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Diet of the mulgara, *Dasycercus cristicauda* (Marsupialia : Dasyuridae), in the Simpson Desert, central Australia

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Abstract

The diet of the mulgara, *Dasycercus cristicauda*, from the Simpson Desert in Queensland, was analysed using scats collected between 1990 and 1995. Insects, arachnids and rodents were the main classes of prey of *D. cristicauda*, but reptiles, centipedes and small marsupials were also consumed. Insects represented 92% by percentage frequency of occurrence in scats, while rodents represented 33% by percentage frequency. Invertebrate prey ≥6 mm in length and vertebrate prey occurred frequently in scats, but small prey (1–5 mm), when present, occurred in large numbers. *D. cristicauda* ate more individual prey items in spring and winter than in autumn, and more large-sized prey in spring than in autumn. In autumn, *D. cristicauda* consumed mostly insects (100% by frequency) and few rodents (8%), but in winter and spring, switched to rodents (38% and 47% respectively) and insects (88% and 93% respectively). Seasonal shifts in diet may reflect changes in the availability of different groups of prey, or changes in prey selectivity by *D. cristicauda* in response to costs imposed by seasonal reproduction. The dietary flexibility of *D. cristicauda* may allow individuals to occupy stable ranges, and has perhaps also promoted the persistence of the species in arid areas that have been subjected to changes in land use since European settlement.

Introduction

Knowledge of the diet of a species is essential for understanding its ecology and physiology and, for threatened species, is important for effective management and conservation. Knowledge of changes in diet may also indicate environmental change and pollution, especially where consumers accumulate toxins or other chemicals (Morton and Baynes 1985; Dickman 1986*a*; Evans and Batty 1986; Fisher and Dickman 1993*a*).

Sampling techniques that have been used to determine the diets of insectivores include analysis of stomach and gut contents, and analysis of scats. Scat analysis has the advantage of not killing or disturbing study animals, and can yield reasonable estimates of the range of foods eaten (Kunz and Whitaker 1983). It also provides a relatively reliable method for determining the diet of generalist insectivores that eat hard-bodied prey, especially if the results are expressed as the number of individuals in which a prey item is found rather than as the minimum number of prey items consumed per animal (Dickman and Huang 1988). However, quantification of the amount of food consumed is usually not possible using analysis of scats (Robinson and Stebbings 1993).

Few studies have analysed the diets of insectivorous marsupials. Most of these have compared the diets of sympatric species in an attempt to assess how food resources are partitioned (Hall 1980; Morton *et al*. 1983; Fox and Archer 1984; Dickman 1986*a*, 1986*b*, 1988; Read 1987; Calver *et al*. 1988). Fisher and Dickman (1993*a*) investigated the diets of six species of dasyurid marsupials in arid Australia, and tested whether these species selected prey on the basis of type, size or hardness and whether harder prey occur more frequently in the diet of arid-zone species. Further study of 21 species of dasyurids throughout continental Australia showed that dasyurids select prey of a particular size which maximises the rate of energy intake (Fisher

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and Dickman 1993*b*). Dasyurids generally (Fisher and Dickman 1993*b*), and *Ningaui yvonneae* in particular (Woolnough and Carthew 1996), take prey by size, in accord with optimal foraging theory. Although these studies provide a strong foundation for the study of diets in dasyurid marsupials, further detailed studies are required to fully understand the ecology of individual species, especially those of the arid zone where marked fluctuations in food supplies are likely to exist (Morton 1978, 1982).

The mulgara, *Dasycercus cristicauda*, is a medium-sized (~100 g) dasyurid that is distributed in a series of small, discontinuous populations in arid sandy regions of Queensland, the Northern Territory and Western Australia (Maxwell *et al*. 1996). This species hunts at night for insects, other arthropods and small vertebrates (Woolley 1995). *Dasycercus cristicauda* prefers prey greater than 7.5 mm in length and is the only dasyurid of the arid zone known to regularly include large, hard beetles in its diet (Fisher and Dickman 1993*a*). In recent years, *D. cristicauda* has declined over much of its range, so that now it is considered vulnerable (Kennedy 1990; Maxwell *et al*. 1996). Threats to the continued survival of *D. cristicauda* are unknown (Gibson and Cole 1992). However, reduced food supplies following periods of extended rainfall may cause local reductions in numbers (Woolley 1990), and predation by introduced carnivores may also be important (Dickman 1996*a*). Except for the preliminary studies of Fisher and Dickman (1993*a*, 1993*b*) and a survey of the diet of *D. cristicauda* near Uluṟu (Masters 1998), little is known about the diet of this desert mammal. In this study, we provide a detailed analysis of the diet of *D. cristicauda* in the Simpson Desert from scat samples collected over a five-year period in the 1990s. We aim specifically to evaluate the range of prey types and prey sizes taken by *D. cristicauda,* and to describe dietary differences among sexes and seasons.

Study area and Methods

Scats of *D. cristicauda* were collected on Ethabuka station, on the eastern edge of the Simpson Desert, Queensland (23°46′S, 138°28′E). This arid area is characterised by leached, sandy soils with parallel sand ridges up to 8 m high. The major vegetation at this site is hummock grass dominated by *Triodia basedowii*, with gidgee, *Acacia cambagei*, occurring on harder clay soils between the sand ridges (Dickman *et al*. 1993).

Scats were collected on fieldtrips in March–May 1990, August 1990, May 1991, October–November 1991, May–August 1992, November 1992 and May–June 1995. Scats were collected from pitfall traps upon first capture of an animal (Dickman *et al*. 1995), and preserved individually in 70% ethanol for later analysis. At the point of capture, animals were sexed and permanently marked by individually clipping ears or toes prior to release so that recaptures could be identified and their scats excluded from further analysis.

In the laboratory, scats were teased apart in a petri dish with 70% ethanol under a zoom binocular microscope (7–40× magnification). Prey items were identified and allocated, when possible, into size classes. Insects were identified to Order, using reference samples collected at Ethabuka and published keys (CSIRO 1970, 1991). Most non-insect prey were identified to Class, but some were classified to Family or Genus. Mammalian hair was identified by microscopic examination of the internal structure and cuticular scales (Brunner and Coman 1974). The percentage frequency of food items in the diet was calculated by expressing the number of scats containing a given prey category as a percentage of the total number of scats in the sample. The scats collected from each animal were considered to comprise one sample. The sizes of prey eaten were estimated by comparison of dietary fragments with whole reference specimens, and placed into five size classes on the basis of length: Class 1, 1–5 mm; Class 2, 6–10 mm; Class 3, 11–15 mm; Class 4, 16–20 mm; Class 5, >20 mm. Vertebrate and invertebrate prey in class 5 were presented separately in the analysis.

Statistical tests were performed using SIGMASTAT for Windows, version 1.0 (Jandel Scientific). A chi-square test was used to compare the overall frequencies of prey types in scats between males and females, and to compare the overall percentage frequencies of prey types among seasons. One-way ANOVA was used to detect any differences in the mean numbers of different-sized prey per scat between size-classes of prey. Following ANOVAs, the Student–Newman–Keuls test was used for pairwise multiple comparisons. The method of Hurtubia (1973) was used to determine whether there were sufficient samples for dietary analyses.

Results

Representativeness of dietary samples

Scats were taken from 52 different individuals of *D. cristicauda*: 15 samples during spring (September–November), 13 from autumn (March–May), and 24 from winter (June–August) over all years of the study combined. Each scat was composed of 1–7 separate droppings (mean = 3), and contained 1–6 different types of prey. The major prey taxa of *D. cristicauda* were insects, spiders, scorpions, centipedes, skinks, marsupials and rodents. The undigested parts of identifiable prey were mainly exoskeletal remains of arthropods, and hair, teeth, bone fragments, claws and scales of mammals and reptiles. Seeds, leaves and other plant remains occurred very infrequently in scats; they were assumed to have been ingested accidentally. The cumulative number of prey taxa reached an asymptote after 13 scats selected in random order (Fig. 1), suggesting that both the seasonal and total sample sizes were sufficient to reliably describe dietary diversity (Hurtubia 1973).

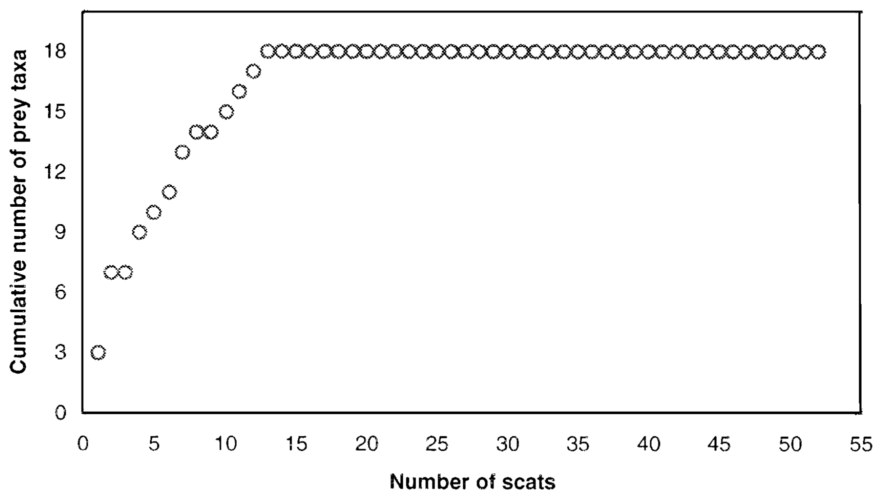

Fig. 1. Cumulative number of prey taxa in scats of *Dasycercus cristicauda* plotted against number of scats analysed.

Types of prey in the diet

The importance of different types of prey to the diet of *D. cristicauda* followed the following sequence: Insecta, Arachnida, Rodentia, Chilopoda, Reptilia, Marsupialia, Amphibia and Aves (Table 1). Insects occurred in 92% of scats overall, with other arthropods, including Arachnida and Chilopoda, occurring less frequently (Table 1). Rodents were the most frequently taken vertebrate prey, accounting for 33% by frequency, and included *Mus musculus, Rattus villosissimus, Notomys alexis* and *Pseudomys* spp. Reptiles (21% by frequency) included geckos, skinks, dragons and pygopodids. Other vertebrates, including small dasyurids (*Ningaui ridei* and *Sminthopsis* spp.), Aves and Amphibia were taken infrequently. The diets of males and females, as expressed by percentage frequency of prey types, were not significantly different (χ^2 = 7.79, d.f. = 7, P > 0.05), so these data were combined for further analyses.

Insect taxa

More detailed inspection of insect remains from scats revealed up to fourteen Orders of insects, including both adults and larvae (Table 2). In all, 62% of *D. cristicauda* had fed on coleopterans, 33% on hymenopterans, 25% on blattodeans, 21% on orthopterans, 15% on lepidopterans, 10% on isopterans and less than 10% on each of the other Orders (Table 2). Coleopteran Families identified included Carabidae, Curculionidae, Chrysomelidae, Elateridae, Scarabaeidae and Tenebrionidae. The first and the last of these Families appeared to be most important in the diet, but our inability to categorise all Coleopteran remains to Family makes it difficult to draw firm conclusions. Hymenopterans were represented primarily by ants (30% of scats), with up to 13 individuals occurring per scat. Isopterans occurred in only 10% of scats, but were represented by up to 60 individuals per scat. Five scats (10%) contained the remains of larvae, including mainly Coleoptera and Lepidoptera, in comparison with 48 scats (92%) that contained the remains of adult insects.

Table 1. Mean percentage frequency of occurrence of different types of prey in scats of *Dasycercus cristicauda*

Item	Percentage frequency			
	Spring *n* = 15	Autumn *n* = 13	Winter *n* = 24	Mean *n* = 52
Insecta	93	100	88	92
Arachnida	60	23	33	38
Chilopoda	7	31	33	25
Mammalia				
Rodentia	47	8	38	33
Marsupialia	0	8	17	10
Aves	0	0	4	2
Reptilia	47	15	8	21
Amphibia	7	0	0	2

Table 2. Mean percentage frequency of occurrence of insect Orders in scats of *Dasycercus cristicauda*

Orders	Percentage occurrence			
	Spring *n* = 15	Autumn *n* = 13	Winter *n* = 24	Mean *n* = 52
Coleoptera	53	31	83	62
Hymenoptera	27	46	29	33
Blattodea	20	31	25	25
Orthoptera	33	15	17	21
Lepidoptera	33	15	4	15
Isoptera	7	8	12	10
Diptera	0	15	4	6
Thysanura	7	0	8	6
Collembola	7	0	4	4
Hemiptera	7	0	4	4
Phthiraptera	0	8	4	4
Neuroptera	7	0	0	2
Phasmatodea	0	0	4	2
Unidentified	0	0	4	2

Sizes of prey in the diet

D. cristicauda ate significantly more individuals of prey in the 1–5-mm size class (Table 3) than in any other size classes. In scats in which such small prey occurred, the largest number in one scat was 60 individuals and the mean was 11.0 (15, 5.1 and 11 individuals for spring, autumn and winter respectively). Termites and ants were the two major types of small prey items, comprising respectively 58% and 37% of small prey. The percentage occurrence of different sizes of invertebrate prey in the sampled scats was 46.9% in the smallest class, 57.5% in the 6–10-mm size class, 43.3% in the 11–15-mm size class, 32.3% in the 16–20-mm size class and 31.9% in the >20-mm size class; the percentage occurrence of vertebrate prey (>20 mm) was 57.0% (Fig. 2), indicating that invertebrate prey 6–10 mm long and vertebrate prey were taken more consistently by *D. cristicauda* than prey in any other size classes. The prey sizes taken by male and female *D. cristicauda* were similar. However, males tended to eat more individual prey (9.3 individuals of prey per scat) than did females (8.6), and the percentage occurrences of different-sized prey in the scats of males were also higher than in those of females, especially in the larger size classes (Fig. 3).

Table 3. Mean number of different-sized prey items in each scat of *Dasycercus cristicauda*
The values with different letters (a, b) in rows among seasons, and the values with different letters (A, B) in columns for means, represent significant differences ($P < 0.05$).

	Invertebrate					Vertebrate	Total	
Season	1–5 mm	6–10 mm	11–15 mm	16–20 mm	>20 mm	>20 mm	>20 mm	All
Spring	5.0	1.5	0.9	0.7	0.5	1.0	1.5	9.5[a]
Autumn	3.0	0.6	0.3	0.4	0.3	0.4	0.7	5.0[b]
Winter	5.3	1.2	0.6	0.3	0.5	0.6	1.1	8.5[a]
Mean	4.7[A]	1.2[B]	0.6[B]	0.4[B]	0.4[B]	0.7[B]	1.1[B]	8.0

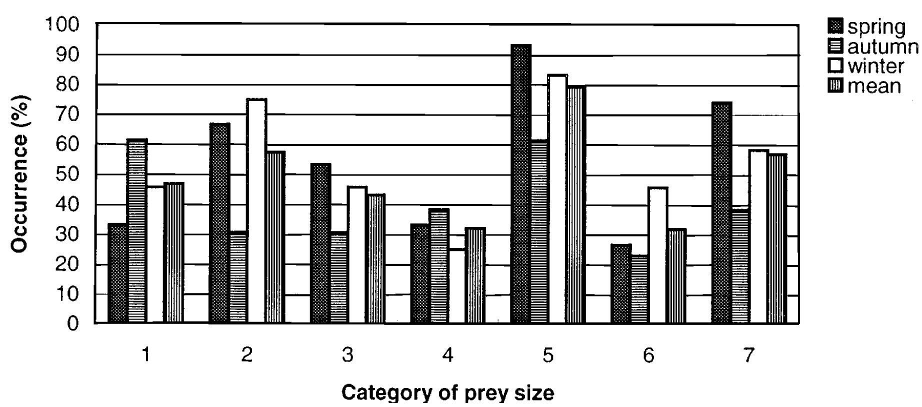

Fig. 2. Mean percentage frequencies of occurrence of different-sized prey in scats of *Dasycercus cristicauda.* Categories 1–4 are classes 1–4 of prey size respectively. Categories 5–7 represent prey >20 mm; category 5 includes both invertebrate and vertebrate prey, category 6 is invertebrate prey >20 mm, and category 7 is vertebrate prey >20 mm. Size classes are prescribed on the basis of prey length: class 1, 1–5 mm; class 2, 6–10 mm; class 3, 11–15 mm; class 4, 16–20 mm; class 5, >20 mm.

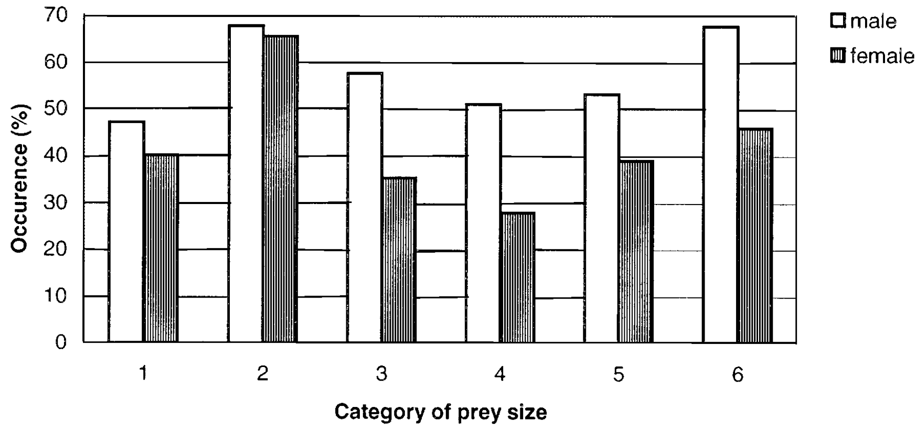

Fig. 3. Mean percentage frequencies of occurrence of different-sized prey in scats of male and female *Dasycercus cristicauda*. Categories 1–4 are classes 1–4 of prey size respectively. Category 5 represents invertebrate prey >20 mm, and category 6 vertebrate prey >20 mm.

Seasonal dietary change

More individual prey items were recorded in scats of *D. cristicauda* in spring (9.5 individual prey per scat) and winter (8.5) than in autumn (5.0) (Table 3). Animals also took more prey >20 mm long in spring than in autumn ($F = 4.09$, d.f. = 2, $P < 0.05$). The contribution of different kinds of prey to the diet of *D. cristicauda* also changed seasonally (Tables 1, 2). Although overall there was only a weak association between prey type and season ($\chi^2 = 15.50$, d.f. = 10, $P = 0.12$), *D. cristicauda* consumed more rodents in winter and spring than in autumn ($\chi^2 = 6.12$, d.f. = 2, $P < 0.05$), and more reptiles in spring than in any other season ($\chi^2 = 6.70$, d.f. = 2, $P < 0.05$). Both males and females consumed more vertebrate prey in spring than in winter and autumn. However, the increase from autumn to spring was 4.77% higher in females than in males, and only males consumed more vertebrate prey in winter than in autumn (Fig. 4). Interestingly, only eight Orders of insects were represented in the diet in autumn compared with ≥10 in other seasons (Table 2).

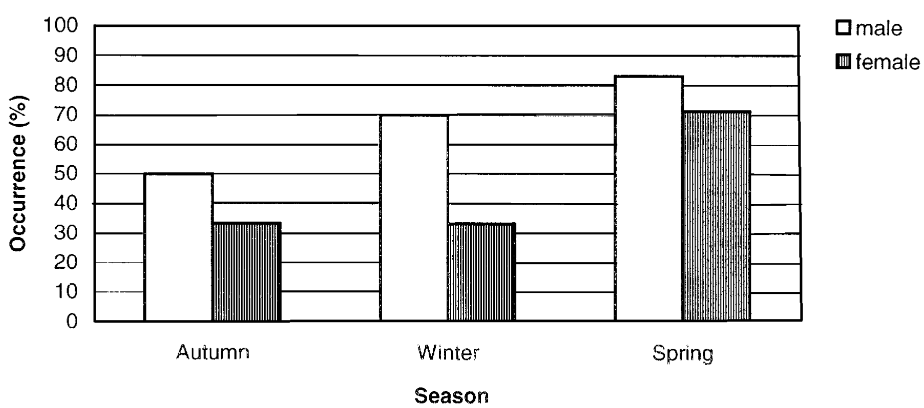

Fig. 4. Mean percentage frequencies of occurrence of vertebrate prey in scats of male and female *Dasycercus cristicauda* among different seasons.

Discussion

Our study confirms that *D. cristicauda* is broadly carnivorous, with invertebrates making up the major part of the diet. Although Fisher and Dickman (1993*a*) found that *D. cristicauda* fed only on invertebrates (on the basis of data from five individuals), small mammals, lizards, invertebrates and fruits were also found in its diet at Uluṟu National Park, Northern Territory (Masters 1998). The range of invertebrates found in the diet of *D. cristicauda* at Uluṟu National Park (Masters 1998) was similar to that in the Simpson Desert, where coleopterans and orthopterans were commonly eaten, but hymenopterans, arachnids and larvae also featured prominently. In both populations, there was no significant difference in the types of prey in the diets of males and females (Masters 1998).

Dasycercus cristicauda consistently takes invertebrate prey 6–10 mm in length, as well as vertebrate prey. The frequent occurrence of such prey in the diet supports the suggestion that large prey (>7.5 mm long) are preferred (Fisher and Dickman 1993*a*, 1993*b*). Vertebrate prey in the diet of *D. cristicauda* consists mostly of rodents (49% of all vertebrates taken), which extends to the field an early laboratory observation that *D. cristicauda* prefers mice to other foods (Sorenson 1970). Large prey items presumably provide a greater rate of energy gain than small prey for large dasyurids and, providing that capture and handing costs are not great, should be selected (Schoener 1987). Interestingly, one very large prey species, the long-haired rat, *Rattus villosissimus* (mean weight 130 g), was recorded in one scat. It is likely that the rat was taken as carrion; the scat was collected in November 1992 when a plague of *R. villosissimus* was subsiding at the study site and sick and moribund individuals were common (Predavec and Dickman 1994). *Dasycercus cristicauda* is characterised by marked sexual dimorphism in body weight and linear body measurements, with males being larger than females (Gibson and Cole 1992). Male *D. cristicauda* not only consume more individual prey items on average, but also more prey in the large size classes, than do females. This result suggests a strong positive correlation between the body size of the predator and prey not only in interspecific comparisons of dasyurids (Fisher and Dickman 1993*b*), but also intraspecifically for *D. cristicauda*.

Small prey (1–5 mm) also occurred moderately frequently in scats, and in larger numbers per scat than large prey. Ants occurred more consistently in the diet (Table 2) but were represented by fewer individuals (mean = 5.3) in scats than termites (mean = 28.2). At Uluṟu National Park termites also occurred in larger numbers per scat than ants, but both termites and ants occurred frequently in the samples (Masters 1998). Termites are eusocial insects that occur in aggregations and presumably provide predators with an opportunity to take many individuals in one feeding bout. Although most families of ants also contain eusocial species, their poor representation per scat suggests that *D. cristicauda* does not select them as a prey type and that they are a less important food source than termites.

There were marked differences in the diet of *D. cristicauda* among seasons. There are two potential reasons for these differences. Firstly, the predators may have altered their diets in response to changes in prey abundance. For example, reptiles were prominent in the diet in spring but not autumn or winter (Table 1), perhaps reflecting inactivity and increased inaccessibility of most species of reptiles during the colder months. Insects tended to be represented most strongly in the diet in autumn and less so in winter, presumably for similar reasons. In comparison, rodents were unimportant in the diet in autumn but prominent in the other seasons (Table 1). Rodent numbers fluctuate dramatically in arid environments (Newsome and Corbett 1975), and during the present study they fell to minimal levels in autumn over most of the study period (Predavec 1994). An alternative explanation for the seasonal diet shift relates to reproduction. *Dasycercus cristicauda* reproduces between winter and early summer in the study area (Dickman, unpublished), and the peak of breeding activity is around August/September (Michener 1969; Ewer 1969; Woolley 1971). Animals may change their diet at this time to meet probable increased energy, water and nutrient requirements of reproduction by selectively taking rodents. Consistent with this suggestion is the observation that female *D. cristicauda* do not display torpor from a few days before giving birth until the end of lactation, whereas males display torpor regularly (47%) throughout the same period (Geiser and Masters 1994). The increased requirements of females for energy, water and nutrients for reproduction, and of males and females for maintenance of normothermic status, coincide with the increased rodent consumption by females in spring and by males in winter and spring; these increased demands coincide also with increased numbers of juvenile rodents (Predavec 1994) which may be relatively easy for *D. cristicauda* to catch.

In contrast to the extensive movements that are made by many species of small mammals in arid Australia (Dickman *et al.* 1995), *D. cristicauda* is relatively sedentary and occupies stable ranges (Dickman 1996*b*; Masters 1998). Long-range movements in rodents and other dasyurids appear to follow rainfall events and provide access to areas with locally increased food. In *D. cristicauda*, however, the flexible diet and ability to switch between different prey types seasonally suggests that mobility confers little benefit, and, indeed, may even be disadvantageous. *Dasycercus cristicauda* is unusual among arid-zone dasyurids in digging its own, often complex, burrow systems (Woolley 1990; Dickman 1996*b*). Frequent movements to new sites would thus increase the energetic expenditure required by individuals to construct new burrows, without necessarily increasing the amount of food available. Murray and Dickman (1994) proposed that dietary flexibility had been advantageous for some species of rodents in allowing them to survive land-use changes induced by European settlement in arid Australia. Although rodents, reptiles and other vertebrate prey are important components of the diet of *D. cristicauda*, especially in the breeding season, sole reliance on vertebrate prey within the sedentary range of *D. cristicauda* could result in starvation and possible local extinction following a decline of vertebrate prey. Instead, its generalist diet enables *D. cristicauda* to persist. We thus suggest that dietary flexibility may have contributed to the persistence of *D. cristicauda* in arid Australia, and contrast the relative success of this medium-sized species with the demise of several similar-sized dietary specialists (Murray and Dickman 1994).

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References

Brunner, H., and Coman, B. (1974). ‘The Identification of Mammalian Hair.’ (Inkata Press: Melbourne.)

Calver, M. C., Bradley, J. S., and King, D. R. (1988). The relationship between prey size and handling time and prey size and capture success in three sympatric species of dasyurid marsupials. *Australian Wildlife Research* **15**, 615–623.

CSIRO. (1970). ‘The Insects of Australia.’ (Melbourne University Press: Melbourne.)

CSIRO. (1991). ‘The Insects of Australia.’ (Melbourne University Press: Melbourne.)

Dickman, C. R. (1986*a*). Niche compression: two tests of an hypothesis using narrowly sympatric predator species. *Australian Journal of Ecology* **11**, 121–134.

Dickman, C. R. (1986*b*). An experimental study of competition between two species of dasyurid marsupials. *Ecological Monographs* **56**, 221–241.

Dickman, C. R. (1988). Body size, prey size, and community structure in insectivorous mammals. *Ecology* **69**, 569–580.

Dickman, C. R. (1996*a*). Incorporating science into recovery planning for threatened species. In ‘Back from the Brink: Refining the Threatened Species Recovery Process’. (Eds S. Stephens and S. Maxwell.) pp.63–73. (Surrey Beatty and Sons: Sydney.)

Dickman, C. R. (1996*b*). Vagrants in the desert. *Nature Australia* **25**, 54–62.

Dickman, C. R., and Huang, C. (1988). The reliability of fecal analysis as a method for determining the diet of insectivorous mammals. *Journal of Mammalogy* **69**, 108–113.

Dickman, C. R., Downey, F. J., and Predavec, M. (1993). The hairy-footed dunnart *Sminthopsis hirtipes* (Marsupialia : Dasyuridae) in Queensland. *Australian Mammalogy* **16**, 69–72.

Dickman, C. R., Predavec, M., and Downey, F. J. (1995). Long-range movements of small mammals in arid Australia: implications for land management. *Journal of Arid Environments* **31**, 441–452.

Evans, D. D., and Batty, M. J. (1986). Effects of high dietary concentrations of glyphosate (Roundup) on species of bird, marsupial and rodent indigenous to Australia. *Environmental Toxicology and Chemistry* **5**, 399–402.

Ewer, R. F. (1969). Some observations on the killing and eating of prey by two dasyurid marsupials: the mulgara, *Dasycercus cristicauda*, and the Tasmanian devil, *Sarcophilus harrisi*. *Zeitschrift für Tierpsychologie* **26**, 23–38.

Fisher, D. O., and Dickman, C. R. (1993*a*). Diets of insectivorous marsupials in arid Australia: selection for prey type, size or hardness? *Journal of Arid Environments* **25**, 397–410.

Fisher, D. O., and Dickman, C. R. (1993*b*). Body size–prey size relationships in insectivorous marsupials: tests of three hypotheses. *Ecology* **74**, 1871–1883.

Fox, B. J., and Archer, E. (1984). The diets of *Sminthopsis murina* and *Antechinus stuartii* (Marsupialia : Dasyuridae) in sympatry. *Australian Wildlife Research* **11**, 235–248.

Geiser, F., and Masters, P. (1994). Torpor in relation to reproduction in the mulgara, *Dasycercus cristicauda* (Dasyuridae : Marsupialia). *Journal of Thermal Biology* **19**, 33–40.

Gibson, D. F., and Cole, J. R. (1992). Aspects of the ecology of the mulgara, *Dasycercus cristicauda* (Marsupialia : Dasyuridae) in the Northern Territory. *Australian Mammalogy* **15**, 105–112.

Hall, S. (1980). The diets of two coexisting species of *Antechinus* (Marsupialia : Dasyuridae). *Australian Mammalogy* **6**, 29–34.

Hurtubia, J. (1973). Trophic diversity measurement in sympatric predatory species. *Ecology* **54**, 885–890.

Kennedy, M. (1990). 'Australia's Endangered Species.' (Simon and Schuster: Australia.)

Kunz, T. H., and Whitaker, J. O., Jr. (1983). An evaluation of faecal analysis for determining food habits of insectivorous bats. *Canadian Journal of Zoology* **61**, 1317–1321.

Masters, P. (1998). The mulgara *Dasycercus cristicauda* (Marsupialia : Dasyuridae) at Uluṟu National Park, Northern Territory. *Australian Mammalogy*, in press.

Maxwell, S., Burbidge, A. A., and Morris, K. (1996). 'The Action Plan for Australian Marsupials and Monotremes.' IUCN/SSC Australian Marsupial and Monotreme Specialist Group.

Michener, G. R. (1969). Notes on the breeding and young of the crest-tailed marsupial mouse, *Dasycercus cristicauda.* *Journal of Mammalogy* **50**, 633–635.

Morton, S. R. (1978). An ecological study of *Sminthopsis crassicaudata* (Marsupialia : Dasyuridae). III. Reproduction and life history. *Australian Wildlife Research* **5**, 183–211.

Morton, S. R. (1982). Dasyurid marsupials of the Australian arid zone: an ecological review. In 'Carnivorous Marsupials'. (Ed. M. Archer.) pp.117–130. (Royal Zoological Society of New South Wales: Sydney.)

Morton, S. R., and Baynes, A. (1985). Small mammal assemblages in arid Australia: a reappraisal. *Australian Mammalogy* **8**, 159–169.

Morton, S. R., Denny, M. J. S., and Read, D. G. (1983). Habitat preferences and diets of sympatric *Sminthopsis crassicaudata* and *S. macroura* (Marsupialia : Dasyuridae). *Australian Mammalogy* **6**, 29–34.

Murray, B. R., and Dickman, C. R. (1994). Food preferences and seed selection in two species of Australian desert rodents. *Wildlife Research* **21**, 647–655.

Newsome, A. E., and Corbett, L. (1975). Outbreaks of rodents in semi-arid and arid Australia: causes, prevention, and evolutionary considerations. In 'Rodents in Desert Environments'. (Eds I. Prakash and P. Ghosh.) pp.117–153. (Junk: The Hague.)

Predavec, M. (1994). Food limitation and demography in Australian desert rodents. Ph.D. Thesis, University of Sydney.

Predavec, M., and Dickman, C. R. (1994). Population dynamics and habitat use of the long-haired rat (*Rattus villosissimus*) in south-western Queensland. *Wildlife Research* **21**, 1–10.

Read, D. G. (1987). Diets of sympatric *Planigale gilesi* and *P. tenuirostris* (Marsupialia : Dasyuridae): relationship of season and body size. *Australian Mammalogy* **10**, 11–21.

Robinson, M. F., and Stebbings, R. E. (1993). Food of the serotine bat, *Eptesicus serotinus* – is faecal analysis a valid qualitative and quantitative technique? *Journal of Zoology (Lond.)* **231**, 239–248.

Schoener, T. W. (1987). A brief history of optimal foraging theory. In 'Foraging Behavior'. (Eds A. C. Kamil, J. R. Krebs and H. R. Pulliam.) pp.5–67. (Plenum Press: New York.)

Sorenson, M. W. (1970). Observations on the behavior of *Dasycercus cristicauda* and *Dasyuroides byrnei* in captivity. *Journal of Mammalogy* **15**, 123–130.

Woolley, P. (1995). Mulgara *Dasycercus cristicauda*. In 'The Mammals of Australia'. (Ed. R. Strahan.) pp.55–56. (Angus and Robertson: Sydney.)

Woolley, P. A. (1971). Maintenance and breeding of laboratory colonies *of Dasyuroides byrnei* and *Dasycercus cristicauda*. *International Zoo Yearbook* **11**, 351–354.

Woolley, P. A. (1990). Mulgaras, *Dasycercus cristicauda* (Marsupialia : Dasyuridae); their burrows and records of attempts to collect live animals between 1966 and 1979. *Australian Mammalogy* **13**, 61–64.

Woolnough, A. P., and Carthew, S. M. (1996). Selection of prey by size in *Ningaui yvonneae*. *Australian Journal of Zoology* **44**, 319–326.

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