantified.

4.7.2. Sterilization

All cats were unsterilized at the time of the questionnaire because it was completed before sterilization. This differs from the reproductive status of much of the Australian pet-cat population and may affect generalizability. Sterilization can alter energy requirements and aspects of roaming behavior, but available evidence does not allow us to determine reliably whether sterilization itself alters predation. Sterilization and feeding of farm cats reduced predation, but the relative contribution of adequate feeding and sterilization are unknown [87]. The direction and magnitude of any resulting bias in our estimates of predation are therefore uncertain.

4.7.3. Reliability of Recall and Incomplete Questionnaires

The study relied on carer-reported information rather than direct observation. Some hunting and prey capture may consequently have been missed, forgotten or misclassified. Recall over a six-month period may be particularly imperfect for prey that are common, small or less memorable, such as insects.

Not all respondents answered every prey-related question, and not all cats reported to hunt had usable prey information. Detailed prey analyses were therefore restricted to the 523 cats for which information was available on hunting and all prey categories, including 269 cats reported to catch at least one kind of prey and 174 cats that caught at least one vertebrate prey. This smaller subset may not have been fully representative of all cats reported to hunt. Data in the tables distinguish the full study population from the subsets contributing to specific analyses.

4.7.4. Inclusion of Semi-Owned Cats

Approximately 12% of cats had previously been semi-owned. Before hearing about the free sterilization program, their carers indicated that they did not consider themselves the owners of these cats and were instead feeding and caring for them. However, to book online for the free service, they had to agree to take ownership at the time of sterilization. Cats, mostly at multi-cat sites, whose carers were unable to take ownership because they could not comply with cat limits and containment laws, were sterilized and microchipped in the program but remained semi-owned, and were managed outside of this online booking system [36,100]. The 12% of previously semi-owned cats may have been observed less consistently before enrolment than cats that had been fully owned throughout the six-month reporting period, potentially reducing the accuracy of reported hunting and prey capture. Differences in outdoor access and the extent to which previously semi-owned cats were observed before enrolment should therefore also be considered when interpreting reported hunting behavior. Previously semi-owned cats had numerically higher levels of outdoor access, reported hunting and prey capture than owned cats, although these differences were not statistically significant. Although none of these differences individually reached statistical significance at $p = 0.05$, excluding previously semi-owned cats reduced the national bird predation estimate from 0.38 million to 0.35 million.

4.7.5. Prey Categories

The prey categories themselves were broad. Rodents were grouped together, as were lizards and geckos, without systematically asking respondents to identify the animal involved. We could therefore not determine the native or introduced status of individual prey. The questionnaire also

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did not record whether reported prey were alive, injured, scavenged or already dead before contact with the cat. The findings should consequently be interpreted as carer-reported prey capture rather than direct observations of successful predation. For example, the only bird brought home in the New Zealand study was already dead before being found by the cat.

The questionnaire included an "other prey" category. Although respondents were not specifically asked to describe these prey, one reported flies, another stated "whatever he finds in the house", and another indicated that the cat "was a stray". Interpretation of broad prey categories may also have varied among respondents, and some may not have considered flies, moths, spiders, cockroaches or other common household invertebrates to be insects.

4.7.6. Prey Captured Versus Killed

Our estimates may overestimate the number of prey killed because the questionnaire asked owners whether their cat hunted and whether they observed prey caught by their cat, but did not ask whether observed prey caught were dead or alive. Cats can bring live prey into the home, and live prey may subsequently be released or escape. For example, a recent study of 553 cats in the United Kingdom found that a proportion of prey returned by cats were alive, although the proportion varied substantially among prey groups [101]. Australian wildlife rescue data similarly indicate that some threatened wildlife caught by cats survive when rescued, with 22% that survived long enough to be rescued were subsequently released alive [13]. There are currently insufficient data to estimate survival rates among different species caught by pet cats and brought home in Australia. Consequently, our estimates of prey caught should not necessarily be interpreted as equivalent to the number of prey killed.

4.7.7. Extrapolations and Estimates

The annual predation estimates involve additional uncertainty. Six-month carer-reported prey counts were annualized and adjusted using previously published estimates of the proportion of killed prey returned home. These correction factors were derived largely from overseas studies and varied among locations, methods and prey groups. They may therefore not accurately represent contemporary urban Australian cats, and our adjusted national estimates should be regarded as approximate rather than precise counts. Two of the studies contributing to these correction factors used data collected approximately 25–50 years ago from US cat populations with patterns of outdoor access that differed from those in our study. The prey communities and observation methods also differed. The direction and magnitude of any resulting bias when these correction factors are applied to contemporary Australian urban cats are therefore uncertain. However, because 87% of cats in our study were confined to the property, even when they had outside access, correction factors derived from free-roaming cats in USA may underestimate the proportion of prey observed by owners in our study. This may be particularly relevant for larger prey such as birds, which could potentially be seen by owners even when left where they were killed.

National extrapolation introduces a further limitation because the Ipswich study population cannot be assumed to represent all Australian pet cats. For example, in inner city areas of capital cities, high-density apartment living is more common and increasing, as demand for housing exceeds availability; in these locations, cats are more likely to be fully contained. However, in Ipswich, high-rise apartments (defined as buildings of 6+ or 9+ storeys) are virtually non-existent, making up less than 0.5% of all housing stock [102]. Total high-density and medium-density dwellings combined account for only 12% of the city's residences, while detached separate houses dominate at over 80%. In addition, the level of relative socioeconomic advantage and disadvantage as measured by the SEIFA index in the suburbs from which most cats originated from was lower (868, 906) than the score for Ipswich (948) and Australia (1000) [35]. In Goodna, 20% of households (2.4 people) have a weekly income of less than $A650 and in only 10.9% of households, weekly income exceeds $A3,000 compared to 16.5% and 24.3% respectively for Australia [43]. In the two suburbs contributing the greatest number of cats, the proportion of residents who were tenants was 58% (Redbank Plains) and

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48% (Goodna) compared to the Australian average of 30.6% [41,43,103]. These differences in housing type, rental status and socioeconomic conditions illustrate why the Ipswich study population may not be representative of cat-owning households elsewhere in Australia and were likely barriers to successful containment for some respondents.

4.7.8. Population-Level Effects

Finally, this study cannot determine population-level effects on wildlife. It describes reported hunting and prey capture by cats enrolled in the program but did not measure wildlife abundance, prey availability, survival or recruitment, habitat quality, vegetation structure or other drivers of wildlife persistence. Our estimates should not be regarded as exact national counts: they are based on carer reports from cats enrolled in a sterilisation program in selected Ipswich communities, and the correction factors for unobserved prey were themselves derived largely from overseas studies.

Consequently, the number of prey reported to be caught cannot by itself establish whether cat predation reduced local wildlife populations. Future assessments of the ecological effects of pet cats in urban environments would be strengthened by directly measuring the abundance of wildlife species of concern and cat predation, while also accounting for habitat availability, vegetation structure, urban land use, road mortality and other major pressures on wildlife.

Despite these limitations, this large contemporary dataset provides valuable information on hunting behavior, prey composition and reported prey capture among urban cats from communities that are often underrepresented in cat-management research. It also provides an empirical basis for examining how the assumptions used in national extrapolations influence estimates of predation by pet cats. Our data demonstrate that national predation estimates can change substantially depending on the source data, study population and assumptions used in extrapolation. Given that our estimates are considerably lower than the estimated total bird population in urban Australia and the expected annual turnover of these birds, this suggests that our estimates may be more realistic.

5. Conclusions

This study provides one of the largest recent Australian datasets on owner-reported predation of pet cats, based on more than 2,400 cats enrolled in a community sterilization program in disadvantaged suburbs; questionnaire completion was required for the online booking process. Most cats were kept indoors or had restricted outdoor access, and only a minority were reported to hunt. Reported prey capture varied substantially among cats and was dominated by insects and rodents, while bird captures were relatively uncommon and usually low in number.

Our national estimates incorporated the observed prevalence of reported hunting, the proportions of hunting cats reported to catch each prey type, and the reported number of prey caught, with published correction factors applied for prey not observed by owners. The resulting estimates were substantially lower than previously published Australian estimates. However, these previously published studies used different source populations, methods and assumptions, including different approaches to accounting for roaming and hunting prevalence, and notably were not designed to determine the proportion of the pet cat population that hunted.

For example, our estimates of bird predation (0.38 million/year) were 161 to nearly 311 times lower than widely cited estimates of pet cat predation of 61 million and 118 million birds, which were approximately 6 to 12 times higher than the total estimated bird population in urban areas of Australia of 11 million birds from 2013. The previous estimates were also many times higher than the estimated annual death rate of birds in urban areas from all causes of approximately 3.6 million each year, suggesting these previously published estimates of pet cat predation in Australia are exaggerated. Using the most recent published estimate of the Australian pet cat population (5.83 million) [4], which is 1.5 times higher than the populations used in the previous extrapolations (3.88 million and 3.77 million) [10,13,40], estimates of bird predation by pet cats would increase to 92 million (Woinarski) and 177 million (Legge), greatly exceeding the estimated total urban bird population.

 doi:10.20944/preprints202609.1612.v1

Importantly, our findings challenge broad claims about the scale of pet cat predation in urban Australia and show that the impacts of pet cats in cities are context-dependent. They should be interpreted alongside stronger drivers of wildlife outcomes in cities, including habitat quality and urbanization. Humane, evidence-based policy should therefore focus on practical, achievable measures such as sterilization and realistic containment support, rather than relying on outdated and generalized assumptions about all pet cats.

Mitigating cat predation effectively relies on identifying and targeting management efforts toward individual cats that are the most prolific hunters. Where threatened or endangered species occur in urban areas, their protection should be treated as a public conservation responsibility, not as a private financial burden for individual residents. These species are a valuable state and national asset, and their protection delivers benefits for the whole community. In these circumstances, governments should provide practical support, such as appropriate fencing, containment or alternative protective measures at no cost to affected landholders, particularly where such measures are required or encouraged to achieve broader conservation outcomes. A targeted and supportive approach is likely to be more effective in protecting vulnerable wildlife than broad mandated containment laws that may be difficult for disadvantaged cat owners to comply with and may also discourage semi-owners from adopting cats they are caring for.

In summary, when previously published estimates of 61 to 118 million birds killed annually by pet cats are compared with an estimated urban bird population of 11 million birds and the annual turnover of approximately 3.6 million birds, those estimates appear implausibly high. Our estimate of approximately 0.3 to 0.4 million birds annually is more consistent with the scale of the urban bird population and its expected annual turnover.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/doi/s1, Figure S1: title; Table S1: title; Video S1: title.

Author Contributions: Conceptualization, J.R.; formal analysis, K.S., K.D.R. and H.H.N.; writing - original draft preparation, K.D.R.; writing - review and editing, J.R. and K.D.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by donors to the Australian Pet Welfare Foundation.

Institutional Review Board Statement: Ethics approval was obtained from the University of Queensland Research Ethics and Integrity Unit (Human Ethics 2019/HE002153; Animal Ethics 2019/AE000207).

Informed Consent Statement: Informed consent was obtained from all participants involved in the study. Consent for inclusion of owned and semi-owned cats in the Community Cat Program and associated questionnaire data collection was obtained from the owner or authorized carer at the time of booking.

Data Availability Statement: The data used in this study are not publicly available due to privacy and ethical restrictions relating to participant confidentiality.

Acknowledgments: The authors used OpenAI's ChatGPT to assist with language editing and improving clarity. The authors take full responsibility for the content and interpretation of the manuscript. Ashleah Williams assisted with data checking, formatting, referencing and editing.

Conflicts of Interest: J.R. has an honorary position at the University of Queensland and is employed by the Australian Pet Welfare Foundation (APWF) which is a research-based not-for-profit that undertakes research aimed at improving the health and welfare of dogs and cats and benefiting pets and the people who care for them. APWF is largely funded by philanthropic gifts. K.D.R is employed by The University of Queensland and volunteers with APWF.

Appendix A

Questionnaire questions

* = Required question

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1. Your cat

1q. Cats Name * *Free-text response*

1s. Cats Sex *

(a) Male; (b) Female

1a. Cats Age (please confirm if in months or years) * *Free-text response*

1c. Cats Breed/hair type *

(a) Domestic Short Hair; (b) Domestic Medium Hair; (c) Domestic Long Hair; (d) Other

a. Cats fur coloring * *Free-text response*

How long have you owned this cat? *Free-text response*

Prior to when you heard about the free desexing program, did you consider that you were the owner of this cat and that it was your property, OR did you consider yourself a carer for this cat, and not regard it as your property? *

(a) Owner; (b)Carer or Guardian

Has your cat been Microchipped *

(a) Yes; (b) No; (c) Don't know

Cat's Microchip number – *Show when 1h is "Yes" Free-text response*

Your cat's environment

How would you describe your cat's outdoor access? *

(a) Indoors Only; (b) More indoors than outdoors; (c) 50/50; (d)More outdoors than indoors; (e) Outdoors only

What is the extent of your cat's outdoor access? – *Show when 2a is not "Indoors Only"*

(a) Enclosed courtyard or back yard; (b) Not restricted to my property

When is your cat able to have access to the outdoors? * – *Show when 2a is not "Indoors Only"*

(a) Day-time only; (b) Night-time only; (c) Day and night

Are there other cats present in his or her usual environment? *

(a) Yes; (b) No; (c) Unknown

Did the cat come from an environment with dogs? *

(a) Yes; (b) No; (c) Unknown

Are those dogs vaccinated? *

(a) Yes; (b) No; (c) Unknown

Where did your cat originally come from? *

(a) Breeder; (b) Friend/family in urban area; (c) Friend/family in rural area; (d) Animal shelter; (e) Online/Facebook/newspaper advertisement; (f) Pet shop; (g) Stray in urban area; (h) Stray in rural area (i) Other (Please provide other details: *Free-text)*

What are your cat's toileting habits? *

(a) Litter box; (b) Both litter-box and outside; (c) Outside

Does your cat ever go to boarding facilities? *

(a) Yes; (b) No

Your Cat's Health and Vaccination Status

Has your cat been tested for Feline Leukaemia Virus (FeLV)? *

(a) Yes; (b) No

Do you know the result? – *Show when 3a is "Yes"*

(a) Positive; (b) Negative; (c) I don't know

Has your cat been tested for Feline AIDS (FIV)? *

(a) Yes; (b) No

Do you know the result? – *Show when 3c is "Yes"*

(a) Positive; (b) Negative; (c) I don't know

Has your cat been vaccinated? *

(a) Vaccinated; (b) Unvaccinated; (c) Unknown

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Was a full-course (two or more) of vaccinations given as a kitten? – *Show when 3e is "Vaccinated"*
(a) Yes; (b) No; (c) Unknown

When was the last vaccine given? – *Show when 3e is "Vaccinated"*
(a) Within the last 6 months; (b) 6-12 months ago; (c) Over a year ago

Has this cat been to a veterinarian before for any reason? *
(a) Yes; (b) No

What did they go to the vet for? – *Show when 3h is "Yes"*
Free-text response

Your Cat's Diet

Which statements best describes your cat's diet? *
(a) All wet food from cans or pouches; (b) All dry food; (c) A combination of wet and dry food; (d) A combination of raw meat and commercial food; (e) A combination of cooked meat and commercial food

Do you ever feed your cat raw meat? *
(a) Yes; (b) No

How often? – *Show when 4b is "Yes"*
(a) Daily; (b) Weekly; (c) Monthly; (d) Occasionally

What types of raw meat have you fed your cat? – *Show when 4b is "Yes"*
Multi-select: (a) Chicken; (b) Beef; (c) Lamb; (d) Pork; (e) Rabbit; (f) Kangaroo; (g) Other (Other please specify: *Free-text response)*

Does your cat hunt? *
(a) Yes, often; (b) Sometimes; (c) Never

Have you ever seen your cat catch prey?
(a) Yes; (b) No

What prey have you seen your cat catch? – *Show when 4f is "Yes"*
Multi-select: (a) Insects; (b) Slugs and snails; (c) Lizards/Geckos; (d) Rodents (mice, rats); (e) Birds; (f) Other prey

On average, how many insects does your cat catch in 6 months? – *Show when 4g has "Insects" selected, Free-text response*

Did your cat eat the insects? – *Show when 4g has "Insects" selected*
(a) Yes; (b) No

On average, how many slugs/snails does your cat catch in 6 months? – *Show when 4g has "Slugs and snails" selected, Free-text response*

Did your cat eat the slugs/snails? – *Show when 4g has "Slugs and snails" selected*
(a) Yes; (b) No

On average, how many lizards/geckos does your cat catch in 6 months? – *Show when 4g has "Lizards/Geckos" selected, Free-text response*

Did your cat eat the lizards/geckos? – *Show when 4g has "Lizards/Geckos" selected*
(a) Yes; (b) No

On average, how many rodents (mice, rats) does your cat catch in 6 months? – *Show when 4g has "Rodents (mice, rats)" selected, Free-text response*

Did your cat eat the rodents (mice, rats)? – *Show when 4g has "Rodents (mice, rats)" selected*
(a) Yes; (b) No

On average, how many birds does your cat catch in 6 months? – *Show when 4g has "Birds" selected, Free-text response*

Did your cat eat the birds? – *Show when 4g has "Birds" selected*
(a) Yes; (b) No

On average, how many other prey does your cat catch in 6 months? – *Show when 4g has "Other" selected, Free-text response*

 doi:10.20944/preprints202609.1612.v1

Did your cat eat the other prey? – *Show when 4g has "Other" selected*
(a) Yes; (b) No

Ownership

When the cat first came into your life, did you regard yourself as the owner or were you just feeding or caring for this cat
(a) Owner; (b) Just feeding or caring for cat

If at first you didn't consider yourself to be the owner, but now you do, what factors made you change your mind (select up to 5 that apply)? – *Show when 5a is "Just feeding or caring for cat"*
Multi-select: (a) I became more attached to the cat over time; (b) I heard about the opportunity to get cat desexed and microchipped for free; (c) The cat continued to hang around; (d) The cat became more friendly; (e) I wanted to do the right thing; (f) The cat was at risk of being trapped by animal control or council officers; (g) I was concerned this cat would be euthanased; (h) to stop kittens being born; (i) I feel responsible now because I have been caring for it; (j) There is no one else to take responsibility for this cat; (k) Initially I was not sure if this cat belonged to someone; (l) I was not sure someone else was feeding and caring for this cat; (m) The cat started coming into the house; (n) The kids or another family member fell in love with it; (o) The cat was in danger of being hurt; (p) The cat required veterinary attention; (q) Other (please explain: *Free-text response*)

Among the factors you selected which was the most important (select only one from the list below)?
(a) I became more attached to the cat over time; (b) I heard about the opportunity to get cat desexed and microchipped for free; (c) The cat continued to hang around; (d) The cat became more friendly; (e) I wanted to do the right thing; (f) The cat was at risk of being trapped by animal control or council officers; (g) I was concerned this cat would be euthanased; (h) To stop kittens being born; (i) I feel responsible now because I have been caring for it; (j) There is no one else to take responsibility for this cat; (k) Initially I was not sure if this cat belonged to someone; (l) I was not sure someone else was feeding and caring for this cat; (m) The cat started coming into the house; (n) The kids or another family member fell in love with it; (o) The cat was in danger of being hurt; (p) The cat required veterinary attention; (q) Other

As the owner/carer of the above cat, I give permission to do the following, as necessary and in line with best practice in veterinary care (please tick)
Multi-select: (a) Desex the cat*; (b) Vaccinate the cat against cat flu and feline enteritis (ie. gastro)*; (c) Give them Bravecto treatments for fleas, ticks and worms*; (d) Tattoo their ear (to indicate the cat is desexed) - this is mandatory in Queensland*; (e) Microchip the cat (for identification) - this is mandatory in Queensland*; (f)Take blood, hair, urine and stool samples to check for various infectious diseases*; (g) To test reproductive tissues removed during desexing for infectious disease*; (h) Provide on the day of desexing, additional free veterinary medical or surgical treatment, including dental extractions, if deemed important to improve the immediate quality of life for your cat. For other conditions identified during the physical examination or surgery, you will be advised to consult your veterinarian*; (i) I have read and understood the below information*; (j) I am satisfied that I have been given the opportunity and means to discuss the study with the project team* (k) I understand that all data pertaining to myself and the cat will be treated in a strictly confidential manner, and will be used to generate information relating to the aim*

Appendix B

Table B1. Calculations for estimates annual rate of predation by owned cats.

Prey type	% (*n*) of all 523* cats that hunted	Median prey caught/ cat that	Published prey return	Median prey caught/cat that	% of cats that caught vertebrat	% of owned cats (448) seen to	Estimated proportion	Proportion of all 2,392 owned	Median number of this prey	Median number of this prey type	Estimated national total	Estimated national total numbers

 doi:10.20944/preprints202609.1612.v1

	that caught this prey type in the last 6 months	caught this prey/year	rate [10–12]	caught this prey/year adjusted for return rate	es (174 cats) that caught this prey type	catch this prey type (excluding semi-owned cats)	of all 2,109** owned cats (hunters and non-hunters combined) that were seen to catch this prey type	and semi-owned cats (553 hunters and 1,839 non-hunters) that catch this prey type	type caught per year, averaged across all cats (owned and semi-owned)	caught per year, averaged across all 2,109 owned cats only	numbers of each prey type caught (million/year) for the 3.88 million pet cats in 2016. Based on proportion of 523 cats (owned and semi-owned) that were (269) or were not seen to catch prey (254) and had data on prey type	of each prey type caught (million/year) for the 3.88 million pet cats in 2016 Based on proportion of hunters 477 and non-hunters 1632 in sample of 2,109 owned cats (excluding semi-owned cats)
Birds	6.12 % (32)	2	29%	6.90	18.39 %	5.80 %	1.31 %	1.41 %	0.10	0.09	0.38 mil/yr	0.35 mil/yr
Mammals (rodents)	18.36 % (96)	4	20%	20	55.17 %	17.86 %	4.04 %	4.24 %	0.85	0.81	3.29 mil/yr	3.13 mil/yr
Reptiles (lizards/geckos)	16.63 % (87)	6	22%	27.27	50.00 %	15.85 %	3.58 %	3.85 %	1.05	0.98	4.07 mil/yr	3.79 mil/yr
Insects	27.92 % (146)	10	—	10	30.46 %	29.46 %	6.66 %	6.45 %	0.65	0.67	2.50 mil/yr	2.59 mil/yr

* 174 cats that caught at least one vertebrate prey, and 349 that did not. ** Proportion of all 2,109 owned cats (hunters & non-hunters combined) catching this prey type (only owned cats where owner answered does your cat hunt prey and based on proportions caught by 174 cats that hunted vertebrate prey - assumed that the hunters among the 2,109 cats hunted the same proportion of vertebrate types as the hunters in the 174 hunting cats with complete prey type information. Excluded 292 of 2392 cats that were semi-owned prior to sterilization.

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