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The diet of the feral cat (*Felis catus*), red fox (*Vulpes vulpes*) and dog (*Canis familiaris*) over a three-year period at Witchelina Reserve, in arid South Australia

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Abstract

Introduced predators have had, and continue to have, severe impacts on Australian biodiversity. At a recently-established conservation reserve, Witchelina, in arid South Australia, we assessed the diet of feral cats (*Felis catus*) (404 samples), red fox (*Vulpes vulpes*) (51 samples) and dog (*Canis familiaris*) (11 samples) over a 3-year period. There was marked overlap (98.5%) in dietary composition between cats and foxes. Rabbits (*Oyctolagus cuniculus*) comprised a major dietary item for all three predators. Invertebrates contributed the largest number of prey items for foxes and cats, but mammals comprised the bulk, by weight, for all three predators. Birds and reptiles had a higher frequency of occurrence in the diet of cats than for foxes or dogs. The size of mammal prey taken was least for cats and greatest for dogs. The diets of cats and foxes showed significant seasonal variation, with reptiles and invertebrates being least common in the diet in winter. The threatened thick-billed grasswren (*Amytornis modestus*) was found for the first time in the diet of feral cats. Bearded dragons (*Pogona vitticeps*) occurred in about a third of cat and fox samples. This study contributes further to the evidence of biodiversity impacts of introduced predators, and the need for their strategic management.

Running head: Diet of cat, fox and dog in arid South Australia

Additional keywords: dietary overlap, conservation management, predation.

Introduction

Two mammalian predators, the domestic cat (*Felis catus*) and red fox (*Vulpes vulpes*), have had severe detrimental impacts on the Australian fauna since their introductions (1788 and thereafter for the cat, and in about the 1870s for the fox: Abbott *et al.* (2014)). Both species now have extensive ranges in Australia, with feral cats occurring across >99% of the land area of Australia and its islands (Legge *et al.* 2017). The impacts of these two introduced predators have been particularly pronounced on medium-sized Australian mammals, with most of the 30 known Australian mammal extinctions, and declines of many other native mammal species, over the last 200 years due at least in part to these two introduced predator species (Burbidge and McKenzie 1989; Dickman 1996; Doherty *et al.* 2017; Woinarski *et al.* 2015). Largely due to recognition of such detrimental impacts, the control of these introduced predators is now recognised to be a main conservation priority at national level and for many individual conservation reserves (Commonwealth of Australia 2015).

The conservation impacts of these two introduced predator species are influenced by their dietary breadth, selectivity and flexibility; their abundance and distribution; by the efficacy of actions that seek to control them; and by the abundance and life histories of prey species. Many recent studies have considered aspects of the diet of cats, foxes and dogs/dingoes (*Canis familiaris*) in various parts of Australia, although there are relatively few studies that have compared the diets of the three species at sites of co-occurrence (Glen *et al.* 2011; Paltridge 2002; Pavey *et al.* 2008; Spencer *et al.* 2014; Triggs *et al.* 1984). For feral cats, information from many dietary studies has been reviewed recently (Doherty *et al.* 2015).

In this paper, we add to this evidence base by describing aspects of the diet of these three predators over a 3-year period at a recently-established conservation reserve (Witchelina Reserve) in inland South Australia. We consider five questions. How much overlap and what differences are there in diet among these three species? How do diets at this site compare with those reported elsewhere? How do these diets vary seasonally? Is there predation by these predator species on any threatened species in this reserve? Are there significant differences in diet associated with local environmental differences? These questions relate to management of this reserve to achieve conservation outcomes.

Methods

Study site

This study occurred in the 4219 km^2 Witchelina Reserve (ca. 30^{o}01'S, 138^{o}03'E) in arid inland South Australia, about 30 km south of Marree. Average annual rainfall for Witchelina (Bureau of Meteorology site 17055) is 153 mm, but rainfall is erratic. Rainfall over the study period did not vary substantially from this annual average, however the two years preceding the study were among the wettest on record. Temperatures show marked seasonality, with mean monthly maximum of ca. 35^{o}C in summer and 20^{o}C in winter (Bureau of Meteorology data for Maree climate station 017031).

The reserve was established in 2010 and is owned and managed by the Nature Foundation SA. Prior to reservation it was operated over a ca. 140 yr period as a pastoral property. Subsequent to its establishment as a reserve, feral predators have been managed through aerial baiting and spotlight-shooting. This program produced no apparent changes in the abundance of feral cats, but coincided with a notable reduction in the abundance of foxes (Table 1a). This latter trend was probably due mostly to lower rainfall tallies in the later years of the study, which also resulted in a reduction in rabbit numbers, although these numbers were not systematically monitored.

The property overlaps parts of three bioregions (Stony Plains, Flinders & Olary Ranges and Gawler) (Thackway and Cresswell 1995) and correspondingly shows marked environmental variation. The main habitats of the study area include chenopod shrublands, gibber plains, salt lakes, riparian woodlands, and *Acacia* woodlands and shrublands on dunefields.

In some instances below, results from this study are compared with a similar study of the diets of cats and foxes in the Roxby Downs area, mostly prior to arrival of rabbit haemorrhagic disease (RHD) to that area (Read and Bowen 2001). Roxby Downs is ca. 120 km WSW of Witchelina and has comparable average annual rainfall (160 mm) and similar sand-dune habitats as occur on the southern third of Witchelina.

Sampling

Samples were collected during routine management operations in 22 sampling episodes, typically spaced at ca. 2 month intervals over the period November 2012 to November 2015. In total, 404 cat specimens, 51 fox specimens and 11 dog specimens were collected. We recognise that the sample size for dogs is relatively small, and accordingly some analyses are restricted to comparisons of diets of cats and foxes.

After collection, all stomach contents were removed and placed in alcohol. Individual components were then sieved and sorted before being identified to the highest taxonomic level readily possible, by reference to standard field guides and museum and other collections. Notably, the identification of invertebrate prey in this study was taken to a finer taxonomic level than is typical for studies of the diets of these three predator species in Australia (Doherty *et al.* 2015; Pavey *et al.* 2008).

Following Kutt (2011), the minimum number of individuals of any identified prey item in a stomach sample was recorded. Individual prey items were not weighed, but weights were assigned retrospectively to individual items based on published average adult body weights for individual species (Kutt 2012). The collection site of predator specimens was recorded with GPS, and this locational information was used to assign samples to bioregions. However, we note that sampled individual predators may have hunted away from the point of their collection (including into adjacent bioregions), and that boundaries delineating bioregions may unrealistically sharpen what are actually gradual transition zones between bioregions.

Analysis

Dietary components were quantified as the number of individuals of any given taxon in a sample, the estimated combined weight of those individuals, and percentage frequency of occurrence (i.e.

the no. of samples with that prey species as a percentage of all samples) of that taxon across all samples (Doherty *et al.* 2015). Internal parasites and maggots (assumed to be consumed incidentally with other prey items) were excluded from analyses.

The diets of the three predator species were compared using Kruskal-Wallis analysis of variance for the number of individuals (and weight) of major prey categories (invertebrates, frogs, reptiles, birds, rabbits (*Oryctolagus cuniculus*), house mice (*Mus musculus*), native mammals, and all mammals). Plant material was recorded simply as presence/absence, so comparisons among predator species in the frequency of occurrence of plant material in samples were undertaken with χ^2 tests. Where appropriate, Bonferroni corrections were applied to re-set probability thresholds for significance within families of related tests.

Dietary overlaps between cats, foxes and dogs were assessed over all samples, and between cats and foxes for every sampling session that included at least five samples for each species. Dietary overlap calculation used the major prey categories stated above (other than 'all mammals', which is a sum of other categories), and followed Pavey *et al.* (2008) in using Pielou's modification of MacArthur and Levin's overlap measure, viz:

$$O_{jk} = \Sigma p_{ij} p_{ik} / \sqrt{(\Sigma p_{ij}^2 \ \Sigma p_{ik}^2)}$$

where O is overlap, p_i is the proportional occurrence of dietary item *i*, and *j* and *k* are the two predator species being compared. Variation in the diet of cats and foxes across seasons and across bioregions was analysed similarly, using Kruskal-Wallis analysis of variance for the weight of major prey categories.

We calculated the number of taxonomically distinct dietary items in all samples, using the dietary categories given in Appendix 1. As example, if a sample contained a *Ctenotus* skink not identifiable to species level, five *Ctenotus regius* individuals, plant material, and a cockroach not identified to species level, then the number of taxonomically different items was scored as 4.

Results

Prey items detected in samples are listed in Appendix 1. Of the cat samples examined, 17 (4.2%) were empty; no dog or fox samples were empty. Plant material was identified in 77 (19.1%) cat samples, 13 (25.5%) fox samples, and 2 (18.2%) dog samples: these proportions did not differ significantly among the three predator species (Table 2).

A total of 4166 individual animal prey items was identified in the cat samples (mean 10.3 prey individuals per sample, range 0-402), 896 in the fox samples (mean 17.6: range 1-125) and 16 in the dog samples (mean 1.5, range 1-3). Most individual food items in the samples of cats and foxes were invertebrates, whereas most (of the few) food items in dog samples were mammals. There was significant variation among the three predator species in the mean number of individuals in dietary samples for invertebrates (fox>cat>dog), frogs (least in dog samples), reptiles (cat>fox>dog), birds (cat>fox>dog), house mice (cat>fox>dog), and 'other mammals' (dog>fox>cat) (Table 2a).

By weight, mammals comprised the bulk of the diet for all three predator species, most notably including >98% of the weight of all items in the dog samples (Table 2b). Of the mammal prey items, introduced species (i.e. rabbits and house mice) comprised most of the recognisable dietary items for all three predator species. Native mammals comprised a similar percentage of all mammal items in samples for cats (14.9%), foxes (9.5%) and dogs (14.3%). There was a significant difference in the size of mammal prey taken between the three predator species (Kruskal-Wallis ANOVA H=17.0, p<0.001), with smallest mammal prey taken by cats (mean 199.5 g, s.e. 12.2), then foxes (324.6 g, s.e. 50.6), then dogs (500 g, no variation). This comparison probably under-emphasises the differences between predator species because no weights could be assigned to the 'unidentified large mammal' component present in most dog samples.

There was a very high dietary overlap (0.985) for cats and foxes across all samples, with much lower overlap for cats and dogs (0.275) and for foxes and dogs (0.241). Dietary overlap between cats and foxes was generally high for those individual sampling sessions with at least five samples for both species (0.978 for November 2012; 0.889 for January 2013; 0.939 for March 2013; 0.438 for May 2013, and 0.977 for March 2015), with the low value for May 2013 associated with a relatively small sample size for foxes (N=5).

Over all three predator species, the vertebrate prey items included two frog, 45 reptile, ten bird and 12 mammal species. Per sample, foxes and cats had a significantly more varied diet than dogs: the number of taxonomically different items per sample was highest for foxes (mean 4.7 taxonomic categories, s.e. 0.39), then cats (mean 4.1, s.e. 0.14), then dogs (mean 1.5, s.e. 0.21) (H=15.6, p=0.0004).

The cat samples included 11 species not reported in a recent major overview of cat diet in Australia (Doherty *et al.* 2015): the frog *Neobatrachus sudelli*, the reptiles *Ctenophorus gibba, Ctenophorus vadnappa, Pseudonaja aspidorhynca, Rhynchoedura eyerensis* and *Ctenotus taeniatus*, the birds *Eurostopodus argus, Amytornis modestus* and *Corvus coronoides*, and the mammals *Planigale gilesi* and *Austronomus australis*. The prey items included one threatened species, thick-billed grasswren (*Amytornis modestus*) (listed nationally as Vulnerable), for which single individuals were recorded from two cat samples.

Some of the samples included large numbers of individual prey items. Examples for individual cat samples included five sets of stomach contents each containing five or more individual *Mus musculus*; and other individual cat samples containing 30 *Ctenotus* spp. individuals (including 12 *C. olympicus*), 400 crickets, 91 Gryllacridid crickets, 36 centipedes and 47 grasshoppers. Comparably, some single fox samples contained many individuals of some prey items, including 43 grasshoppers (of which 42 were plague locusts (*Chortoicetes terminifera*)), 118 Gryllacridid crickets, 47 Tenebrionid beetles, and 35 *Calosoma schayeri* (a beetle). The consumption of many individual *Calosoma schayeri* is notable given the strong chemical defence exhibited by this species when disturbed.

Bioregional variation in diet

There was no significant difference in weight in cat dietary samples among the three bioregions (Flinders & Olary Ranges [314 samples], Gawler [73 samples] and Stony Plains [14 samples]) for any of the major dietary items – invertebrates (H=3.77, P>0.1), frogs (H=0.19, p>0.1), reptiles (H=1.70, p>0.1), birds (H=1.28, p>0.1), rabbits (H=0.62, p>0.1), house mouse (H=4.17, p>0.1), native mammals (H=1.02, p>0.1) or total mammals (H=0.88, p>0.1). Likewise there was no significant difference between fox samples from Flinders & Olary Ranges (N=25) and Gawler (N=26) bioregions in weight for any of these major dietary items (z<2.00, p>0.05 for all comparisons).

Seasonal variation in diet

There was marked seasonal variation in the dietary composition of cats and, to a lesser extent, foxes (Figure 1; Table 3a), most notably with relatively low occurrence of reptiles and invertebrates in the diet of both predator species in winter months. The diversity of dietary items per sample also varied among seasons for cats, with the largest number of different dietary items in summer (Table 3b). There were similar trends for foxes, but this difference was not significant.

Comparison with Roxby Downs

Although rabbits had the highest frequency of occurrence in samples from cats and foxes in the present study, that incidence was significantly less than the respective values reported for the Roxby Downs study. In contrast, most other major dietary items occurred at higher incidence in this study (Table 4). Nonetheless, the total incidence of vertebrate species in the diet of cats in this study is broadly similar to that reported by Read and Bowen (2001) at Roxby Downs, who estimated that ‘a cat will kill, on average, approximately 3 non-rabbit vertebrate prey per day’: for our study, this tally was 2.85 (Table 2). At species level, there was a high concordance among the two studies: for example, of the ten reptile species found in the highest proportion of cat samples in this study, seven species were also in the top ten incidences in cat samples in the Roxby Down study.

Discussion

This study represents another contribution to an increasingly comprehensive set of detailed assessments of the diet of introduced mammalian predators in Australia (Dickman *et al.* 2014; Doherty 2015; Doherty *et al.* 2015; Kutt 2011; Kutt 2012; Molsher *et al.* 2017; Paltridge 2002; Pavey *et al.* 2008; Read and Bowen 2001; Yip *et al.* 2014), all demonstrating substantial levels of predation on many native species. The main results of this study are largely consistent with this body of previous studies: foxes and cats take a very broad range of vertebrate and invertebrate prey; the diets of both species show substantial flexibility as some prey items change in abundance seasonally (or in response to management and other factors); there is a high dietary overlap between cats and foxes, but cats tend to take a higher proportion of birds and reptiles than do foxes; for all three predator species (but especially so for dogs), rabbits may comprise a high proportion of the diet; and cats tend to take smaller mammalian prey than do foxes and dogs. However, there are notable nuanced variations in dietary composition among studies: for example, the frequency of occurrence of reptiles and invertebrates in cat samples in our study is among the highest reported in studies with large samples (Doherty *et al.* 2015).

The conservation impact of this predation is difficult to determine from studies, such as this, that examine diet alone. In this study, cat predation was recorded – for the first time – on the threatened thick-billed grasswren. Predation by cats and foxes has previously been listed as a potential threat to this species (Garnett *et al.* 2011), but the records from our study represent the first definite evidence of such predation. The results presented here suggest that introduced predators at this site take considerable toll on wildlife. As reported in some other studies (Jones and Coman 1981; Paltridge 2002; Read and Bowen 2001), some individual cats and foxes in this study consumed large numbers of particular prey items, with the most notable example here being of a single cat stomach that held 30 individual *Ctenotus* skinks. Without more knowledge of the population densities and life histories of such frequently preyed-upon species, it is difficult to assess the population-level impacts of such targeted and effective predation. However, this predation rate is sufficiently high that some monitoring of impact would be worthwhile. It is not only the large numbers of prey items in some individual samples that may be of concern, but also the high incidence of some prey species across predator samples. A notable example is the bearded dragon (*Pogona vitticeps*), which was recorded in about one third of samples for both cats and foxes. This study indicates a high level of predation by cats and foxes on this and some other reptile species, with such evidence complementing recent studies from predator-exclosure studies that have demonstrated increases of some reptile species where introduced predators are excluded relative to comparable adjacent areas with introduced predators (Read and Scoleri 2015; Stokeld *et al.* 2016).

Our study area overlapped with three bioregions characterised by different sets of environments. However, we detected no significant differences in the dietary composition of cats sampled in sites in these three bioregions, or of foxes sampled in two of the bioregions. This result may be because (i) our analysis considered only broad dietary categories, and bioregional differences in prey composition may have been more apparent if we compared prey types at finer taxonomic categories (e.g. individual species of *Ctenotus* skinks); (ii) environmental variation in the study area was at least partly transitional rather than abruptly coincident with bioregional boundaries; and (iii) individual predators may have hunted across bioregional boundaries before their collection.

Although they were a dominant dietary item for all three predator species in this study, rabbits occurred less frequently in the diets of cats and foxes in this study relative to other similar studies in the same general area. These previous studies (Bayly 1976; Bayly 1978; Read and Bowen 2001) were (mostly) conducted prior to the arrival of RHD and the corresponding regional decrease in rabbit abundance (Bowen and Read 1999), whereas our study was done many years after the arrival of RHD and its consequent reduction in rabbit abundance. Furthermore, management at Witchelina also used a range of control mechanisms to reduce rabbit abundance. Across much of Australia, cats feed mainly on rabbits when they are available, but consume more of other species when rabbits are less readily available (Doherty *et al.* 2015; Read and Bowen 2001). Any activity that reduces grazing pressure by rabbits is likely to provide benefits for native vegetation, and may also result in reduced abundance of feral cats and foxes (Read and Bowen 2001). However, any remaining cats and foxes may also respond by increasing their proportional take of other prey types, such as native mammals, reptiles, birds and invertebrates (Table 4) (Marlow and Croft 2016), although recent evidence indicates that there may be overall net conservation benefit in control programs that reduce rabbit abundance (Pedler *et al.* 2016). Parallel control programs for introduced prey (rabbits) and introduced predators (foxes and cats) are likely to be necessary to maximise benefit for native wildlife.

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Table 1. Extent of control activity and relative abundance (numbers seen km^{-1} of road traversed by managers) of cats and foxes over the study period. The number of individuals shot is also given as a % of the number of individuals seen.

Year	**Distance sampled (km)**	**Cat**			**Fox**		
		no. seen	**no. km^{-1}**	**no. shot (%)**	**no. seen**	**no. km^{-1}**	**no. shot (%)**
2012	2836	161	0.057	108 (67.1)	151	0.053	124 (82.1)
2013	4316	144	0.033	114 (79.2)	34	0.008	34 (100)
2014	3820	158	0.041	120 (75.9)	8	0.002	7 (87.5)
2015	4980	229	0.046	164 (71.6)	8	0.0004	8 (100)

Table 2a. Differences among predator species in the number of dietary items per sample for main animal food types, and for plant frequency of occurrence.

Values in body of table are means (with standard errors, and % of all items in brackets). H values are from Kruskal-Wallis ANOVA, with associated probability (p) values, for comparison among the three predator species. Z values are for Mann-Whitney U test for comparison between cats and foxes. For plants, comparisons were made with χ^2 test. Note that testing here involves a family of nine separate comparisons, so a Bonferroni correction is applied to set the probability significance threshold at 0.05/9=0.0055: the table reports uncorrected probabilities.

Dietary item	**Cat (n=404)**	**Fox (n=51)**	**Dog (n=11)**	**H (p)**	**z (p)**
Plant	19.1%	25.5%	18.2%	χ^2= 1.2 (p=0.561)	χ^2=0.8 (p=0.682)
Invertebrate	7.11 (1.11: 69.0%)	15.02 (3.28: 85.5%)	0.18 (0.18: 12.5%)	19.49 (p=0.0001)	2.66 (p=0.0077)
Frog	0.03 (0.02: 0.3%)	0.10 (0.04: 0.6%)	0	15.77 (p=0.0004)	3.89 (p<0.0001)
Reptile	1.89 (0.15: 18.3%)	1.47 (0.22: 8.4%)	0	13.83 (p=0.0010)	0.08 (p=0.937)
Bird	0.34 (0.03: 3.3%)	0.22 (0.12: 1.2%)	0.09 (0.09: 6.3%)	7.66 (p=0.0217)	2.43 (p=0.0149)
Rabbit	0.35 (0.03: 3.4%)	0.25 (0.07: 1.4%)	0.55 (0.16: 37.9%)	3.90 (p=0.142)	1.23 (p=0.218)
House mouse	0.37 (0.04: 3.6%)	0.12 (0.05: 0.7%)	0	7.84 (p=0.020)	2.19 (p=0.0285)
Other (native) mammal	0.22 (0.03: 2.1%)	0.39 (0.08: 2.3%)	0.64 (0.20: 44.1%)	16.33 (p=0.0003)	2.93 (p=0.0034)
Total mammal	0.94 (0.06: 9.1%)	0.76 (0.09: 4.4%)	1.18 (0.12: 81.3%)	3.46 (p=0.177)	0.30 (p=0.763)

Table 2b. Differences among predator species in estimated weight (g) of dietary items per sample.

Conventions as for Table 2a. Note that testing here involves a family of eight separate comparisons, so a Bonferroni correction is applied to set the probability significance threshold at 0.05/8=0.0063: the table reports uncorrected probabilities.

Dietary item	**Cat (n=404)**	**Fox (n=51)**	**Dog (n=11)**	**H (p)**	**z (p)**
Invertebrate	19.8 (3.3: 7.5%)	39.4 (9.0: 17.6%)	0.4 (0.4: 0.1%)	19.01 (p=0.0001)	2.52 (p=0.0116)
Frog	0.3 (0.2: 0.1%)	1.0 (0.4: 0.4%)	0	15.77 (p=0.0004)	3.89 (p=0.0001)
Reptile	41.7 (2.9: 15.8%)	37.2 (6.2: 16.7%)	0	13.74 (p=0.0010)	0.38 (p=0.705)
Bird	17.7 (2.5: 6.7%)	4.9 (2.7: 2.2%)	4.5 (4.5: 1.3%)	8.41 (p=0.015)	2.60 (p=0.0093)
Rabbit	173.3 (13.2: 65.7%)	127.5 (33.8: 57.1%)	272.7 (78.7: 80.3%)	3.90 (p=0.142)	1.23 (p=0.218)
House mouse	6.4 (0.8: 2.4%)	2.0 (0.9: 0.9%)	0	7.84 (p=0.020)	2.19 (p=0.0284)
Other (native) mammal	4.5 (0.5: 1.7%)	11.4 (2.2: 5.1%)	61.8 (47.0: 18.2%)	21.65 (p<0.0001)	3.46 (p=0.0005)
Total mammal	184.1 (13.1: 69.8%)	140.8 (33.0: 63.1%)	334.5 (72.9: 98.5%)	7.92 (p=0.0190)	0.22 (p=0.826)

Table 3a. Seasonal variation in the number of individual prey items in cat and fox samples. Values in body of table are H values from Kruskal-Wallis ANOVA, with associated probability (p) values. See Fig.1 for more information on seasonal variation in dietary composition. Note that testing here involves a family of eight separate comparisons, so a Bonferroni correction is applied to set the probability significance threshold at 0.05/8=0.0063: the table reports uncorrected probabilities.

Dietary item	**Cat**	**Fox**
Invertebrates	51.59 (p<0.0001)	7.64 (p=0.054)
Frogs	3.68 (p=0.298)	3.02 (p=0.388)
Reptiles	42.38 (p<0.0001)	10.67 (p=0.014)
Birds	5.57 (p=0.135)	1.25 (p=0.742)
Rabbit	23.38 (p<0.0001)	2.93 (p=0.403)
House mouse	9.15 (p=0.027)	1.86 (p=0.602)
Native mammals	6.23 (p=0.101)	3.34 (p=0.342)
Total mammals	12.37 (p=0.0062)	11.21 (p=0.011)

Table 3b. Seasonal variation in the number of taxonomically different items in cat and fox samples. Values in body of table are means (with standard errors in brackets). H values are from Kruskal-Wallis ANOVA, with associated probability (p) values.

Season	**Cat**	**Fox**
Spring	3.34 (0.26)	5.00 (0.92)
Summer	5.03 (0.24)	5.45 (0.91)
Autumn	4.25 (0.22)	4.58 (0.55)
Winter	2.43 (0.27)	2.60 (0,24)
H	44.09 (p<0.0001)	4.21 (p=0.239)

Table 4. Comparison of frequency of occurrence of main prey items in cat and fox samples for this study compared with a comparable study at Roxby Downs.
Note that the Roxby Downs values are taken from the Appendix of Read and Bowen (2001) (i.e. excluding stray cats), but recalculated as a percentage of all samples (i.e. with inclusion of empty stomachs).

Prey type	This study		Roxby Downs area		χ^2 Comparison	
	Cat	Fox	Cat	Fox	Cat	Fox
Empty	4.2	0	12.2	8.9	15.6 (p=0.0001)	3.4 (p=0.07)
Plant material	19.1	25.5	3.6	3.0	45.7 (p<0.0001)	15.9 (p=0.0001)
Invertebrates	66.3	74.5	30.3	33.7	97.6 (p<0.0001)	21.1 (p<0.0001)
Frogs	1.2	9.8	0.8	2.0	n/a	n/a
Reptiles	62.4	68.6	29.4	19.8	81.6 (p<0.0001)	32.9 (p<0.0001)
Birds	28.0	11.8	11.2	3.0	32.7 (p<0.0001)	3.3 (p=0.07)
Rabbits	32.2	23.5	49.7	69.3	51.3 (p<0.0001)	25.9 (p<0.0001)
Other mammals	35.6	41.2	10.3	3.0	66.4 (p<0.0001)	34.4 (p<0.0001)

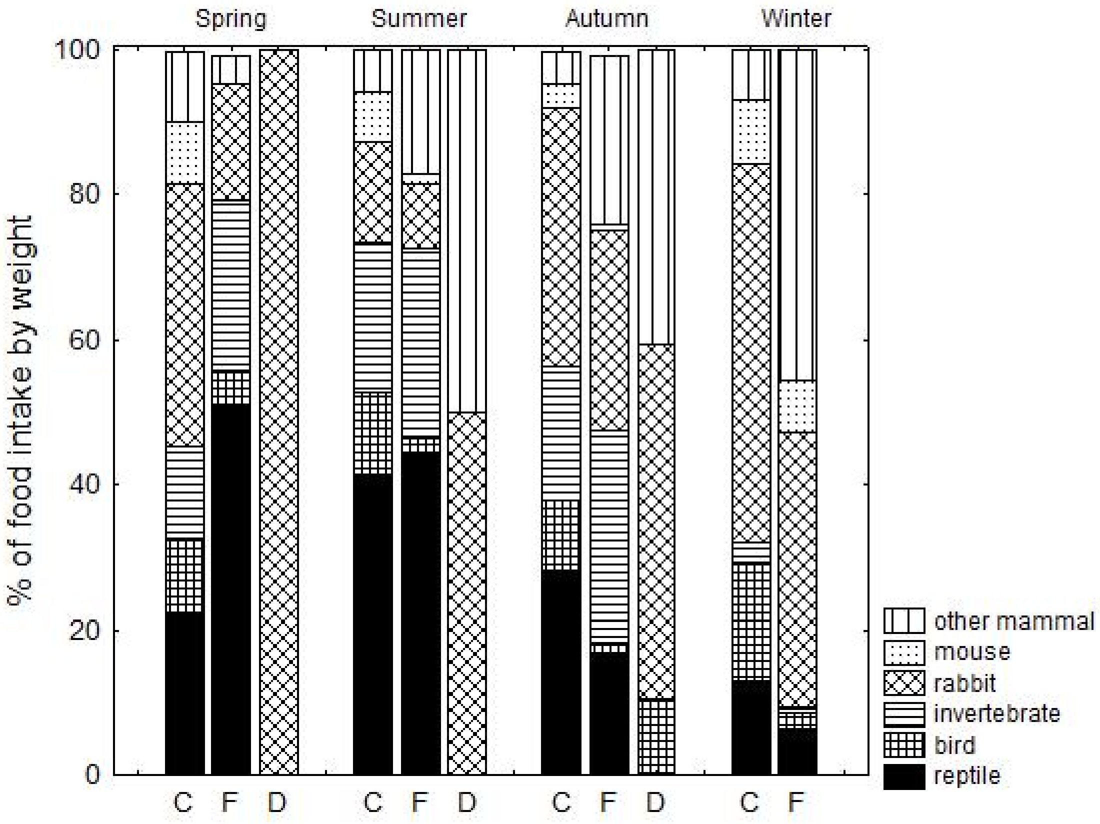

Fig 1. Seasonal variation in proportion of prey types, by weight, for cats (C), foxes (F) and dogs (D).

Appendix 1. List of all items identified in samples of cats, foxes and dogs. Note that higher taxonomic levels marked with asterisks are summed across other individual items of lower taxonomic rank. Values in body of table show the number of samples (and %) with that item; and the total individuals across all samples.

Dietary item	**Cat**	**Fox**	**Dog**
Empty	17 (4.2)	0	0
Plant material	77 (19.1); n/a	13 (25.5); n/a	2 (18.2); n/a
Invertebrates			
*All invertebrates	268 (66.3); 2873	38 (74.5); 766	1 (9.1); 2
Hymenoptera (wasps)	3 (0.7); 5	1 (2.0); 1	0
Formicidae (ants)	2 (0.5); 41	0	0
Scolopendramorpha (centipedes)	106 (26.2); 357	22 (43.1); 72	0
Scutigera coleoptrata (house centipede)	1 (0.2); 1	0	0
*All crickets and grasshoppers	243 (60.1); 2155	31 (60.8); 399	0
Gryllacrididae (raspy crickets)	129 (31.9); 896	11 (21.6); 92	0
Gryllidae (crickets)	75 (18.6); 763	19 (37.3); 242	0
Acrididae (grasshoppers)	129 (31.9); 496	9 (17.6); 65	0
Scorpiones: unidentified spp.	0	4 (7.8); 9	0
Urodacus sp.	1 (0.2); 1	0	0
Urodacus armatus	1 (0.2); 1	1 (2.0); 1	0
Araneae (spiders)	29 (7.1); 42	6 (11.8); 9	0
Mygalomorphae	14 (3.5); 16	0	0
Odonata (dragonflies)	1 (0.2); 36	0	0
*All Lepidoptera	19 (4.7); 133	0	0
unidentified spp.	9 (2.2); 20	0	0
unidentified caterpillars.	1 (0.2); 74	0	0
Hippotion celerio (caterpillars)	2 (0.5); 18	0	0
Hyles livornicoides (caterpillars)	9 (2.2); 21	0	0

Dietary item	**Cat**	**Fox**	**Dog**
Neuroptera (lacewing)	1 (0.2); 1	0	0
* Coleoptera (all beetles)	33 (8.2); 60	26 (51.0); 266	0
unidentified spp.	21 (5.2); 31	17 (33.3); 116	0
Bolboceratidae (geotrupid)	9 (2.2); 13	0	0
Calosoma schayeri	0	1 (2.0); 35	0
Calosoma oceanicum	1 (0.2); 14	0	0
Cicindelinae (*Megacephala* sp.)	0	1 (2.0); 13	0
Megacephala australis	0	2 (3.9); 7	0
Curculionidae (weevil)	1 (0.2); 1	0	0
Scarabaeidae (scarab)	1 (0.2); 1	2 (3.9); 35	0
Zietzia geologa	1 (0.2); 1	1 (2.0); 2	0
Tenebrionidae (darkling)	1 (0.2); 1	7 (13.7); 58	1 (9.1); 2
Blattodea (cockroaches)	0	2 (3.9); 3	0
Cicadidae (cicadas)	3 (0.7); 4	0	0
Tettigoniidae (katydids)	2 (0.5); 2	0	0
Mantodea (mantises)	9 (2.2); 12	3 (5.9); 3	0
Coenomantis kraussiana	4 (1.0); 4	0	0
Phasmatodea (stick insects)	2 (0.5); 2	1 (2.0); 1	0
maggots	5 (1.2); n/a	0	0
Frogs			
*All frogs	5 (1.2); 12	5 (9.8); 5	0
unidentified frog spp.	1 (0.2); 1	1 (2.0); 1	0
Litoria rubella	1 (0.2); 5	0	0
unidentified *Neobatrachus* sp.	2 (0.5); 5	3 (5.9); 3	0
Neobatrachus sudelli	1 (0.2); 1	1 (2.0); 1	0
Reptiles			
*All reptiles	252 (62.4); 763	35 (68.6); 75	0
*All geckoes	77 (19.1); 118	9 (17.6); 11	0
Diplodactylus conspicillatus	1 (0.2); 1	0	0

Dietary item	**Cat**	**Fox**	**Dog**
Diplodactylus tessellatus	4 (1.0); 5	0	0
unidentified *Gehyra* spp.	18 (4.5); 26	1 (2.0); 1	0
Heteronotia binoei	10 (2.5); 12	0	0
unidentified *Lucasium* spp.	5 (1.2); 6	1 (2.0); 1	0
Lucasium byrnei	3 (0.7); 4	0	0
Lucasium damaeum	2 (0.5); 3	0	0
Lucasium stenodactylum	23 (5.7); 26	3 (5.9); 3	0
Nephrurus levis	7 (1.7); 7	2 (3.9); 2	0
Rhynchoedura eyerensis	19 (4.7); 23	2 (3.9); 4	0
unidentified *Strophurus* spp.	1 (0.2); 1	0	0
Strophurus ciliaris	1 (0.2); 1	0	0
Underwoodisaurus milii	2 (0.5); 3	0	0
*All pygopodids	7 (1.7); 8	0	0
Lialis burtonis	3 (0.7); 3	0	0
Pygopus nigriceps	2 (0.5); 2	0	0
Pygopus schraderi	3 (0.7); 3	0	0
*All agamids	154 (38.1); 216	28 (54.9); 31	0
unidentified agamid spp.	7 (1.7); 7	4 (7.8); 4	0
Pogona vitticeps	127 (31.4); 165	19 (37.3); 20	0
Ctenophorus fordi	7 (1.7); 7	0	0
Ctenophorus gibba	1 (0.2); 1	0	0
Ctenophorus nuchalis	7 (1.7); 7	2 (3.9); 2	0
Ctenophorus pictus	8 (2.0); 8	1 (2.0); 1	0
Ctenophorus vadnappa	2 (0.5); 2	0	0
unidentified *Tympanocryptis* spp.	4 (1.0); 4	0	0
Tympanocryptis intima	6 (1.5); 6	3 (5.9); 3	0
Tympanocryptis tetraporophora	9 (2.2); 9	1 (2.0); 1	0
Varanus gouldii	25 (6.2); 25	5 (9.8); 5	0
*All skinks	135 (3.3); 348	0	0

Dietary item	**Cat**	**Fox**	**Dog**
unidentified skink spp.	15 (3.7); 15	0	0
unidentified *Cryptoblepharus* spp.	2 (0.5); 2	0	0
unidentified *Ctenotus* spp.	51 (12.6); 70	2 (3.9); 2	0
Ctenotus leonhardii	1 (0.2); 1	0	0
Ctenotus olympicus	20 (5.0); 43	1 (2.0); 1	0
Ctenotus regius	40 (9.9); 81	0	0
Ctenotus robustus	11 (2.7); 11	0	0
Ctenotus schomburgkii	17 (4.2); 25	0	0
Ctenotus strauchii	7 (1.7); 7	0	0
Ctenotus taeniatus	21 (5.2); 29	0	0
Egernia stokesii	4 (1.0); 6	1 (2.0); 1	0
Eremiascincus richardsonii	22 (5.4); 24	1 (2.0); 1	0
unidentified *Lerista* spp.	2 (0.5); 2	2 (3.9); 2	0
Lerista desertorum	3 (0.7); 6	0	0
Lerista labialis	5 (1.2); 5	2 (3.9); 2	0
Liopholis inornata	2 (0.5); 4	0	0
Menetia greyii	4 (1.0); 4	0	0
unidentified *Morethia* spp.	1 (0.2); 1	0	0
Morethia adelaidensis	3 (0.7); 3	0	0
Morethia boulengeri	2 (0.5); 2	0	0
Tiliqua rugosa	7 (1.7); 8	2 (3.9); 2	0
*All blind snakes	17 (4.2); 18	10 (19.6); 17	0
unidentified *Ramphotyphlops* spp.	5 (1.2); 6	6 (11.8); 7	0
Ramphotyphlops bituberculatus	8 (2.0); 8	0	0
Ramphotyphlops endoterus	4 (1.0); 4	5 (9.8); 10	0
Antaresia stimsoni	1 (0.2); 1	0	0
*All elapids	26 (6.4); 29	0	0
unidentified elapid spp.	5 (1.2); 5	0	0
Pseudechis australis	2 (0.5); 2	0	0

Dietary item	Cat	Fox	Dog
unidentifed *Pseudonaja* spp.	1 (0.2); 1	0	0
Pseudonaja aspidorhynca	5 (1.2); 5	0	0
Pseudonaja modesta	3 (0.7); 3	0	0
Suta suta	12 (3.0); 13	0	0
Birds			
*All birds	113 (28.0); 137	6 (11.8); 11	1 (9.1); 1
unidentified bird spp.	75 (18.6); 79	2 (3.9); 2	1 (9.1); 1
unidentified bird spp. (eggs)	2 (0.5); 2	0	0
emu *Dromaius novaehollandiae* eggs	0	2 (3.9); 2	0
unidentified quail spp.	2 (0.5); 2	0	0
crested pigeon *Ocyphaps lophotes*	2 (0.5); 2	0	0
spotted nightjar *Eurostopodus argus*	1 (0.2); 1	0	0
unidentified button-quail sp.	1 (0.2); 1	0	0
little button-quail *Turnix velox*	3 (0.7); 3	0	0
painted button-quail *Turnix varius*	1 (0.2); 1	0	0
unidentified parrot spp.	2 (0.5); 2	0	0
galah *Cacatua roseicapilla*	2 (0.5); 2	0	0
budgerigar *Melopsittacus undulatus*	1 (0.2); 1	0	0
unidentified *Malurus* spp.	9 (2.2); 11	0	0
thick-billed grasswren *Amytornis modestus*	2 (0.5); 2	0	0
Australian raven *Corvus coronoides*	2 (0.5); 2	0	0
unidentified finch spp.	2 (0.5); 3	0	0
zebra finch *Taeniopygia guttata*	16 (4.0); 24	2 (3.9); 7	0
Mammals			
*All mammals	239 (59.2); 381	32 (62.7); 39	11 (100); 13
unidentified large mammals	24 (5.9); 24	18 (35.3); 18	6 (54.5); 6
rabbit *Oryctolagus cuniculus*	130 (32.2); 140	12 (23.5); 13	6 (54.5); 6
short-beaked echidna *Tachyglossus aculeatus*	0	0	1 (9.1); 1
*All rodents	106 (26.2); 176	5 (9.8); 5	0

Dietary item	**Cat**	**Fox**	**Dog**
unidentified rodents	13 (3.2); 15	0	0
house mouse *Mus musculus*	93 (23.0); 151	5 (9.8); 6	0
desert mouse *Pseudomys desertor*	2 (0.5); 4	0	0
central short-tailed mouse *Leggadina forresti*	6 (1.5); 6	0	0
*All dasyurids	30 (7.4); 34	0	0
unidentified dasyurids	3 (0.7); 3	0	0
Giles' planigale *Planigale gilesi*	1 (0.2); 3	0	0
narrow-nosed planigale *Planigale tenuirostris*	4 (1.0); 4	0	0
fat-tailed dunnart *Sminthopsis crassicaudata*	8 (2.0); 8	2 (3.9); 2	0
stripe-faced dunnart *Sminthopsis macroura*	15 (3.7); 16	0	0
*All bats	3 (0.7); 7	0	0
unIdentified bats	1 (0.2); 1	0	0
Chalinolobus spp.	1 (0.2); 1	0	0
Gould's wattled bat *Chalinolobus gouldii*	1 (0.2); 1	0	0
Mormopterus spp.	1 (0.2); 1	0	0
lesser long-eared bat *Nyctophilus geoffroyi*	1 (0.2); 1	0	0
white-striped freetail bat *Austronomus australis*	1 (0.2); 2	0	0