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Original Investigation

Behavioural ecology of four-horned antelope (*Tetracerus quadricornis* de Blainville, 1816) in the tropical forests of southern India

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ABSTRACT

Four-horned antelope is one of the smallest Asian bovids, endemic to India and Nepal. Despite its wide distribution in India, the species has received very little scientific attention. We studied its habitat preference, activity budget, diet, social behaviour and breeding in Mudumalai Wildlife Sanctuary. Among tropical dry deciduous and thorn forests, where the species is distributed, higher abundance was observed in dry deciduous areas (0.26 individuals/km, 95% CI = 0.22–0.29) especially the short grass habitat associated with stunted and sparse tree growth known as 'tree-savanna' than the dry thorn forest (0.09 individuals/km, CI = 0.001–0.18). The antelopes follow a bimodal feeding pattern with 52% morning (06:00–10:00 h) and 65% evening (14:00–18:00 h) devoted to feeding. Diet was studied by analyzing 59 pellets collected from two major habitat types during the dry season. Of the 52% of the diet components identified, grass (28.6%, 14 species) and browse biomass (23.3%, 10 species; with five herbs (9.6%), one shrub (5.6%) and leaves and fruits from four trees (8.2%)) constituted equal parts indicating a mixed feeder category. Mean group size of 1.5 (±0.71 SD range: 1–4) individuals estimated from 94 direct sightings with solitary individuals (62%) and adult with fawn/s (11%) constituting over 70% of the sightings indicating a non-herding nature of the species. Newborns were sighted from February to May with a peak during April and the reported gestation period of c. 8 months suggests mating taking place during June–August. Mean litter size was 1.6 (±0.53 SD, $n = 9$). The study suggests the need for including dry thorn forest habitats of Sigur plateau in the existing protected areas and detailed studies for long-term conservation of the species in this region.

Introduction

The four-horned antelope or chowsingha (*Tetracerus quadricornis*) is a small tropical antelope endemic to India and Nepal and lives in undulating or hilly terrain (Prater, 1980; Rahmani, 2001). Unlike most other antelopes, this species, like the deer, has adapted to live in wooded forest. The species, currently listed as vulnerable (IUCN, 2010), is distributed in all Indian states south of Uttar Pradesh, except Kerala (Rice, 1990). Despite its wide distribution in India, the species has received little scientific attention. Literature review shows that the species is mentioned briefly in multi-species studies (Schaller, 1967; Krishnan, 1972; Sharatchandra and Gadgil, 1975; Karanth and Sunquist, 1992; Singh, 2001; Sharma et al., 2003) or occasional observations (Saxena, 1996). Berwick (1974) was the first study to provide information on population density, age structure and diet of the species in Gir Forest. Rice (1990) reported the status of four-horned antelope based on information collected through a questionnaire survey. Since late 2000, there have been a few targeted field based studies on its population and behavioural ecology in southern India. Baskaran and Desai (1999) assessed distribution of four-horned antelope in relation to major habitats, its time activity, feeding, breeding and social organization in Mudumalai Wildlife Sanctuary. Krishna et al. (2008) investigated habitat factors influencing the four-horned antelope occurrence in Bandipur Tiger Reserve. Baskaran et al. (2009) evaluated population distribution and conservation status of four-horned antelope in Mudumalai Wildlife Sanctuary. Similarly, in Central India, Sharma (2006) and Sharma et al. (2009) have studied its behavioural ecology in Panna National Park. More recently, there have been a few review documentations on its taxonomic nomenclature, distribution, ecology and behaviour (Leslie and Sharma, 2009; Krishna et al., 2009). Site specific published data on food and feeding, social organization, breeding and their implications are essential for conservation planning of any wildlife animals and it is more important for habitat specific species like four-horned antelope that lives in

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low density with high sensitivity to human disturbance (Baskaran and Desai 1999; Baskaran et al., 2009; Krishna et al., 2008). Nevertheless, the vital data are still lacking for most of the population ranges of four-horned antelope, and more specifically for southern Indian ranges. In general, the species is defined as data deficient by IUCN and it recommends the need for detailed studies to fill current gap in understanding the species biology and behavioural ecology. This study comprehensively documents the habitat preference, activity pattern, diet, group size, and composition and breeding habits of free-ranging four-horned antelope in the tropical forests of Mudumalai Wildlife Sanctuary, southern India.

Material and methods

Study area

The study was conducted in Mudumalai Wildlife Sanctuary (presently a Tiger Reserve), which is located in Western Ghats at the tri-junction of southern states – Tamil Nadu, Karnataka and Kerala. It lies between 11°32′ and 11°45′N and 76°20′and 76°45′E. It is bounded by Bandipur Tiger Reserve in north and by Wayanad Wildlife Sanctuary in north and west and Nilgiri North Forest Division in south and east. The terrain is undulating with an average elevation of 900–1000 m. River Moyar, its larger tributaries and some man-made water holes are perennial in nature. The study area has a long wet season and a short dry season. It receives rainfall from southwest and northeast monsoon. Based on the climate of the study area, the year can be classified into three seasons: Dry season (January–April), first wet season (May–August) and second wet season (September–December). The rainfall has a marked east-west gradient, with the eastern areas getting the least amount of rain (600–1000 mm) and the western regions the heaviest (1000–2000 mm). Temperature ranges from 8 °C in December to 35 °C in April (Baskaran, 1998). The vegetation follows a similar gradient as the rainfall with tropical dry thorn forests to the east of the sanctuary followed by tropical dry deciduous short grass and dry deciduous tall grass forests in the middle, and the tropical moist deciduous forests to the west. There are also a few patches of semi-evergreen and evergreen forests to the west (Champion and Seth, 1968). While intensive study on habitat preference, diet and social behaviour was carried out between September 1998 and February 1999, records on distribution, sightings and behavioural observations on the species were gathered over a longer period during 1990–2006, while the first author was working continuously or occasionally on various other species in the park.

Habitat preference

To understand the habitat preference of this antelope in available major habitat types, viz. tropical dry deciduous and thorn forests where it is distributed in the study area (Baskaran et al., 2009), encounter rates (the number of antelopes sighted per unit effort/km walked) were calculated using total number of individuals sighted and total distance walked during our survey period. In dry deciduous habitat, three different sites consist of: site 1 dry deciduous short grass, site 2 dry deciduous tall grass, and site 3 dry deciduous tall grass with *Shorea talura* regeneration class domination were sampled for 28, 26 and 28.3 km respectively, while in dry thorn forest 21 km was sampled with no spatial replicate due to non-availability of appropriate site with antelope distribution. Sampling was carried thrice/site in all the four sites between 06:00–09:00 h and 16:00–18:00 h, more or less with equal effort. Of the four different sites, visibility was relatively higher in dry thorn habitat occupied by antelopes followed by dry deciduous short grass, dry deciduous tall grass with *S. talura* regeneration class domination and lowest in dry deciduous tall grass due to dense growth of tall grass. To compare the habitat preference of antelope, encounter data from the three sites in dry deciduous forests that consist broadly a similar vegetation type were pooled together and compared with that of from dry thorn forest, which differs from the former one in term of plant species composition. Therefore, overall visibility is relatively higher in dry thorn than the dry deciduous patches sampled in this study. The encounter rate between dry thorn and dry deciduous, and within dry deciduous among three sites were tested using one-way ANOVA.

Activity pattern and budget

Our initial attempts to study the activity pattern of antelopes using direct observation methods did not yield sufficient data due to poor visibility, their high sensitivity and low population density. They would also run away on sighting the observer. There was only one occasion when the animal was observed over two hours (between 10:00 and 13:00 h) and during this period, feeding was the major activity (90% of the time). Another two attempts lasted about half an hour each while the animal was eating salt at an artificial salt lick. All the remaining attempts were less than few minutes, which did not represent the activity pattern. Therefore, the activity catalogue such as fodder feeding, salt feeding, moving and resting was recorded noting down the time at every sighting of the antelope during day light hours (06:00–18:00 h). The observations were pooled within 2 h intervals and then the percentage of observations of a particular activity was calculated by dividing the number of sightings of particular activity by the total number of sightings of all activities) separately for each two hour interval. Feeding on salt considered as a separate category as it took place mostly while the animal come to roadside for resting. The data was computed at two hours interval to arrive at pattern of activity in relation to different day light hour. Although sampling effort to record the direct sighting was biased to some extent during morning (06:00–11:00 h) and evening (15:00–18:00 h), due to the reason that observers' spent more time in the field during these hours, number of sightings recorded in the 2 h intervals during the morning (06:00–08:00 h) and evening (16:00–18:00 h) were less compared to other periods, because in the study area it was easier to sight antelopes when they were in resting (that takes place mostly during 08:00–14:00 h in open places like roads and foot paths) compared to other activity times. Since, the activity of antelopes changes according to daylight hours (personal observations), any bias in observation at particular hours of the day would result in over- or under-estimation of a particular activity. To standardize such bias in activity budget (time spent on various activity with daylight hours) the percentages of various activities/two hour interval was derived from observed two hour-pooled data (irrespective of season & year), and from this percentage, the mean time spent on various activities (weighted average) was calculated.

Diet composition

Pellet collection

Since direct observations to study diet and feeding habits was not possible, the indirect method of pellet analysis was adopted following Satakopan (1971). Use of fecal examination technique is limited because a large percentage of lists in any point-sampling source remain unclassified as plant parts consumed get highly degraded by the effective digestive system like deer (Korschgen, 1971). However, given the reason that in animal species where it is not possible to obtain data on direct observation on feeding or large number of stomach content for diet analysis, fecal examination technique could supplement these methods with advantage of unlimited sampling to obtain baseline information on food and

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feeding. Therefore, the method has been widely used as a reliable taxonomic basis for determining the botanical composition of herbivores diets both in tropical (India: Satakopan, 1971 for herbivores including the four-horned antelope, Srivastava et al., 1996; Easa, 1997; Ashokkumar, 2011 and Nepal: Chetri, 2006) and in temperate regions (North America: Spark and Malechek, 1968; Zyznar and Urness 1969; Holechek, 1982; Stevens et al., 1987).

The four-horned antelope defecate regularly at specific sites within their ranges (defecation/lavatory site, Baskaran and Desai, 1999; Baskaran et al. 2009), which are easily identifiable, as they are found in heaps at open places, with fresh pellets at the middle of the heap. Of the two major habitats where antelopes were found, representative sites––four from dry deciduous (two in short grass, and one each in tall grass & tall grass with *S. talura* domination) and two from dry thorn habitats – far apart from each other, were selected for periodic pellet sampling. Fresh pellets belonging to the same defecation, less than two-days old, identified based on texture and moisture content, were collected in polythene bags and labeled with location, date and status of the sample. These samples were air-dried on drier sheets for over three–four days to remove moisture and prevent fungal growth. During January–February 1999, a total of 59 pellet samples were collected from six lavatory sites (five samples per site per month) and analyzed for diet composition.

Plant sample reference slides

Plant parts (leaves, twigs and fruits) from 32 species that are suspected to form the diet of the four-horned antelope were collected from the same areas where the antelopes were sighted. Each sample was identified and processed for the preparation of reference slides. A few bits of twigs, leaves and fruits were taken from each plant sample, shredded coarsely and placed in a test tube. Two–three ml of chloral hydrate aqueous solution (50 g in 20 ml) was added to the test tube. The tube was then heated in a water bath (water at boiling point) for a minute or two. Highly coloured material needed second boiling with a fresh quantity of chloral hydrate. After cooling, the liquid was drained off and washed repeatedly in distilled water. It was then dehydrated in alcohol passed through grades of alcohol and xylol mixtures with the latter in increasing proportion in successive mixtures (3:1, 1:1, 1:3) and finally in pure xylol. Mounting was done in Canada balsam keeping the slides over a warming plate. In total, 32 reference slides (one slide per species) were prepared (22 grass species, five herb species, one shrub species and 4 tree species (leaves and fruits)

Pellet analysis

A starting sample of whole pellets was put in a tray, shaken and tossed several times before spreading on the tray; it was first halved and quartered. Opposite quarters were combined and the combined one was retained and the other discarded. This process was continued until there were only 3–4 pellets in each quarter. The opposite quarters were combined and again halved to get three pellets in each half. In this, one was discarded and other was treated as final starting sample. This sample was put in a mortar and ground loosely so that pellets were broken up into discrete particles in a coarse powder form. The grinding should not fractionate the particles but merely separate the agglomerates into single particles, large or small, as they may be. Three sieves (ASTM No. 30, 40, 50 approx.) were placed one above the other and the powder sieved. The portion on the top sieve was discarded, and the fractions of the middle and bottoms sieves, as well as that in the tails (portion that has passed through the bottom most sieves) were stirred up and a little portion from each of the three was taken. These were mixed thoroughly and halved, one half was the 'final sample' and the other was half served as reserve in case the final sample was lost in the subsequent processing. The final sample was boiled for a few minutes in 2–3 ml of chloral hydrate solution over a water bath of boiling water. If the chloral hydrate was too dark or blackish, the powder was allowed to settle; supernatant poured off and fresh quantity of chloral hydrate was added and the boiling repeated. Whenever necessary, the sample was boiled the third time. When the powder appeared to the eye as fairly clarified, the cooking was considered sufficient. It was then allowed to cool, after which distilled water was added to the sample, shaken thoroughly, and allowed to settle. The supernatant was poured off and the washing was repeated until all the chloral hydrate was washed off. A dehydration process with alcohol followed the washing and was repeated two or three times to remove all water. Thereafter, the alcohol–xylol treatment employed for the preparation of plant reference slides was followed and the final mounts were made in Canada balsam. The slides were examined using binocular microscope. The structure of plant remains (trichomes, epidermal cells, cuticles and stone cells) from the 59 pellets appeared under microscopic examination were hand-sketched and identified comparing them with the plant tissue particles of reference slides

Estimation of diet preference

For estimating the relative use of the food plants identified from the microscopic analyses of pellets, five slides of each pellet group from 59 pellets analyzed were randomly chosen. Ten random focuses were made on each slide under a microscope. In each focus, percent occurrence of a particular plant part was visually estimated and latter arrived at percent (mean) occurrence of various food items in each habitat following Satakopan (1971). Since the percent occurrence of various plant species did not vary statistically among the four different habitats (Kruskal–Wallis Test $\chi^2 = 0.0557$, $df = 3$, $p = 0.996$), the average of all such 2950 focuses from 59 pellets was taken to estimate the food preferences of the antelopes.

Social behaviour and breeding

Data on social behaviour such as group size, composition and association among group members were recorded at every sighting of the antelope. Owing to poor visibility and high sensitivity, sex differentiation was not possible on many occasions; only the age structure of the individuals were categorized into three age classes – adults (>45 cm), yearling (sub-adults 30–45 cm) and fawns (<30 cm) (Acharjyo and Misra, 1975, 1981; Prater, 1980). However, we considered the adults sighted with fawn(s) as adult females, since young ones usually accompany mothers. To assess breeding (mating and fawning) seasons, association between males and females and the occurrence of newborn fawn during the study period were recorded. In total 94 sightings recorded during the study period that spread across all the months (7.8 ± 2.25 (SD) sightings/month) but marginally with less sightings during dry season ($n = 41$) than during wet ($n = 53$) seasons, although time spent was more during the former season than the later due to climate conditions.

Results and discussion

Habitat preference

Among the two major habitats where antelope distribution was found, encounter rate or relative abundance was significantly more in dry deciduous forest (0.26 individual/km, 95% Confidence Interval 'CI' = 0.22–0.29; 21 individuals/82.3 km) compared to dry thorn forest (0.09 individual/km, CI 0.001–0.18; 2 antelope/21 km) (one-way ANOVA: $f = 10.776$, $df = 1$, $p = 0.03$) (Fig. 1). Within the dry deciduous forest, habitat composed of short grass and more open canopy with sparse and stunted trees growth referred as tree-savannah (Pascal et al., 1982) and less weed cover was preferred by antelopes (0.29 individuals/km (CI = 0.22–0.35);

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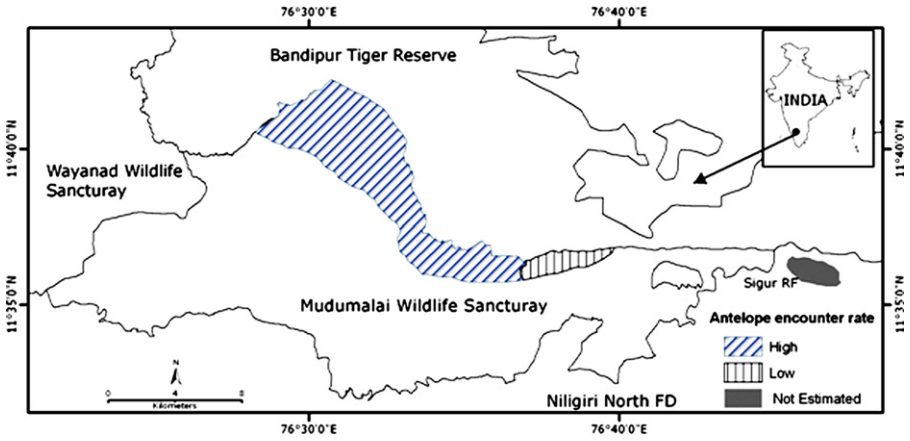

Fig. 1. Map of study area showing four-horned antelope distriution within Mudumalai Wildlife Sanctuary and areas outside the protected area network.

8 antelopes in 28 km) than dry deciduous habitat with tall grass (0.27 individuals/km (CI = 0.20–0.33); 7 antelopes in 26 km) and dry deciduous tall grass with *S. talura* domination (0.21 individuals/km (CI = 0.12–0.29); 6 antelopes 28.3 km), but statistically insignificant (one-way ANOVA: $f = 1.303$, $df = 2$, $p = 0.3$). Though dry thorn forest site with short grass and more open canopy appears more suitable habitat, antelopes were still found in low abundance. The dry thorn forest habitat is strongly affected by anthropogenic pressure from neighbouring villages (Desai and Baskaran, 1996) and this could potentially be the reason for the lower preference or abundance of species. Therefore, the availability of short grass habitat, with sparse and stunted tree growth and open canopy areas without biotic pressure and weed abundance are possible factors that support a higher abundance of antelope as documented elsewhere (Baskaran and Desai, 1999; Krishna et al., 2008).

Activity pattern and budget

In total, the activity of the antelope was recorded on 90 occasions. Overall, feeding (on fodder 50% and salt 6% together) accounted for the highest occasions of sightings (56%), followed by moving (28%), resting (15%) and drinking (1%). Feeding was the major activity during morning (06:00–10:00 h) and evening (14:00–18:00 h) (Fig. 2). However, it is interesting to note that feeding on artificial salt was more frequent during midday hours, when the animals visit the roadside for resting. Resting was more during midday (35%) (10:00–14:00 h), and were observed mostly in open areas along roadsides. Their movement was observed throughout the day (Fig. 2) but it was more frequent during morning and evening hours (>30%). Given the poor visibility and high sensitivity of the species, total number of observations obtained (overall = 90 sightings) as well during 06:00–08:00 h and 14:00–18:00 h were less. Therefore, the activity budget (total time spent) estimated may not reflect the actual time spent on various activities. Nevertheless, the time activity pattern observed *i.e.* the antelopes being more active with a bimodal feeding during morning, and evening and rest during the midday like any other herbivores in the study area (Baskaran et al. 2009) reveal the usefulness of these findings. Our findings are different from Sharma (2006), who showed no pattern in the activity budget of antelopes.

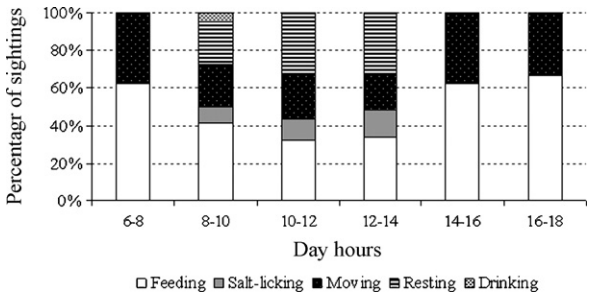

Fig. 2. Time activity pattern of antelope observed in direct sightings during daylight hours ($n = 90$).

Diet composition

In total, we have identified 24 plant species (Table 1) through histological study of the pellet samples ($n = 59$). The plant species include 14 grasses, five herbs, four trees and one shrub. The food species represent predominantly a dry season diet, as all the pellet groups were collected during January and February. Of the 24 food plant species, 12 were identified based on their specific unicellular trichomes, three by their multi-cellular trichomes, three with their stomatal structure, four using their cuticle pattern and one by stone cells. The 12 species identified based on their unicellular trichome include seven grass species (*Cypnaceae* (family), *Echinochola* sp., *Panicum* sp., *Pseudanthistria umbellata*, *Sehima* sp., *Ottoebola nodosa* and *Digitaria* sp.), three herbs (*Indigofera* sp., *Leucas aspera* and *Tinospira* sp.), one shrub (*Grewia hirsuta*) and one tree (*Zizyphus xylopyrus*). The three species that were identified using their multicellular trichomes were: one each of grass (*Imperata cylindrica*), a herb (*Tinospira* sp), and a tree (*Cordia wallachi*). *Themida cymbaria*, *P. umbellata* and *Axonopus* sp. are the three species of grass identified using their stomatal structures. Four species – *Cynodon* sp., and *Sporobolus* sp. (grass), *Helichrysm* sp. (herb) and *Randia dumetorum* (tree) – were identified with their unique cuticle structure. One species (*Emblica officianalis*) was identified with its unique stone cell structure. *Eulalia tripsicata* (grass species) and *Sida acuta* (herb species) were identified based on the structure of some unidentified cells. The characteristic features of uni- and multi-cellular trichomes, stomatal, cuticle and stone cell structures are given Annex I.

The percent composition of various food plants as inferred from the microscopic analyses of the 59 pellet samples is given in Table 1. In the 24 species of food plant identified, *G. hirsuta* (a shrub) was the most frequently used food plant, which contributed nearly 5.6% (95% CI = 5.31–5.81%) to the overall diet. In this species, both leaves and fruits were eaten with the latter being eaten more frequently. Other important food plants include grasses such as *Panicum* sp., *T. triandra*, and *T. cymbaria*, herb *Tinospira* sp. and tree species *C. wallachi* and *E. offcianalis*. The remaining 17 food species were eaten occasionally. In general, grasses constituted major part of the diet contributing to 28.6%, followed by shrub (5.6%), trees (8.2%) and

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Table 1
Percent composition of various plant species identified from the pellets of four-horned antelopes ($n = 59$).

Family	Food plants	In diet (%)	95% Confidence interval	
			Lower (%)	Upper (%)
Grass				
Poaceae	*Axonopus* sp.	0.22	−0.15	0.60
	Cynodon sp.	3.96	3.56	4.32
	Digitaria sp.	0.03	−0.02	0.07
	Eulalia trispicata	3.30	1.89	4.70
	Echinochloa sp.	1.79	0.85	2.74
	Imperata sp.	0.57	0.15	0.99
	Ottoebola nodosa	0.90	0.46	1.33
	Panicum sp.	5.01	4.44	5.59
	Pseudanthistria umbellata	2.43	0.78	4.08
	Setaria sp.	2.83	2.21	3.44
	Sporobolus sp.	0.09	−0.002	0.17
	Themeda cymbaria	2.86	0.85	4.88
	Themeda triandra	3.93	2.19	5.67
Cyperaceae	*Cyperaceae* family	0.68	0.34	1.02
Herbs				
Asteraceae	*Helichrysum* sp.	1.91	1.40	2.42
Fabaceae	*Indigofera* sp.	0.39	− 0.11	0.89
Lamiaceae	*Leucas aspera*	0.06	0.001	0.12
Malvaceae	*Sida acuta*	2.16	1.00	3.32
Menispermaceae	*Tinospora* sp.	5.09	2.85	7.32
Shrub				
Malvaceae	*Grewia hirsuta* (leaves and fruits)	5.56	5.31	5.81
Tree				
Rubiaceae	*Randia dumetorum*	0.21	0.004	0.41
Moraginaceae	*Cordia wallichii*	4.57	2.76	6.37
Rhamnaceae	*Ziziphus xylopyrus*	1.40	0.79	2.00
Phyllanthaceae	*Phylanthus emblica* (fruits)	2.00	0.88	3.11
	Unidentified plant remains	48.07	44.71	51.43

herbs (6.7%). It should be noted that only 52% of the plant remains from the pellet were identified and the rest (48%) were unidentified either due to over digestion of cells or due to lack of reference slides.

The study shows that grass and browse constitute equal proportion of the diet. During dry season, the grass species in the tropical forests become too coarse (Baskaran, 1998) and less nutritive compared to wet season (Sukumar, 1989). Since the pellet samples analyzed were from dry season, grass species are likely to have contributed lower quantity to the dry season than the wet season diet of antelope. Feeding observations on free ranging (Berwick, 1974) and tamed antelopes (Solanki and Naik 1998; Sharma, 2006) report browse domination in the diet, mostly during dry season from central and western India. The browse domination could be the effect of dry season as reported earlier. Nilgai (*Boselaphus tragocamelus*), the largest Indian antelope, and Chinkara (*Gazella gazelle*) are hyperbrowser (Bagchi et al., 2003), while the blackbuck (*Antilope cervicapra*) is a hypergrazer (Jhala, 1998). Studies on dietary preference of African antelopes show mixed feeding to grazing dominated diet (see Gagnon and Chew 2000). The 59 pellets represent early dry season (January–February) and the fact that 48% of the plant parts from across pellets (range 26–60% per pellet) were unidentified makes it is inappropriate to use the results as entire range of four-horned antelope diet. Rather, it would be more reasonable to recognize that this antelope is dependent on both browse and grass, and appears to adapt its feeding according to availability. The large percent of unidentified food parts in the pellets could be the degradation of plant particles due to high degree of mastication and efficient digestive system of the ungulates. Plant parts consumed will be highly degraded by the effective digestive system of deer (Korschgen, 1971) and thus the use of fecal examination technique is limited since a large percentage of lists in any point-sampling source will remain unclassified. In addition, our limited reference specimens (36 species) may also have contributed to the higher proportion of unidentified food material. A detailed feeding study through pellet analysis with samples (pellet and reference specimens) from various micro and macro habitats and seasons would improve our understanding of the feeding of the species.

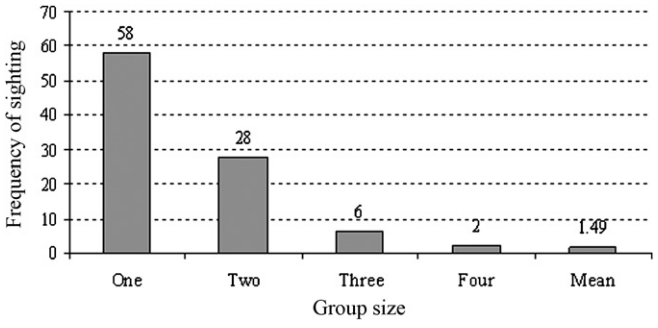

Fig. 3. Group sizes of four-horned antelopes recorded during direct sightings ($n = 94$).

Social behaviour

Group size

Data on group size was recorded on 94 occasions during the study period. The data showed that group size ranged from one to four individuals with a mean of 1.49 ± 0.715 (SD) individuals. Of the 94 records, single individuals were sighted on 62% ($n = 58$) and two on 30% ($n = 28$) of the occasions. Group sizes of three (6%, $n = 6$) and four (2%, $n = 2$) individuals were sighted infrequently (Fig. 3). In all the 36 sightings in which the group size was more than one,

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Table 2
Group composition recorded during sightings of four-horned antelopes ($n = 88$).

Group size	Composition	Frequency	Percentage frequency (100% for each group size)
One	Adult	41	89.13
	Sub-adult	4	8.70
	Fawn	1	2.17
Two	Adult and sub-adult	12	52.17
	Adult and fawn	10	43.48
	Two fawns	1	4.35
Three	Two adults and one fawn	1	16.67
	One adult and two fawn	5	83.33
Four	One adult, one sub-adult and two fawns	2	100

the group was composed of an adult with a sub-adult, or an adult with one or two fawns, or an adult with two fawns and a sub-adult. The highest occurrence of single individual sightings (62%) and the rest either of adult with fawns or sub-adult suggests that the four-horned antelope is a solitary animal and does not live in social groups. Similar to the present findings, Sharma et al. (2005) reported various group sizes of antelopes from Panna National Park, India; in Gir National Park, India, maximum group size recorded was four individual but averaged 1.5–1.6 (Berwick, 1974) and comparatively Khan et al. (1996) reported smaller mean group sizes of ≤1.2. Karanth and Sunquist (1992) observed a maximum group size of two in Nagarahole National Park, South India, but 80% of their sightings were of single individuals.

Group composition

Out of the 94 direct sightings of antelopes, data on group composition was recorded on 77 sightings (Table 2). Of the 52 sightings of single individual, 41 out of 46, where age classification could be done, were of adults, four were sub-adults and one was a fawn. Group size two recorded on 28 occasions consisted equally of adult with a sub-adult (12 occasions, likely the mothers with grown-up young ones) and adult with one fawn (10 occasions). There was one sighting in which only a pair of fawns was sighted. Of the six sightings of group size of three, five sightings were of an adult (probably female) with two fawns and one sighting of two adults (one female and a male) and a fawn. Group size four was recorded on two occasions and in both, an adult, a sub-adult and two fawns were sighted together. The sub-adult sighted in this group of four could be the offspring of the female belonging to the previous breeding season.

Very rare sighting of two adults together (1 out of 77) indicates that male and female live separately and come together only during the breeding season. Young ones appeared to live with their mothers for a year after which, probably, when the females produce the next young, the earlier young ones may disperse. There was one sighting of two individuals consisting of an adult (appeared to be in advanced pregnancy) with a sub-adult, indicating that young stay with the mother at least until next fawning. This is also supported by two sightings of an adult with two fawns and a sub-adult (the adult female is most likely their mother). These findings are in accordance with Sharma (2006).

Breeding behaviour

Breeding season

Some information is available on the breeding of this antelope in captivity. Shull (1958) recorded mating during the month of July; Prater (1980) states that mating takes place during rainy season. During our study period, there was a sighting of an adult male and an adult female together during the month of May 1998. Although we have not recorded mating on this occasion, considering the fawning period (February–April) recorded in the present study and a gestation period of eight to eight and half months (Prater, 1980), mating appears to take place between June and August in this area. These observations coincide with increased adult male–female association and coupulatory bouts observed during May–July in Panna National Park, India (Sharma et al., 2005). Overall twenty sightings of newborn fawns with adults, adults and sub-adults and independently (alone or in twin) (Table 2) were sighted from February until May with a peak in April. These observations indicate that fawning starts in February and continues until May; most females give birth during March and April. Shull (1958) reported that a female had given birth to a single fawn in the month of March. Asdell (1964) observed three births in February and others in May and June in London Zoo. Acharjyo and Misra (1975) recorded three births in January, two in March and one in April in Nandankanan Biological Park, Orissa. The present observation of fawning period in the wild from February to May with a peak in April is well within the period reported earlier.

Litter size

In total, nine different females were observed with newborn fawns. Of these nine, four were observed with one fawn and remaining five with two fawns. Therefore, 14 new fawns were recorded with nine females giving a mean litter size of 1.6 (SD = 0.527). Under captive conditions, Asdell (1964) recorded three twins out of five births (1.6/litter) in London Zoo and Acharjyo and Misra (1975) in Nandankanan Biological Park, Orissa, reported 1.8 fawns/litter from six birth records of eleven young. The litter size (1.6) estimated in the present study under wild is comparable to that reported in captivity (Asdell, 1964; Acharjyo and Misra, 1975). It is possible that offspring die at birth or at earlier stage may go unnoticed in the wild condition and this could result in marginal underestimation of litter size by studies on natural population compared to those in captive condition. Considering this, it is reasonable to assume that the litter size estimated is the minimum for the wild population; it could possibly be higher. The fawns were seen resting alone (without the female nearby) on two occasions. It appears that four-horned antelopes hide their young ones while on their routines.

Recommendations

The population of four-horned antelope is low in Mudumalai Sanctuary and is also likely to be low in Bandipur Tiger Reserve and Nagarahole National Park. In this part of its range most of its distribution lies outside the protected area network (Sigur Plateau) (Fig. 1) and their naturally (relative to some other species) low population densities require that large areas be protected to ensure a viable population for long-term conservation. Therefore, the present study points to the need for including dry thorn forest habitats in the existing protected areas. They not only harbour the four-horned antelope but also many other near threatened species like the Striped Hyaena (*Hyaena hyaena*). Detailed studies on population distribution, food feeding and genetic effect of

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isolated population are essential for long-term conservation of the species in this region.

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Appendix 1. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.mambio.2011.06.010.

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