Diet of feral cats, *Felis catus*, on Dirk Hartog Island

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ABSTRACT

Ten mammal species of conservation priority have been lost from Dirk Hartog Island, off the coast of Western Australia, most likely due to predation by the feral cat. We examined the diet of fourteen feral cats from Dirk Hartog Island to understand the potential impact of cat predation on remaining extant species. We examined the contents of the stomach and large intestine, and used stable isotope analysis of faeces, liver and muscle. The vertebrate species identified in the digestive tracts included at least six bird species, including two terrestrial birds and four shorebirds, seven reptile species, and one mammal (introduced *Mus musculus*). Analysis of δ13C and δ15N determined that the diet of feral cats was primarily terrestrially derived, although samples from the northern area of Dirk Hartog Island showed a skew towards marine derived food sources. The research findings showed that on this island, in the absence of rabbits, cats preyed mainly on terrestrial birds and reptiles.

KEYWORDS: Feral cat, diet, Dirk Hartog Island, stomach content and faecal analysis, stable isotopes

INTRODUCTION

Feral cats (*Felis catus*) are found on most major island groups worldwide (Nogales *et al*. 2004) and are thought to be the cause of extinctions of many native species, especially rodents (Fitzgerald 1988; Berovides & Comas 1991; Nowak 1999), reptiles (Iverson 1978; Gibbons 1984; Alberts 2000; Mitchell *et al*. 2002) and birds (Fuller 2000). On Dirk Hartog Island, off the coast of Western Australia, ten mammals have become locally extinct, of an original thirteen species recorded there (Baynes 1990; McKenzie *et al*. 2000; Algar *et al*. 2011; Table 1). The loss of these ten species from the island is most likely due to predation by the feral cat (Burbidge 2001; Burbidge & Manly 2002) and a cat eradication program is currently underway. If successful, Dirk Hartog Island will be the largest island worldwide to have feral cats eradicated. There is a plan to use Dirk Hartog Island as a site for fauna reconstruction and it could potentially support one of the most diverse mammal assemblages in Australia (Algar *et al*. 2011).

As part of the research program conducted prior to commencement of the feral cat eradication on Dirk Hartog Island, we examined the diet of cats in late autumn – the same time of year as that proposed for the baiting program, the primary control technique to be used. This study was expected to provide useful information on what cats were feeding on at that time of year and the potential impact on the effectiveness of the baiting program. The study also presented a unique opportunity to examine the diet of cats in the absence of introduced prey species, such as the rabbit (*Oryctolagus cuniculus*) and black rat (*Rattus rattus*), and in the absence of other introduced predators, such as the fox (*Vulpes vulpes*). The house mouse (*Mus musculus*) is present on Dirk Hartog Island and, depending upon abundance, could contribute significantly to the feral cats' diet.

Stable isotope analysis can be used to overcome the limitations of the traditional diet analysis of faecal and stomach content (Stapp 2002) and it allows a larger dietary scope to be analysed as it is an integrated measure of different food sources over time, whereas analysis of stomach or faecal contents reveals only the last few meals. Carbon and nitrogen stable isotopes have been the most widely used for the identification of diet sources (Peterson & Fry 1987; Gannes *et al*. 1998; Hobson 1999; Kelly 2000; Stapp *et al.* 1999; Stapp 2002). This is attributed to the ability to determine foraging locations, particularly in coastal habitats, using carbon isotope ratios due to differences in pelagic and benthic food

Table 1. Extant and locally extinct mammals of Dirk Hartog Island (from Algar *et al*. 2011). * Introduced.

	Species	Common name
Extant	*Pseudomys albocinereus*	Ash-grey mouse
	Pseudomys hermannsburgensis	Sandy inland mouse
	Sminthopsis dolichura	Little long-tailed dunnart
	Mus musculus	House mouse*
Locally extinct	*Bettongia lesueur*	Boodie
	Bettongia penicillata	Woylie
	Perameles bougainville	Western barred bandicoot
	Dasyurus geoffroii	Chuditch
	Dasycercus cristicaudata	Mulgara
	Parantechinus apicalis	Dibbler
	Leporillus conditor	Greater stick-nest rat
	Pseudomys desertor	Desert mouse
	Pseudomys fieldi	Shark Bay mouse
	Pseudomys shortridgei	Heath mouse

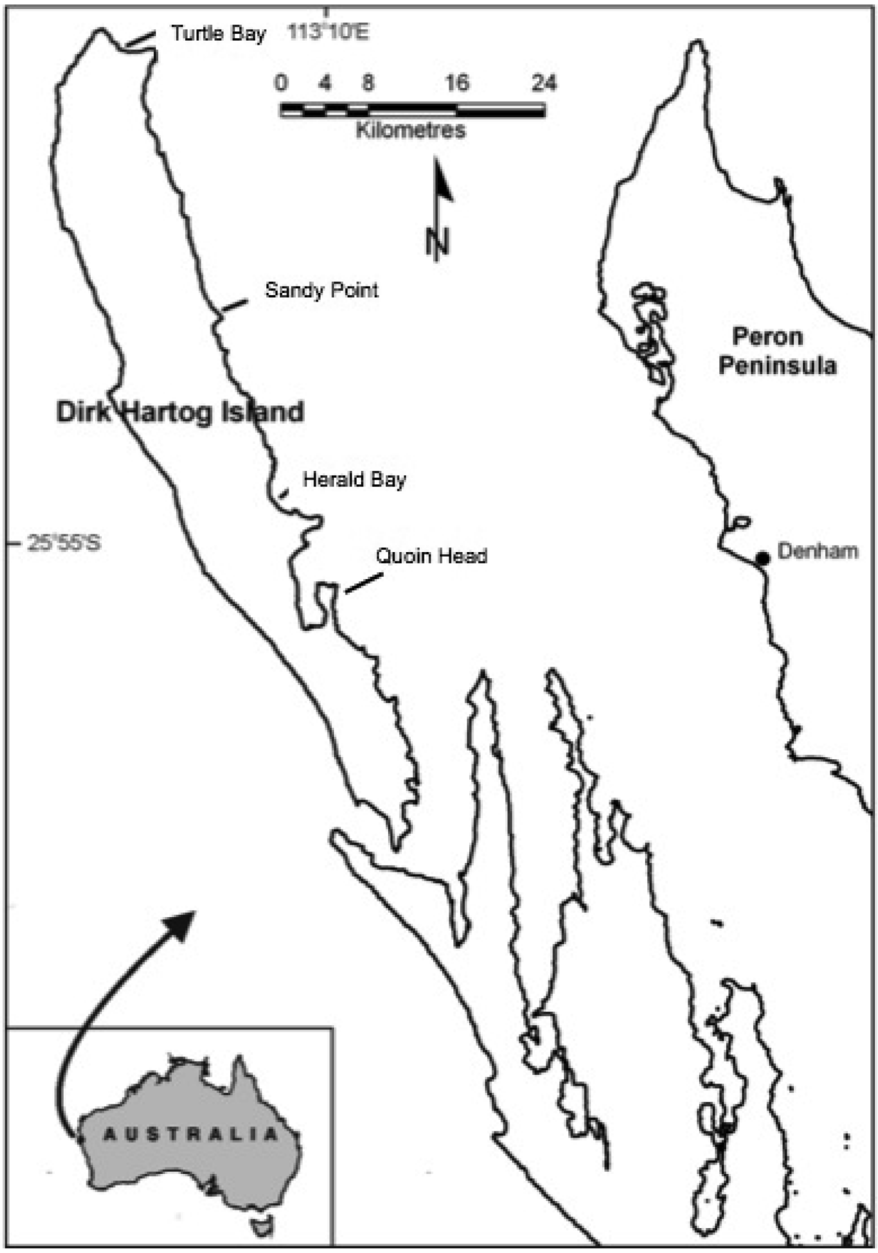

Figure 1. Dirk Hartog Island showing reference points of extent of study area (modified from Algar *et al.* 2011).

webs (terrestrial or inshore versus marine or offshore) (Peterson & Fry 1987; Hobson 1999; Rubenstein & Hobson 2004). Nitrogen stable isotopes are in turn used to determine trophic level and diet composition (Dahl *et al*. 2003; Morrison & Hobson 2004; Quillfeldt *et al*. 2008). Marine resources were expected to be part of the diet of feral cats on the island, since previous tracking data revealed distinct patrolling of beaches (Algar *et al.* 2011).

METHODS

Fieldwork was conducted from 27 March to 8 April 2013 on Dirk Hartog Island (25°50' S 113°0.5' E; Fig. 1). The island lies within the Shark Bay World Heritage Property and is the largest island in Western Australia, covering 620 km^2, spanning 79 km in length and a maximum of 11 km in width. The fieldwork was focused on the east coast of the island, extending from Herald Bay in the south to Turtle Bay in the north (Fig. 1).

Feral cats were trapped over a period of 12 trapping nights and euthanized. The traps used in this study were covered padded leg-hold (soft catch) traps (Oneida Victor, size 3, Woodstream Corp., Lititz, Pa.; U.S.A) using cat faeces as the attractant. Sex and body weight were recorded in the field. All cat carcasses were frozen in the field before analysis in the laboratory. The cats were then dissected with muscle and liver tissue removed from the same location of each cat (shoulder and second lobe of the liver respectively).

Samples were thawed, sections of the gastrointestinal tract separated and then examined individually. The contents of the stomach were pooled with the contents of the small intestine. Food items were sorted macroscopically by eye. Identifiable material was sorted into the five main food categories adapted from Risbey *et al.* (1999) of mammal, bird, reptile, invertebrate and plant material. Plant material was only classed as a food item if it contained fruits/berries, while other vegetation, such as sticks and leaves, were treated as incidental intake (Martin *et al*. 1996; Risbey *et al*. 1999). Mammal remains were identified by the presence of hairs, or identifiable body parts including legs and ears. Once all large identifiable samples had been removed from a section the remaining material was then washed twice through 1 mm mesh sieves (Coman & Brunner 1972; Risbey *et al*. 1999). Percentage occurrence was recorded as the number of stomachs containing a particular item as a percentage of the total fourteen stomachs examined. Proportion of occurrence was a visual estimate of the available space filled by an item.

Faeces was collected from the large intestine as no scats were collected from the field. Each faecal pellet was analysed whole as a prey item can occur in multiple sections of the same scat (Nogales *et al*. 1988). The identification of prey and the sieving process followed the same procedure as that of stomach contents.

Reference samples of prey species were collected opportunistically from the field. These included crab, bait fish, sand goanna (*Varanus gouldii*) and cormorant feathers (*Phalacrocorax* species). Samples were freeze-dried before being ground to a fine powder. Carbon and nitrogen isotope ratios were measured using a continuous flow system consisting of a Delta V Plus mass spectrometer connected with a Thermo Flush 1112 Conflo IV (Thermo-finnigan/Germany). Between 0.7–0.8 mg of each animal tissue sample (muscle, liver, and feather) and 1.1–1.2 mg of faecal samples were combusted in a tin cup for the simultaneous determination of carbon and nitrogen isotope ratios. Multi-point normalization was used in order to reduce raw values to the international standard (Paul *et al*. 2007; Skrzypek *et al.* 2010). The statistical comparisons of the δ13C and δ15N values of individuals and areas were analysed using a one-way ANOVA. Within-individual correlation of isotope ratios for different tissue types were analysed using a paired t-test.

RESULTS

Fourteen cats were trapped, comprising 11 males and three females. Twelve cats were trapped on the coastal tracks and two along the central track. Cats sampled had a mixed diet (Table 2), with animal items in 11 of 14 cats, and plant matter occurring in 6 of 14 cats. The major food categories found in stomachs were bird followed by reptile. Of the vegetative matter in stomachs no items were classed as food as none contained fruiting bodies. Invertebrates consisted mostly of an unidentified centipede species with some beetles. No stomach samples contained marine items.

The highest average proportions of stomach contents were again bird and reptile, both with a large variation (Fig. 2). The average proportion of mammalian remains in stomachs was 11.3%, with results as high as 50%. The highest proportion of reptile remains in stomachs was 90% and the highest proportion of bird remains in 14 stomachs was 55%.

Table 2. Percentage of feral cats from Dirk Hartog Island (of a total of 14) containing five major food categories and empty space, in stomachs and large intestines.

Category	Stomach (n = 14)	Large Intestine (n = 14)
	%	%
Mammal	35.7	42.8
Reptile	57.1	71.4
Bird	78.6	92.8
Invertebrate	28.6	64.3
Plant	42.8	0
Empty	42.8	14.3

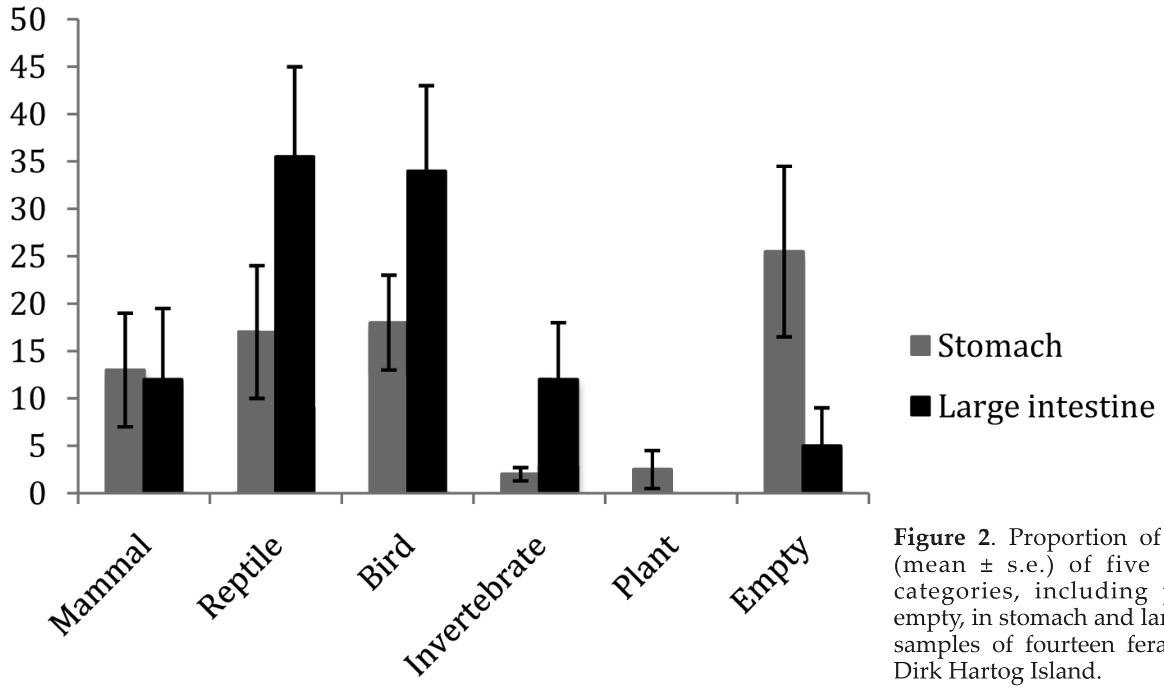

Figure 2. Proportion of occurrence (mean ± s.e.) of five major diet categories, including proportion empty, in stomach and large intestine samples of fourteen feral cats from Dirk Hartog Island.

The large intestines all contained animal items with none containing plant matter (Table 2). Bird and reptile remains were also found most in the large intestine, occurring in 92.8% and 71.4% respectively, of all cats. There was a pronounced increase in the presence of invertebrate remains (62.4%) compared with the stomach contents. Mammal remains were identified in 6 of 14 cats. No large intestine samples contained marine items. Proportions of the five main food categories were calculated in all 14 large intestine samples (Fig. 2) and on average reptile and bird remains made up the largest proportion.

In the stomach and large intestine samples combined, there were several vertebrates identified to species level, including six birds and seven reptiles. Of the six birds, there were two terrestrial birds and four shorebirds (Table 3). Mammal remains were found in three of the fourteen cats and included cat hairs (presumably from self-grooming), one *Mus musculus* and two other small mammals that could not be identified to species level because of the small amount of material.

The carbon and nitrogen isotope ratios varied only slightly between terrestrial, coastal and marine reference samples (Fig. 3). The three habitat types overlapped considerably in δ15N, where the main difference was found in elevated levels in cormorant feathers collected from Sandy Point (Fig. 4). There was overlap in the carbon isotope ratio for reference samples from marine sources and seabird feathers, with a lower number for the terrestrial samples from *Varanus gouldii* (Fig. 3).

Cats were grouped based upon the trap line where they were caught (North, South and West). Consistent with the stomach and large intestine analysis, the carbon isotope ratios of muscle, liver and faeces showed a wide range (Fig. 4) with little overlap with the isotopic background data. The only sample type to differ between trapping lines was liver with carbon and nitrogen, $P = 0.025$ and $P = 0.002$ respectively (Table 4).

Within-individual correlation of the three sample types (faeces, liver and muscle) indicated some degree of individual consistency of diet, especially a strong correlation between liver and muscle samples. The evidence for a consistency of tissues with the last few

Table 3. Vertebrate species identified from the digestive tracts of fourteen feral cats on Dirk Hartog Island.

Species name	Common name	Number of individual cats
Birds		
Calamanthus campestris hartogi	Rufous fieldwren	2
Malurus lamberti	Variegated fairy-wren	1
Calidris canutus	Red knot	1
Calidris ruficollis	Red-necked stint	1
Haematopus longirostris	Australian pied oystercatcher	1
Himantopus himantopus	Black-winged stilt	1
Reptiles		
Ctenophorus sp	Dragon lizard	5
Pogona minor	Western bearded dragon	1
Ctenotus sp	Skink	1
Ctenotus fallens	West-coast laterite Ctenotus	2
Tiliqua rugosa	Bobtail	1
Varanus gouldii	Gould's monitor	1
Antaresia stimsoni	Stimson's python	1
Mammals		
Mus musculus	House mouse	1

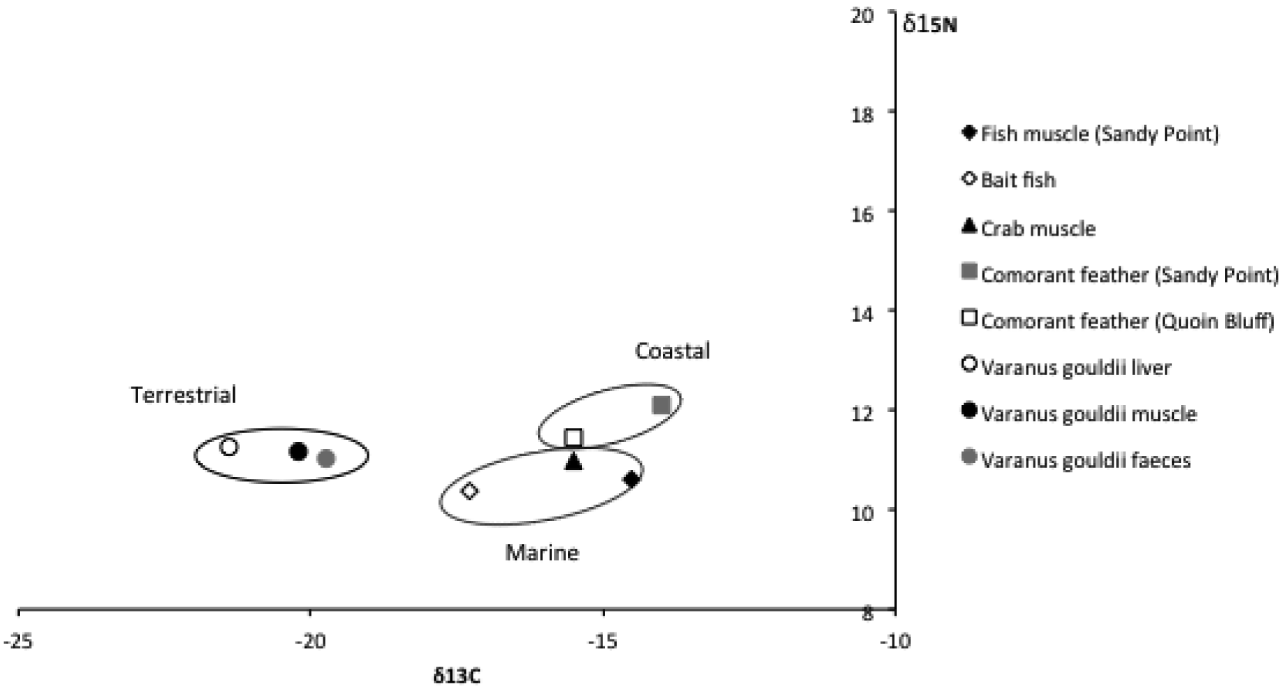

Figure 3. Carbon and nitrogen stable isotope ratios for reference material from different areas and habitat types on Dirk Hartog Island.

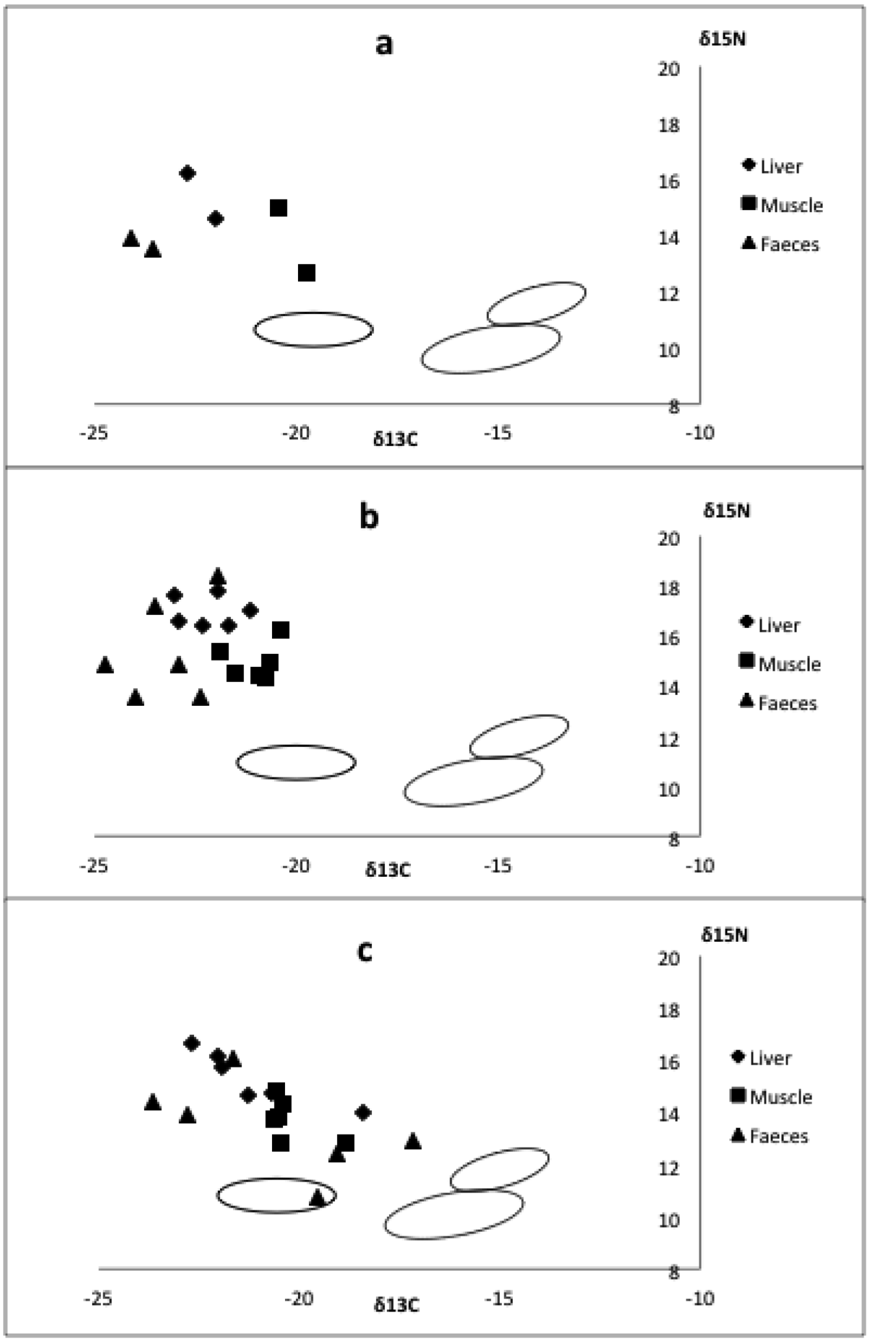

Figure 4. Carbon and nitrogen isotope stable isotope ratios for feral cats from a. Western, b. Southern and c. Northern trap lines on Dirk Hartog Island. Ovals represent values for reference samples shown in Figure 3.

Table 4. Stable isotope signatures of feral cats on Dirk Hartog Island (mean ± s.e.) and results from multivariate ANOVA tests for differences between areas.

	Southern Line (n = 6)	**Northern Line (n = 6)**	**Western Line (n = 2)**	**ANOVA results**
Muscle				
$\delta^{13}C$	-21.01 ± 0.230	-20.24 ± 0.276	-20.09 ± 0.362	P = 0.127
$\delta^{15}N$	14.98 ± 0.297	13.76 ± 0.326	13.79 ± 1.154	P = 0.107
Liver				
$\delta^{13}C$	-22.17 ± 0.297	-21.17 ± 0.614	-22.36 ± 0.360	P = 0.025
$\delta^{15}N$	16.98 ± 0.250	15.34 ± 0.410	15.39 ± 0.840	P = 0.002
Faeces				
$\delta^{13}C$	-23.23 ± 0.424	-20.64 ± 1.010	-23.80 ± 0.273	P = 0.095
$\delta^{15}N$	15.41 ± 0.812	13.40 ± 0.745	13.72 ± 0.176	P = 0.279

Table 5. Within-individual correlation of isotope ratios for three sample types of feral cats on Dirk Hartog Island, P values from a paired t-test.

Sample type	Faeces	Liver
$\delta^{13}C$		
Muscle	0.003	<0.001
Faeces	–	0.159
Liver	–	–
$\delta^{15}N$		
Muscle	0.477	<0.001
Faeces	–	<0.001
Liver	–	–

meals (faeces) and short-term diet (liver) was mixed. The data for tissues and faeces (short-term diet) and muscle (long-term diet) were not correlated (Table 5).

DISCUSSION

The food items eaten by feral cats on Dirk Hartog Island were generally similar to those found for cats from mainland Western Australia and throughout other regions of Australia. One important difference was that whilst the major prey class throughout Australia is mammals, predominantly introduced rodents and rabbits (Coman & Brunner 1972; Catling 1988; Martin *et al*. 1996; Paltridge *et al*. 1997; Risbey *et al*. 1999), the major prey classes on Dirk Hartog Island were terrestrial birds and reptiles and thus it is these taxa that are most likely to benefit from the removal of cats. Since cats are opportunistic predators and scavengers (Coman & Brunner 1972; Nogales *et al*. 2004) whose diet is determined by the relative availability of prey species (Coman & Brunner 1972; Veitch 1985; Catling 1988), it is likely that the low percentage of occurrence of mammals in the diet of feral cats on Dirk Hartog Island can be explained by a low abundance of native mammals, and especially by the absence of introduced rabbits and rats.

The vertebrate species identified in the digestive tracts of cats included at least six bird species, including two terrestrial birds and four shorebirds, seven reptile species, and at least one mammal (*Mus musculus)*. One of the bird species, the rufous fieldwren (*Calamanthus campestris hartogi*) is classified as vulnerable under the Environment Protection and Biodiversity Conservation Act 1999. Since the fieldwork was conducted in autumn, outside the spring breeding season of the majority of birds inhabiting the island (Johnstone *et al*. 2000), it is likely that the sampling underestimated the number of bird species that may be preyed upon by cats.

The analysis of remains in the digestive tract found no evidence of marine species being consumed. This was somewhat surprising, as Algar *et al.* (2011) reported that many cats on Dirk Hartog Island were found in coastal or near-coastal areas, so it was expected that cats may have predated or scavenged on fish or other marine detritus. Turtle hatchlings were expected to form part of the diet seasonally (Hilmer *et al.* 2010), but were not detected in the digestive tracts, despite being present on the island during the study. There was evidence, however, of at least four species of shorebirds being either preyed on or scavenged – the red knot (*Calidris canutus*), red-necked stint (*Calidris ruficollis*), Australian pied oyster catcher (*Haematopus longirostris*) and the black-winged stilt (*Himantopus himantopus*).

Although no marine items were found in the analysis of stomach or intestinal contents, the stable isotope analysis of cats from the northern trap line showed some evidence of a potentially marine-derived diet. The carbon isotope ratio of faeces, muscle and liver showed a result similar to that of marine reference samples as well as that of previous studies (δ13C of -20 to -16; Quillfeldt *et al*. 2008). This may reflect cats scavenging food along shorelines, or may partly reflect cats preying on species such as the shorebirds, which would presumably have an isotopic signature similar to marine fauna (Hobson 1987). The amount of isotopic reference samples was limited in this study because reference material was collected opportunistically in the field. Ideally, a more comprehensive number of reference samples from all potential prey species would have been collected to allow for more accurate identification of prey species, but time and budget constraints prevented this.

The locations available for trapping on Dirk Hartog Island were also limited, to along existing tracks and beach fronts, due to the density of vegetation. This limitation resulted in the inland portion of the island being difficult to trap extensively, whereas the coastal areas were relatively accessible with many tracks and beaches. The number of feral cats caught during this study was also limited by the amount of time available for trapping, and possibly because a previous trapping and pilot baiting program (Algar *et al*. 2011) had reduced the population size.

Feral cats showed a high consistency between liver and muscle isotope ratios, and thus probably had a consistent diet for a time of several weeks. This can be deduced due to the turnover rates of liver, one week, and muscle, four weeks (Tieszen *et al*. 1983). The mixed consistency between liver and faecal isotope ratios possibly reflects the opportunistic nature of feeding behaviour that is well documented in feral cats. It was expected that there would be very little consistency between muscle and faecal isotope ratios as they represent the most distinct sample types in terms of dietary time scale.

The findings of this study suggest that cats may be food-deprived during late autumn, as shown by the large percentage occurrence of empty stomachs at this time. This could be beneficial for management of cats, as late autumn is the period for toxic baiting as part of the eradication process. As reptiles are one of the major prey classes of cats on Dirk Hartog Island, the timing of baiting must also consider their abundance.

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