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The importance of rodents in the diet of jungle cat (*Felis chaus*), caracal (*Caracal caracal*) and golden jackal (*Canis aureus*) in Sariska Tiger Reserve, Rajasthan, India

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Abstract

Many small carnivores include rodents in their diet. However, due to varying evolutionary strategies, carnivores differ in their metabolism and energy requirements. Hence, comparisons of diet between carnivores would be more meaningful if the body size and energetics of the predators are considered. The diet of three small carnivores (jungle cat *Felis chaus*; caracal *Caracal caracal*; golden jackal *Canis aureus*) from a semi-arid part of western India was studied through scat analysis, and the importance of rodents in their diet was estimated as a percentage of their daily energy requirement. Although percentage frequency in scats and biomass consumption showed rodents to be equally important to all three carnivores, energy calculations showed that rodents were more important as prey for the felids than the jackal. Up to 70% of the daily metabolizable energy in felids was obtained from rodents, as compared to 45% in the jackal. Rodents are generally viewed as pests, and their importance to the small carnivore community is overlooked. Change in land use over the decades in the arid/semi-arid tract of western India has led to several adverse as well as favourable modifications in rodent assemblages, which could influence the persistence of species like the caracal and jungle cat in this region, that largely depend on rodents for their survival.

Key words: felids, canids, scats, rodents, energetics

INTRODUCTION

Rodents are generally viewed as pests due to the economic losses caused to agriculture and the prospects of spread of disease from them. However, they play an important ecological role as prey of numerous small carnivores (Pearson, 1964; Moehlman, 1986; Kitchener, 1991; Sillero-Zubiri & Gottelli, 1995). The western part of India, which is largely arid and semi-arid, has a large, fast-growing human and livestock population. To meet their needs, this region has been subjected to large-scale land use change, and consequent opening and conversion of habitats into scrub and agriculture in several areas over the decades (http://goidirectory.nic.in/fstateut.htm). In this region, not only have numbers of some generalist rodent species such as *Rattus rattus*, *Bandicota bengalensis*, *Golunda ellioti* and *Tatera indica* increased to pest proportions, but their distribution ranges have also expanded due to expansion of irrigated farming (Sharma & Sankhala, 1984; Prakash, 1995; Prakash, Singh & Saravanan, 1995). Some desert rodents such as *Gerbillus gleadowi* and *Meriones hurrianae* have been replaced by species such as *Millardia meltada*, *Bandicota bengalensis*, *Rattus rattus*, *Golunda ellioti* and *Tatera indica* that were more adaptable to these changing conditions (Prakash, 1995). Studies on effects of changing land use on rodents report both negative (Delany & Happold, 1979; Happold, 1983) and positive effects (Prakash *et al*., 1995).

Western India harbours several small carnivores, many of which presumably feed on rodents. These include, the caracal *Caracal caracal*, the desert cat *Felis sylvestris ornata*, rusty spotted cat *Prionailurus rubiginosa*, desert fox *Vulpes vulpes*, jungle cat *Felis chaus*, small Indian civet *Viverricula indica*, common palm civet *Paradoxurus hermaphroditus*, grey mongoose *Herpestes edwardsii*, ruddy mongoose *Herpestes smithii*, small Indian mongoose *Herpestes javanicus*, ratel *Mellivora capensis*, golden jackal *Canis aureus* and common Indian fox *Vulpes bengalensis*. What are the effects of changing land use and rodent abundance on these small carnivores? What is the extent of their dependence on rodents as prey? Which species of small carnivores can persist under this changing land use? Are some species able to benefit from the increase in rodent population? Most of these questions remain unanswered, since the extent to which these carnivores depend on rodent prey remains unknown. In

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this paper, we examine the diets of three sympatric small carnivores, the jungle cat, the caracal and the golden jackal, and evaluate the importance of rodents in their diets.

Studies investigating diets of small carnivores have often used the per cent occurrence of each prey item in scats to determine the most important prey species. However, this method tends to overestimate the importance of smaller prey (Floyd, Mech & Jordan, 1978; Ackerman, Lindsey & Hemker, 1984, Carrs & Elston, 1996). By applying correction factors to the percentage frequency method, the biomass of prey consumed can be calculated (Floyd *et al*., 1978; Ackerman *et al*., 1984). Biomass consumed gives a more informative and accurate representation of diet than percentage frequency alone (Floyd *et al*., 1978; Ackerman *et al*., 1984).

In the present study, we estimated the biomass contributed to the diet by each prey species, to estimate the importance of rodents for three small carnivores caracal, jungle cat and golden jackal. However, since these small carnivores vary in their physiology and metabolism, we went a step further and estimated the importance of rodents in their diet, as a percentage of their daily energy requirement.

Amongst the three carnivores we studied, the caracal inhabits a wide range of habitats, and has a wide distribution globally with the centre of its global range situated in Africa. India is at the eastern fringe of this distribution. Currently, within India its distribution is restricted to some patches in the dry western region (Kitchener, 1991; Corbet & Hill, 1992; IUCN, 1996). This cat, which is extremely rare in India, once had a wider distribution through most of the arid and semi-arid regions of the country. The Asian subspecies is listed in Appendix I of CITES (IUCN, 1996). On the other hand, the jungle cat is the most common wild felid in India, with a wide distribution and occurring in a variety of habitats. Its global distribution is centred in India (IUCN, 1996). The golden jackal is the most common canid in India and occurs widely, inhabiting a variety of habitats, including degraded open areas around human habitation.

STUDY AREA

The study was conducted in Sariska Tiger Reserve (STR) (800 km^2) located in the western state of Rajasthan (74°17′ to 76°34′N and 25°5′ to 27°33′E), from January 1994 to May 1996. STR has a core area of 300 km^2 with National Park status, which functions as a tourism zone. People living in villages in and around the core zone are responsible for lopping trees, cutting grass, poaching and grazing livestock in this area. Tourism is unregulated and there are numerous vehicles in the area to transport pilgrims to a temple situated inside STR.

There are three distinct seasons: winter (October–March), summer (April–June) and monsoon (July–September). Temperatures in peak winter drop to 0 °C. The summer is short but temperatures rise to 50 °C (for short durations). During monsoons, the area receives approximately 600 mm of rainfall.

Champion & Seth (1968) described the vegetation as tropical dry deciduous and tropical thorn forest type. The scrub has grass and *Cassia tora* as ground cover and bushes such as *Grewia flavicens, Capparis decidua, Capparis sepiaria, Zizyphus nummularia* and *Adhatoda vasica* as the next layer above. Trees are scattered and dominated by *Balanites aegyptiaca, Acacia leucophloea, Zizyphus mauritiana* and *Acacia senegal*.

The wildlife found in this area includes 13 carnivores: tiger *Panthera tigris*, leopard *P. pardus*, caracal, jungle cat, rusty spotted cat, hyaena *Hyaena hyaena*, grey wolf *Canis lupus*, golden jackal, grey mongoose, small Indian mongoose, ruddy mongoose, common palm civet and small Indian civet. Five species of wild ungulates occur in STR, the nilgai *Boselaphus tragocamelus*, sambar *Cervus unicolor*, chital *Axis axis*, chowsingha *Tetracerus quadricornis* and wild pig *Sus scrofa*. Two primates, common langur *Presbytis entellus* and rhesus macaque *Macaca mulatta* are found in STR. Other mammalian fauna found are the rufous-tailed hare *Lepus nigricollis ruficaudata*, porcupine *Hystrix indica* and small rodents, such as the Indian gerbil *Tatera indica*, the bush rat *Golunda ellioti* and the spiny-tailed mouse *Mus platythrix*. Due to the presence of villages, many domesticated animals such as buffaloes, cows, goats, camels, dogs and cats also occur within STR. Two hundred and eleven bird species belonging to 52 families have been reported from STR (Sankar, Mohan & Pandey, 1993).

This study was conducted within the National Park. We chose a 10 km^2 patch of scrub to collect scats of jungle cat, caracal and golden jackal. Although this was a heavily disturbed area, it was also the only relatively large patch of scrub in the Park where we could conduct a comparative study on all three species, since the scrub formed the main habitat of the two felids.

METHODS

Diet of the small carnivores was studied through scat analysis (Reynolds & Aebischer, 1991). We collected scats on transects that were used for measuring small carnivore as well as ground bird abundance, on dirt tracts, along paved roads and during random searches within the scrub, all year round (except during the monsoon). On collection, the location, date and other data (if available) such as occurrence of tracks around scats were recorded on the collection bag. Scats were sun-dried in the field and later oven dried at 60 °C in the laboratory for 48 h. Carnivores secrete bile for fat digestion and the excess is excreted in scats. Earlier studies have shown that bile acids vary in quantity and type in different species. These bile acids can be extracted from scats and can be used to determine predator identity. We used fat and bile acid content of scats to classify them to species using thin layer chromatography (Major *et al*., 1980). We used scats of known origin (when the individual was seen defecating in the field, as well as from captive individuals in zoos) to standardize the technique. In all we had 15 scats of golden jackal and 5 of jungle cat, as standards. We did not have standard caracal scats, as there are no captive caracals in the country. Hence, we used the elimination method, and scats that showed patterns differing from the scats of golden jackal, jungle cat or leopard were recorded as those of caracal. Results of the chromatographic technique were corroborated through some scats that had signs such as tracks found around them in the field, and by those that were collected around den sites of known species.

Scats were teased apart, and the contents separated into mammals, birds, reptiles, invertebrates and vegetable matter. We further separated mammal remains into hair, jaws and other bones. Jaws usually belonged to rodents or hare. We analysed 69 scats of jungle cat, 25 scats of caracal and 140 scats of jackal.

Amount of food ingested by an animal depends on its Basal Metabolic Rate (BMR). Kleiber (1961) showed that BMR, measured as oxygen consumption, is related to body size and scales to the 0.75 power of body mass ($m^{0.75}$). Apart from body size, diet is a major factor that influences BMR (McNab 1988, 1989). Carnivores that feed primarily on vertebrate prey (e.g. felids, mustelids) have BMRs equal to or higher than predicted by the Kleiber curve, those with an omnivorous diet (e.g. jackal, coyote *Canis latrans*, some viverrids) have BMRs as expected from the curve and those that feed on invertebrates and fruits (e.g. red panda *Ailurus fulgens*, some viverrids) have lower BMRs than predicted by the Kleiber curve (McNab, 1989).

The mean BMR of carnivores is found to be 17% higher than the mean BMR of mammals in general (McNab, 1988, 1989). The BMR of some cats such as the ocelot *Leopardus pardalis* and bobcat *Lynx rufus*, are 11% and 52% higher, respectively, than predicted by the carnivore curve, while that of the coyote, is 96% of the curve (McNab, 1989). The high BMR of species that largely feed on vertebrate prey is attributed to the higher specific dynamic action (metabolic cost of processing) of proteins as compared to carbohydrates and fat (Peters, 1986).

On average, carnivores consume food equalling 7–10% of their body mass per day (Hilton, 1978; Gasperetti, Harrison & Büttiker, 1986; Caro, 1989; Aldama, Beltrán & Delibes 1991; Jhala, 1991; Heptner & Sludskii, 1992; Olbricht & Sliwa, 1997). Hence the daily biomass consumption by jungle cat (mean body mass = 4 kg, Pocock, 1939) and jackal (mean body mass = 8 kg, Roberts, 1977) could be estimated. Body mass of Indian caracal is not documented. However, body measurements such as total length (head and body) for Indian caracal are available (Pocock, 1939), and caracal body measurements as well as body mass from Israel and Africa are recorded (Dayan *et al*., 1990; Sunquist & Sunquist, 2002). Indian caracals are much smaller than their African and Israeli counterparts, and the body measurements suggest that the average Indian caracal weighs around 6 kg (Pocock, 1939; Dayan *et al*., 1990; Sunquist & Sunquist, 2002). About 30% of animal tissue is dry matter (DM) and 1 g of DM has approximately 22.59 kJ, and, thus, the gross energy (GE) could be calculated as DM*22.59 (Peters, 1986; Powers, Mautz & Perkins, 1989). The GE consumed by an animal is converted to digestible energy (DE) and faecal energy (FE). The DE is further used to give urine energy and metabolizable energy (ME). ME is used for growth and development. Studies have shown that felids and canids digest 90% of the protein they consume while the remaining (10%) is excreted (Golley *et al*., 1965; Livaitis & Mautz, 1980). Hence FE could be calculated as 10% of GE. Each gram of dry faeces containing bird and mammal remains has 11.29 kJ of energy (Golley *et al*., 1965). We estimated the expected dry scat weight produced per day, by dividing FE by 11.29. To obtain the number of scat depositions per day by each predator, we divided the expected dry scat weight produced per day, by the observed average weight of dry scats of each predator.

Studies on bobcats *Lynx rufus* and coyotes *Canis latrans* have shown that approximately 77% of total GE intake by bobcats is metabolizable (Golley *et al*., 1965; Powers *et al*., 1989), whereas for coyotes ME is 84.5% of GE (Livaitis & Mautz, 1980). We assumed the physiology of digestion of the jungle cat and caracal to be similar to the bobcat, and that of the jackal to be similar to the coyote.

To obtain estimates of rodent consumption by the carnivores, we first identified rodent species from the jaws found in scats by comparing the dentition with known specimens, and photographs and descriptions from Roberts (1977). We then calculated the number of individuals of each rodent species consumed by counting jaw parts (jaws were usually present as 2 halves of upper and 2 halves of lower jaws, hence 4 parts would make 1 individual). In most cases, the carnivores consumed rodents completely and excreted all jaw parts in a single scat. In less than 5% of scats, all parts were not present, and in these cases the presence of even a single portion or fragment of jaw with dentition was recorded as 1 individual.

We captured rodents in STR to estimate the mean body mass of different species. The number of individuals of each rodent species found per scat was multiplied by the number of scat depositions per day to estimate the number of rodents consumed per day. This was multiplied by the mean body mass of rodents, to obtain biomass consumption of rodents per day by each predator species. From the biomass intake we calculated the GE and ME, obtained from rodents. The ME obtained from rodents was expressed as a percentage of the total ME of each small carnivore.

Through the computer programme Simstat (Peladeau, 2000) we subjected the results of the scat analysis to re-sampling using the bootstrap simulation. Sub-samples equalling the original sample size of scats for each species were iterated 10 000 times, to generate means and bias corrected for 95% confidence intervals, percentage frequency of prey items in predator scats, the number of individuals of rodent species occurring per scat, the number of individuals of rodent species consumed per day and for the biomass of rodents consumed per day. Comparisons were made from the bootstrap bias corrected 95% confidence intervals.

Table 1. Mean percentage frequency of prey items in scats of jungle cat *Felis chaus*, caracal *Caracal caracal* and golden jackal *Canis aureus* from India, with 95% confidence intervals (CI) and variance after bootstrapping simulation (10 000 iterations)

Prey		Jungle cat ($n = 69$)	Caracal ($n = 25$)	Golden jackal ($n = 140$)
Mammal	Mean (%)	94	92	95
	95% CI	88–99	76–100	90–98
	Variance	0.1	0.3	0
Rodent	Mean (%)	73	84	75
	95% CI	62–83	68–96	67–81
	Variance	0.3	0.5	0.1
Wild ungulate	Mean (%)	12	0	10.7
	95% CI	6–20		6–16
	Variance	0.1		0.1
Bird	Mean (%)	42	36	40
	95% CI	32–55	16–56	31–49
	Variance	0.4	0.9	0.2
Reptile	Mean (%)	26	20	16
	95% CI	15–36	8–40	11–23
	Variance	0.3	0.7	0.1
Invertebrate	Mean (%)	23	40	17
	95% CI	15–33	16–52	11–24
	Variance	0.3	0.9	0.1
Vegetable matter	Mean (%)	19	16	43
	95% CI	10–29	4–32	36–51
	Variance	0.2	0.5	0.2
Others (plastic, paper)	Mean (%)	9	8	4.3
	95% CI	4–18	0–20	1–8
	Variance	0.1	0.3	0

RESULTS

More than 90% of scats of all three predators had remains of mammals (Table 1). Seventy three percent of jungle cat scats, 84% of caracal scats and 75% of the scats of golden jackal had rodent remains (Table 1). Birds occurred in 42% of jungle cat scats, 36% of caracal scats and 40% of golden jackal scats, while reptile remains were found in 26% jungle cat scats, 20% caracal scats and 16% golden jackal scats, and invertebrates occurred in 23% jungle cat scats, 40% caracal scats and 17% jackal scats (Table 1). A higher percentage of golden jackal scats (mean: 43%, 95% CI: 36–51) had remains of vegetable matter than either of the cat species (jungle cat mean: 19%, 95% CI: 10–29; caracal mean: 16%, 95% CI: 4–32) (Table 1). Hare and domestic livestock remains were found in less than 5% of the scats of jungle cat and golden jackal and were not present in caracal scats.

The Indian gerbil *Tatera indica* was the largest rodent with a mean body mass (± SD) of 77 g (± 39), while the spiny-tailed mouse *Mus platythrix* was the smallest rodent with a mean body mass of 16 g (± 7). Only two captures of bush rat *Golunda ellioti* were made and both individuals weighed 60 g each. The mean number of individuals of *T. indica* and *G. ellioti* found per scat did not differ among the predators (Table 2). However, the mean number of individuals of *M. platythrix* per scat was higher in caracal (mean: 2.00, 95% CI: 1.20–3.10) than in jungle cat (mean: 0.566, 95% CI: 0.304–0.899) and golden jackal (mean: 0.507, 95% CI: 0.160–1.04) (Table 2).

The GE consumed per day, was estimated as 1898–2711 kJ for the jungle cat, 2847–4067 kJ for caracal and 3796–5423 kJ for golden jackal (Table 3). The average expected dry weight of scats produced per day was estimated as 21 g for jungle cat, 31 g for caracal and 41 g for golden jackal and the number of scats produced per day was estimated as three for jungle cat and four each for caracal and golden jackal (Table 3).

The mean number of individuals of *T. indica* and *G. ellioti* consumed per day did not differ among the three predators (Table 4). However, the caracal consumed higher numbers of *M. platythrix* (mean: 8, 95% CI: 5.1–12.8) per day than the jungle cat (mean: 1.70, 95% CI: 0.96–2.73) or the golden jackal (mean: 2.0, 95% CI: 1.30–2.80) (Table 4).

The mean biomass of *T. indica* consumed per day by jungle cat was 73 g (95% CI: 45–101), by caracal was 51 g (95% CI: 0–115) and by golden jackal was 80 g (95% CI: 38–166) (Fig. 1). The mean biomass of *G. ellioti* consumed per day by jungle cat was 89 g (95% CI: 60–127), by caracal was 125 g (95% CI: 48–221) and by golden jackal, 142 g (95% CI: 113–177) (Fig. 1). The mean biomass of *M. platythrix* consumed per day, was higher in caracal (mean: 133 g, 95% CI: 82–205) than in jungle cat (mean: 27g, 95% CI: 15–44) and golden jackal (mean: 32, 95% CI: 21–45) (Fig 1). Jungle cat and golden

Table 2. Mean number of individuals of rodent species found per scat of jungle cat *Felis chaus*, caracal *Caracal caracal* and golden jackal *Canis aureus* from India, with 95% confidence intervals (CI) and variance generated from bootstrap simulation (10 000 iterations)

Rodent species		Jungle cat ($n = 69$)	Caracal ($n = 25$)	Golden jackal ($n = 140$)
Tatera indica	Mean (%)	0.304	0.160	0.250
	95% CI	0.188–0.420	0–0.360	0.120–0.520
	Variance	0.004	0.008	0.010
Golunda ellioti	Mean (%)	0.493	0.520	0.593
	95% CI	0.319–0.696	0.200–0.880	0.320–0.920
	Variance	0.009	0.032	0.024
Mus platythrix	Mean (%)	0.566	2.00	0.507
	95% CI	0.304–0.899	1.20–3.10	0.160–1.04
	Variance	0.023	0.228	0.051

Table 3. Daily intake of dry matter (DM), gross energy (GE) and number of scats produced by jungle cat *Felis chaus*, caracal *Caracal caracal* and golden jackal *Canis aureus* from India (see text for methods of calculation)

Species (average body mass in kg)	Daily DM intake (g)	GE (kJ)/day	Average expected dry scat weight (g)	Observed mean dry scat weight (g)	No. of scats/day
Jungle cat (4)	84–120	1898–2711	21 (17–24)	8	3
Caracal (6)	126–180	2847–4067	31 (25–36)	8	4
Golden jackal (8)	168–240	3796–5423	41 (34–48)	10	4

Table 4. Mean number of individuals of rodents eaten per day by jungle cat *Falis chaus*, caracal *Caracal caracal* and golden jackal *Canis aureus* in Sariska Tiger Reserve, India, with 95% confidence intervals (CI) and variance generated from bootstrap simulation (10 000 iterations)

Rodent species		Jungle cat ($n = 69$)	Caracal ($n = 25$)	Golden jackal ($n = 140$)
Tatera indica	Mean (%)	0.91	0.640	1.0
	95% CI	0.56–1.26	0.16–1.6	0.71–1.37
	Variance	0.32	0.137	0.028
Golunda ellioti	Mean (%)	1.48	2.00	2.37
	95% CI	0.91–2.04	0.64–3.5	1.9–2.94
	Variance	0.080	0.512	0.070
Mus platythrix	Mean (%)	1.70	8.00	2.0
	95% CI	0.96–2.73	5.1–12.80	1.30–2.80
	Variance	0.199	3.7	0.145

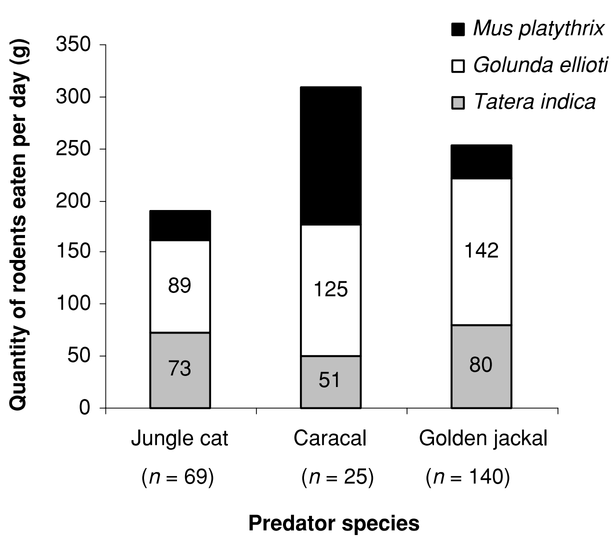

Fig. 1. Mean biomass of rodents consumed per day by jungle cat *Felis chaus*, caracal *Caracal caracal* and golden jackal *Canis aureus* between 1994 and 1996, Sariska Tiger Reserve, Rajasthan, India.

jackal consumed a lower mean biomass of *M. platythrix* than of *T. indica* or *G. ellioti*, per day, whereas the mean biomass of the three rodents consumed per day by the caracal did not differ (Fig. 1). The total mean biomass of rodents consumed per day was 189 g by jungle cat (95% CI: 143–241), 309 g by caracal (95% CI: 218–405) and 255 g by golden jackal, (95% CI: 218–296) (Table 5). Overall, *G. ellioti* was the most important rodent prey and formed 47% of total rodent intake in jungle cat, 40% in caracal and 56% in golden jackal (Fig. 1).

Table 5. Percent metabolizable energy (ME) obtained from rodents by jungle cat *Felis chaus*, caracal *Caracal caracal* and golden jackal *Canis aureus* in Sariska Tiger Reserve, India. (See text for methods of calculation)

Species	ME (kJ)/ day	Rodent biomass (g) ingested/day	ME (kJ) obtained from rodents/day	% ME obtained from rodents/day
Jungle cat	1461–2087	189	986	47–67
Caracal	2192–3131	308	1607	51–73
Golden jackal	3207–4582	255	1460	32–45

Although the percentage frequency of rodents in scats and the total mean biomass of rodents consumed per day did not differ among predators, predictions from a daily food intake of 7–10% of body mass suggested that the felids obtained higher amounts of ME from rodent consumption, than the golden jackal (Table 5).

DISCUSSION

Mammals and birds formed the most important prey of the small carnivores in our study. This was consistent with observations made elsewhere (Schaller, 1967; Johnsingh, 1983; Stuart, 1983; McShane & Grettenberger, 1984; Palmer & Fairall, 1988; Mukherjee, 1989; Sultana & Jaeger, 1989; Weisbein & Mendelssohn, 1990; Avenant & Nel, 2002). Studies on jungle cats and golden jackal have shown rodents to occur in more than 60% of the scats analysed (Schaller, 1967, 1970; Johnsingh, 1983; McShane & Grettenberger, 1984; Sultana & Jaeger, 1989). However, comparisons based on just percentage frequencies can be misleading. Our results indicate the importance of estimating the contribution of prey species in terms of energy rather than simply biomass or percent occurrence. Although the percentage frequency in scats and biomass consumed indicated rodents were of equal importance as prey for the jungle cat, caracal and golden jackal, energy calculations revealed that the felids obtained a higher amount of ME from rodents than the jackal. Comparisons of diets, of carnivores in sympatry as well as of species across several geographical locations, would be more precise and meaningful if the energetics of the predators are taken into account. Many species of carnivores show a large variation in body size across their global range (Pocock, 1939; Sunquist & Sunquist, 2002). The average body mass of jungle cat and caracal from Africa and West Asia are two to three times that of conspecifics from India (Pocock, 1939; Dayan *et al*., 1990; Sunquist & Sunquist, 2002). Since energy demands are related to body mass, it is important to consider this when comparing diets across geographical locations.

High nocturnal activity in felids has been attributed to their specialization in catching nocturnal rodents (Ludlow & Sunquist, 1987). We found the average percent biomass of nocturnal rodents in caracal scats to be 58%, in jungle cat scats 53% and in jackal scats 44%. However, the most important rodent prey in STR, accounting for over 40% of biomass consumption of all rodents for all three carnivores, *G. ellioti*, was, in fact, diurnal. We believe that this rodent, although diurnal, was more vulnerable to nocturnal predation being a bush dweller, compared to other species that were fossorial.

Delany & Happold (1979) stated that intensive grazing by large ungulates degrades the land and makes it uninhabitable for rodents because of loss of cover and food. The livestock density in the semi-arid and arid tracts of western India is very high at 140/km^2 (census figures of 1990 and 1997, http://goidirectory.nic.in/fstateut.htm), leading to a high intensity of grazing pressure on the land. Carnivores such as felids that depend on rodents to a large extent, could be impacted by changes in rodent abundance. Some carnivores that inhabit this region, such as the caracal, occur in low numbers (Sharma & Sankhala, 1984; Sunquist & Sunquist, 2002). Little is known of the ability of these rare species to persist in human-dominated landscapes.

On the other hand, rodents are often seen as pests because of the damage they cause to crops and also because they are reservoirs of diseases. In the semi-arid and arid tracts of western India, there has been a vast expansion of land under irrigated agriculture over the decades and this has benefited some rodent species while exterminating others (Sharma & Sankhala, 1984; Prakash, 1995; Prakash *et al*., 1995). While an increase in rodent abundance would seemingly benefit rodent-eating carnivores, it must be noted that conversion to agriculture in many cases destroys cover, which is essential for hunting especially in felids. Retaining patches of bushes within agricultural fields could benefit small carnivores. Our results show that each jungle cat eats three to five rodents per day and 1095 to 1825 rodents per year, each caracal eats eight to nine rodents per day and 2920 to 3285 rodents per year, and each golden jackal eats five to six rodents per day and 1825 to 2190 rodents per year. Together, one jungle cat, one caracal and one golden jackal eat 5840 to 7300 rodents per year. Facilitating the conservation of these predators could have economic benefits, especially in areas where rodents have reached pest proportions.

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