Activity and social behaviour of four-horned antelope (Tetracerus quadricornis de Blainville, 1816) in tropical deciduous forests of Aravalli mountain range, Western India

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Activity and social behaviour of four-horned antelope (*Tetracerus quadricornis* de Blainville, 1816) in tropical deciduous forests of Aravalli mountain range, Western India

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Abstract. The four-horned antelope (*Tetracerus quadricornis*) is a vulnerable, solitary endemic and smallest Asian herbivore bovid. Its activity and social behaviour were observed in the three wildlife sanctuaries of western India, by opportunistic focal animal sampling method from April 2014 to May 2016. The results show two peaks in animal activity; first in morning hours and second in evening hours mostly devoted to feeding (28.12 %) and walking (22.35 %). The species was observed to be mostly solitary (67.06 %) and the mean group size was 2.5 (± 1.29 SD). The mean flight initiation distance was 62.53 (± 23.47 SD) m, which was insignificantly related to freezing duration ($r^2 = 0.188$, Y-intercept = 46.33 ± 8.49, $P = 0.08$). Localized defecation of *T. quadricornis* was found along with three mammals, while direct observations showed its association with six other mammals. The species also gleaned four plant parts of 13 tree species dropped by langurs.

Key words: bovid, solitary, flight initiation distance, mammals, Rajasthan

Introduction

Animals must divide their time between various activities among which there is a fundamental distinction (Rowcliffe et al. 2014). The sequential and organized activities are expected to be oriented to maximize the fitness of individuals. Similarly, activity budget reflects a balance between the costs and benefits of energy expenditure. Activity often involves elevated exposure to predation risk (Stankowich 2008) and is controlled by intrinsic factors such as age, sex, reproductive status and social rank (Corp et al. 1997, Ramesh et al. 2015), as well as extrinsic factors such as seasons (Koli & Bhatnagar 2016), day time, habitat, food availability, food quality and social organization (Mendiratta et al. 2009, Mekonen et al. 2010, Baskaran et al. 2011, Challender et al. 2012, Kuo & Lee 2012, Lillywhite & Brischoux 2012, Giné et al. 2015).

Species gain benefits in multiple ways by participating in association with other species. For example, risk to an individual from predators decreases when the individual responds to alarm calls of at least one other species in association (Majolo & Ventura 2004, Stankowich 2008). In other cases, an individual's ability to locate food increases as the discarded food of one species can be available to another species (Stensland et al. 2003, Majolo & Ventura 2004). Feeding associations have been frequently reported among vertebrates as well as in many species of deer (Majolo & Ventura 2004). For example, sika deer improve their foraging efficiency by gleaning in association with Japanese macaques (Majolo & Ventura 2004, Tsuji et al. 2007) and the similar association is also reported between langurs and spotted deer (Newton 1989). Localized defecation is another common practice in mammals, usually used for scent marking (Brashares & Arcese 1999), antiparasite strategy (Ezenwa 2004), maintenance of dominance hierarchies, demarcation of home range (Wronski & Plath 2010), territorial occupancy (Blank et al. 2015), territory maintenance (Brashares & Arcese 1999), advertisement (Attum et al. 2006) and olfactory communication (Wronski et al. 2006), which are also directly related to reproductive success of the species.

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The four-horned antelope (*Tetracerus quadricornis* de Blainville, 1816) or *chowsingha* is the smallest solitary Asian herbivore bovid (adult weight 17-22 kg, stands 55-64 cm at the shoulder) endemic to peninsular India and Nepal (Leslie & Sharma 2009); lives in undulating and hilly terrain (Prater 1980, Baskaran et al. 2011). At the landscape level, it uses tropical dry deciduous forest habitats, but the distribution is patchy (Krishna et al. 2009, Sharma et al. 2013, Pokharel et al. 2016). As an elusive, cryptic and shy species, it is extremely difficult to observe directly in wild throughout its range. Four horns in male distinguish sexes at maturity (Leslie & Sharma 2009). Several ecological variables, i.e. water availability, slope, temperature seasonality, tree species richness (Sharma et al. 2013, Pokharel et al. 2016), precipitation, elevation, and anthropogenic disturbance (Pokharel et al. 2016) are predicted to govern its spatial distribution in tropical dry deciduous forests. The spreading of an alien weed *Lantana camara* is found negatively related to its occurrence (Krishna et al. 2008). Direct field observation and cafeteria experiments showed that *T. quadricornis* diet includes fruits, flowers, grasses, and climbers (Sharma et al. 2009, Kunwar et al. 2016). *T. quadricornis* is listed as vulnerable by the IUCN (Mallon 2008) due to low population, decreasing population trend, and habitat destruction mainly through habitat clearance for agriculture. It is also included in Schedule I of Indian Wildlife (Protection) Act 1972 (amended 2006) that provides absolute protection. Beside this, IUCN also defined it as data deficient and recommends more detail scientific studies on its ecology and ethology.

Effective conservation relies on the detailed knowledge of species' ecological requirements and

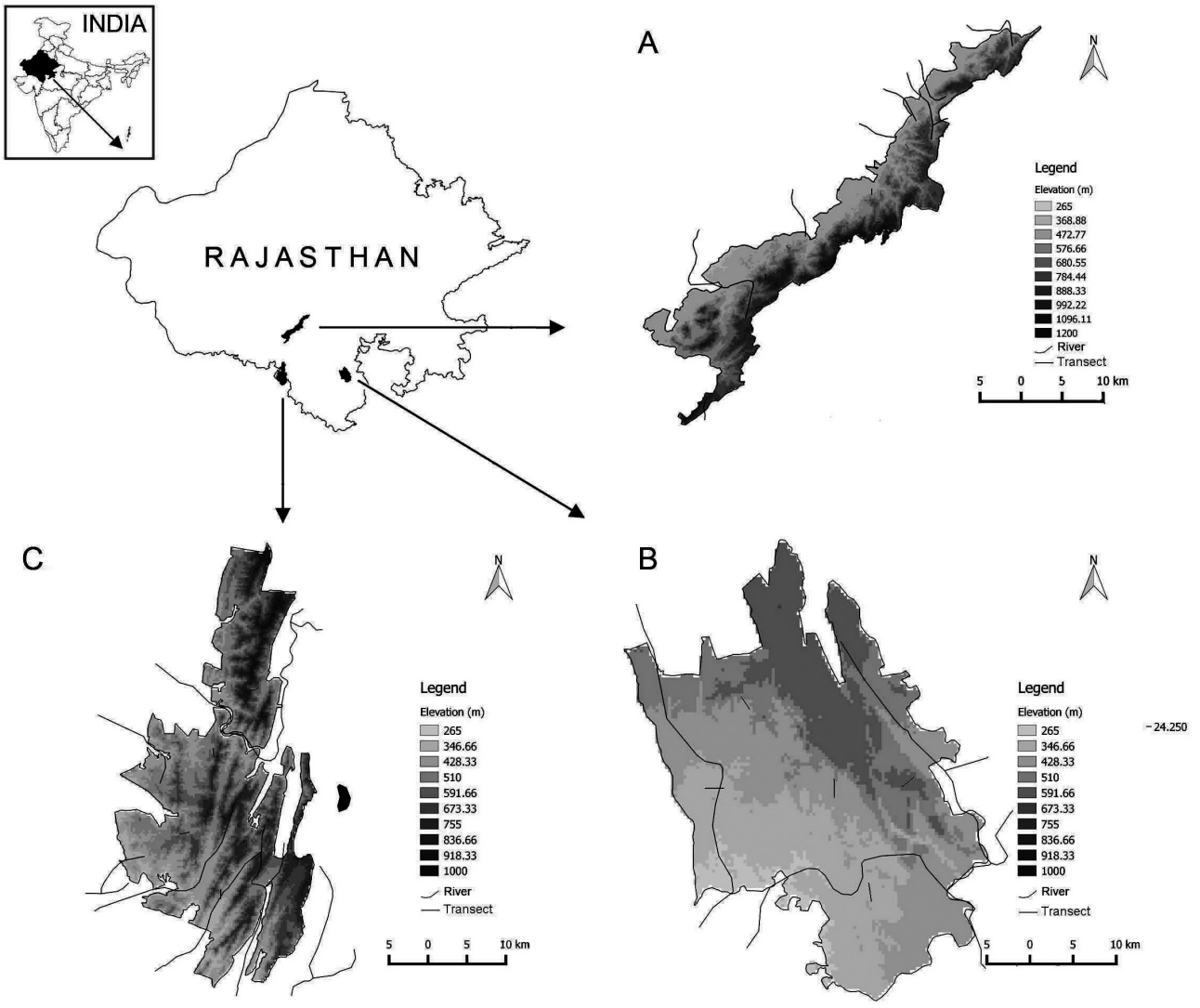

Fig. 1. Location of three wildlife sanctuaries (WLS) as a study area; Kumbhalgarh WLS (A), Sitamata WLS (B) and Phulwari-ki-nal WLS (C) in southern Rajasthan.

behavioural studies that can also help to improve knowledge on species' habitat ecology. Knowledge of activity patterns and its budget is a key metric for understanding the fundamental behavioural trade-off (Rowcliffe et al. 2014) and provides insight into how an animal adapts to the environment through behavioural modification (Pokharel 2015). Since limited information is available on the threatened *T. quadricornis*, therefore, in this paper, we are describing the activity and social behaviour of this species on the basis of two years' observation with the possible explanations in the tropical deciduous forests of western India.

Study Area

The study was conducted in three wildlife sanctuaries i.e. Sitamata Wildlife Sanctuary (WLS), Kumbhalgarh WLS and Phulwari-ki-nal WLS, located in the world's oldest Aravalli mountain ranges in south Rajasthan (Fig. 1) from April 2014 to May 2016. Forests of this area are mainly tropical dry deciduous type (Champion & Seth 1968). The climate of the study area is characterized by three seasons: summer (March-June), monsoon (July-October), and winter (November-February). The maximum daily temperature varies from 46 °C in May to 25 °C in January, and the minimum night temperature ranges from 26 °C in July to 5 °C in January. The major mammalian fauna includes, leopard (*Panthera pardus*), striped hyena (*Hyaena hyaena*), Indian wolf (*Canis lupus pallipes*), jackal (*Canis aureus*), southern plains gray langur (*Semnopithecus dussumieri*), chinkara (*Gazella gazella*), jungle cat (*Felis chaus*), Indian fox (*Vulpes begalensis*), sambar (*Rusa unicolor*), blue bull (*Boselaphus tragocamelus*) and sloth bear (*Melursus ursinus*) (Sharma 2007, FES 2010a, b, Koli & Bhatnagar 2011, Meghwal et al. 2014).

Material and Methods

Field observations

Since no animal was radio-tagged and, owing to elusive in escape tactics, small size and shy nature of *T. quadricornis*, opportunistic focal animal sampling method (Altmann 1974) at one-minute interval was used to study its activity in wild from April 2014 to May 2016. First, thorough surveys were done in the study area on foot or on the motorcycle to identify areas having a high probability of *T. quadricornis* occurrence. Thereafter, five transects of 1 km were laid in each sanctuary for further observations. The total length of transect lines was 15 km. Each transect was walked 12 times (once in a month and four times in a season) in the morning (06:00-10:00 h.), mid-day (10:00-14:00 h.) and evening (15:00-18:00 h.), totaling 180 surveys of 15 transects. Morning and evening hours are preferred in most of line transects surveys, but mid-day sampling was also chosen in this study to observe the complete activity of *T. quadricornis* in day light hours as per Carbyn (1975) and Baskaran et al. (2011). These transects were surveyed intensely on foot at a speed of 1 km/h to locate active animals (i.e. those not bedded) during each season. The frequency of encounter and duration of observation was recorded as an additional variable indicating whether *T. quadricornis* were visibly disturbed or undisturbed due to our presence. All opportunistic sightings were considered as independent observations as per Sharma et al. (2009). Once located, individuals were observed without disturbing the animal as long as our presence was tolerated by it. Whenever the animal was disturbed, it moved back or sprinted into the thickets in our presence, the flight initiation distance (FID) and freezing duration was recorded by a laser range finder (Bushnell Model #202645) and stopwatch to analyze tolerance limit of the species.

Activity of the *T. quadricornis* was classified into eight categories (Pokharel 2015): feeding (including picking food from the forest floor, nibbling and intake), walking (antelope moving from one site to another in search of food), resting (animal was seen sitting with cud-chewing), threat response (when animal displayed an alert position, sprinted away into the thickets or took evasive action on seeing predator/hearing any significant sound), water intake (water drinking by animal), salt licking (when the animal was seen to be licking the rocks), and others (those behaviours that were not recorded for significant duration in the study and accounted only a few instances).

The *T. quadricornis* lives solitarily or in small groups (Leslie & Sharma 2009, Baskaran et al. 2011). During the survey, total individuals in a group were recorded at the spot to estimate group size of the species in the study area. Antelope were considered the member of the same group if they exhibited some form of cohesive behaviour (e.g. moving together, escaping together) (Lagory 1986). Due to poor visibility and high sensitivity, sex identification was not possible during every encounter but noted whenever possible. Following Leslie & Sharma (2009) and Baskaran et al. (2011), the age structure of individuals was categorized broadly into two categories: adult (> 45 cm) and fawn (< 30 cm). Male and female were distinguished by the presence of horns.

Table 1. Total time (minutes)/hours spent in observing four-horned antelope *Tetracerus quadricornis* activities in each study area.

Time slot	Sitamata WLS	Kumbhalgarh WLS	Phulwari-ki-nal WLS
06:00-07:00	13	18	6
07:00-08:00	8	33	7
08:00-09:00	10	12	1
09:00-10:00	7	20	7
10:00-11:00	15	21	17
11:00-12:00	11	28	8
12:00-13:00	10	22	6
13:00-14:00	18	20	7
14:00-15:00	12	18	3
15:00-16:00	9	22	11
16:00-17:00	10	9	8
17:00-18:00	10	8	11
Total	142	231	92

The *T. quadricornis* have a common tendency to defecate on and along with middens of other mammals (Sharma et al. 2009), therefore, localized defecation was recorded to identify the species engaged in association and its possible functions. Pellets were identified on the basis of some diagnostic differences in shape, size, colour, and weight (Prater 1980). Besides midden sharing, habitat sharing and association of *T. quadricornis* with other mammals was also undertaken. The literature suggests that encounter of ungulates with other mammals does not chance encounter (Newton 1989, Desbiez et al. 2010). Therefore, whenever *T. quadricornis* was encountered, other mammal species present within 50 m diameter area of the species were also noted. Gleaned plant parts by *T. quadricornis*, those dropped by *S. dussumieri*, were also recorded along with tree species. Interactions between these species were also observed.

Data analysis

Activities of *T. quadricornis* were broadly categorized into active and passive. The active period of the animal was defined when the animal was not resting. Activity was calculated by pooling data at one-hour interval between 06:00-18:00 h. The active period was divided into three sessions for the precise description of the activity: first four hours (06:00-10:00 h.) as the morning, second four hours (10:00-14:00 h.) as mid-day and remaining four hours (12:00-18:00 h.) as evening. Data were pooled for daily activity pattern and evaluated by calculating the amount of time allocating to each behavioural activity as a percentage of total time for all recorded activities. Activity budget devoted to each activity type was expressed as a percentage of total activity time.

Disturbed activities due to our presence were excluded from the study data to evaluate activity pattern. The normality of the data was tested with the Shapiro-Wilk test. Multiple-group comparisons with non-normally distributed data were analyzed with the Kruskal-Wallis ANOVA to examine the difference between the study sites, i.e. sanctuaries, while multiple comparisons were performed by Bonferroni's method. Linear regression was applied to test the null hypothesis that flight initiation distance (FID) is not related to freezing duration of the animals. The results

Table 2. Mean (± SD) percentage of different activities (total observation minutes) of four-horned antelope *Tetracerus quadricornis* in day light hours of the tropical deciduous forest, western India.

Time slot	Feeding (138 min)	Walking (113 min)	Resting (82 min)	Threat response (64 min)	Water intake (55 min)	Salt licking (8 min)	Others (5 min)
06:00-07:00	60.40 ± 5.49	35.25 ± 0.65	-	4.34 ± 6.14	-	-	-
07:00-08:00	73.62 ± 0.40	24.20 ± 3.48	-	2.17 ± 3.07	-	-	-
08:00-09:00	45.00 ± 7.07	32.50 ± 10.61	-	22.50 ± 3.56	-	-	-
09:00-10:00	40.63 ± 4.41	53.13 ± 13.26	-	6.25 ± 8.83	-	-	-
10:00-11:00	8.49 ± 3.69	19.93 ± 3.23	31.70 ± 13.40	12.83 ± 1.50	25.65 ± 3.00	1.38 ± 1.96	-
11:00-12:00	1.56 ± 2.21	24.48 ± 12.52	28.96 ± 3.24	11.15 ± 6.33	29.17 ± 5.89	4.68 ± 6.62	-
12:00-13:00	6.09 ± 3.17	16.03 ± 0.90	50.32 ± 11.33	15.71 ± 10.43	11.86 ± 4.98	-	-
13:00-14:00	14.86 ± 2.56	10.69 ± 3.33	38.22 ± 4.86	10.69 ± 3.33	25.54 ± 0.76	-	-
14:00-15:00	4.34 ± 6.14	16.52 ± 4.91	41.74 ± 2.46	16.52 ± 4.91	9.34 ± 0.92	11.52 ± 2.15	-
15:00-16:00	9.54 ± 0.64	26.36 ± 5.14	19.55 ± 14.78	6.81 ± 9.64	23.64 ± 5.14	-	14.09 ± 5.78
16:00-17:00	33.89 ± 8.64	10.56 ± 0.78	10.56 ± 0.78	31.67 ± 2.35	13.33 ± 4.71	-	-
17:00-18:00	68.63 ± 2.77	14.22 ± 3.46	-	17.16 ± 0.69	-	-	-

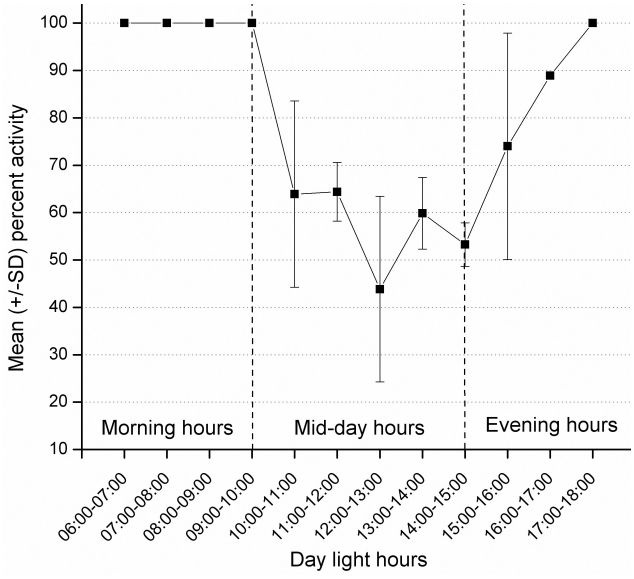

Fig. 2. Daily activity pattern of four-horned antelope *T. quadricornis* in tropical deciduous forest, western India. A total of 122 animals were observed for 465 minutes during 86 sightings. Lowest activity was found between 12:00-13:00 h.

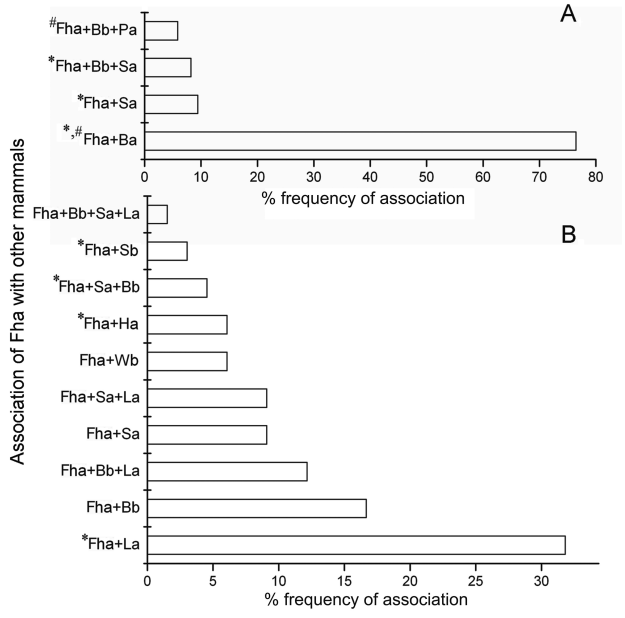

Fig. 3. Percent frequency of association of four-horned antelope *T. quadricornis* with other mammals observed by localized defecation (A) and by direct observation (B) in tropical deciduous forest, western India. Localized defecation was observed 85 times (maximum = 65 with Bb and minimum 5 with Bb + Pa), while direct observation was taken on 48 sightings (maximum = 18 with La and minimum = 1 with Sb and Bb + Sa + La each). Association category sharing a common superscript differ significantly (multiple comparison with the Bonferroni's multiple comparison test in each figure separately, $P < 0.01^{*}$, $P < 0.001^{\#}$; Fha = four-horned antelope, Bb = blue bull, Sa = sambar, Pa = panther, La = langur, Wb = wild boar, Ha = hare, Sb = sloth bear).

were considered significant at $P < 0.05$ level. All statistical analysis was done using Prism GraphPad (ver. 3.02) software.

Table 3. Group composition of four-horned antelope *Tetracerus quadricornis* recorded in the tropical deciduous forest, western India (M = male, Fe = female, Fw = fawn, Un = unidentified).

Group size	Group type	No. of sighting	% frequency
One	M	26	30.59
	Fe	19	22.36
	Un	12	14.11
Two	M + Fe	8	9.41
	Fe + Fe	2	2.36
	Fe + Fw	9	10.59
	M + Un	1	1.18
Three	M+ Fe + Fw	3	3.52
	Fe + 2Fw	4	4.7
Four	Un + 3Fe	1	1.18

Table 4. Tree species and items (fl = flowers, p = pods, fr = fruits, l = leaves) dropped by langurs and gleaned by four-horned antelope *Tetracerus quadricornis*.

Family	Tree sp.	Plant part
Malvaceae	*Bombax ceiba*	fl
Fabaceae	*Butea monosperma*	fl, p
Combretaceae	*Terminalia crenulata*	fr
	Terminalia bellirica	fr
Phyllanthaceae	*Emblica officinalis*	l
Rutaceae	*Aegle marmelos*	l
Fabaceae	*Albizia odoratissima*	p
Apocynaceae	*Wrightia tinctoria*	p
Moraceae	*Ficus racemosa*	fr
Sapotaceae	*Madhuca longifolia*	fr, fl
Boraginaceae	*Cordia dichotoma*	fr
Anacardiaceae	*Lannea coromandelica*	fr
Meliaceae	*Soymida febrifuga*	fr

Ethical statement

All the observation was made without physical contact of the animal in the study area. We neither collected any type of animal samples nor carried out any type of laboratory-based work. To carry out field work, necessary permission was taken from the Principal Chief Conservator of Forests (PCCF), Forest Department, Government of Rajasthan, vides letter no. 3(01)tak-11/PCCF/2010/687, dated 28.4.2014.

Results

The *T. quadricornis* was observed for a total of 465 minutes (231 min in Kumbhalgarh WLS, 142 min in Sitamata WLS and 92 min in Phulwari-ki-nal WLS), wherein observation > 10 minutes duration continuously was only on few occasions due to its

shyness and quite elusive escape tactics. Total time/ hours spent in the observation of *T. quadricornis* activities in each study area is shown in Table 1. The maximum duration of observation was 30 min. In total, the activity of *T. quadricornis* was recorded during 85 sightings, wherein 14 sightings were in the morning hours, 38 were in mid-day hours and 33 sightings were in the evening hours. Feeding was accounted highest (28.12 %), followed by walking (22.35 %), resting (19.71 %), threat response (13.46 %), water intake (13.22 %), salt licking (1.92 %), and others (1.20 %), respectively. Two peaks were observed in activity (Fig. 2); first peak was in the morning hours (06:00-10:00 h.), while second was during the evening hours (17:00-18:00 h.). Each activity showed a different pattern in daily routine. Feeding was highest during morning and evening and dropped during mid-day, while resting, water intake and salt licking were mostly observed during mid-day and evening hours. Walking and threat response showed a similar pattern throughout the day (Table 2). All sightings of *T. quadricornis* during water intake were on water holes during surveys.

Group size of *T. quadricornis* ranged from one to four individuals with a mean of 2.5 (± 1.29 SD) individuals. Out of 85 sighting records, single individual was observed in 67.06 % (n = 57), two at 23.54 % (n = 20), three at 8.22 % (n = 7), and four at 1.18 % (n = 1) of the occasions. Overall, animals were sighted in the group (more than one) on 28 occasions (32.94 %), but varied in composition (Table 3). Due to the quick response of *T. quadricornis* when disturbed, sex of the animals was unidentified several times, but all were adults. Out of 126 sighted individuals, total females were 39.68 % (n = 50), male 30.15 % (n = 38), fawn 15.88 % (n = 20) and unidentified were 14.29 % (n = 18). On eight occasions male and female were found together, while on 16 occasion, fawns were found along with adults. The fawn was never sighted alone (Table 3). Group size composition was found significantly different seasonally (Kruskal-Wallis H = 14.06, $P < 0.001$).

Whenever we encountered *T. quadricornis*, it showed various responses to escape, but we were able to record the threat response on 17 occasions, wherein Freeze + Run was the most common practice (n = 8), while direct running was noted only on two occasions (Table 5). In one case, adults did not include running in flee decision along with fawn. They only walked. The overall mean FID for *T. quadricornis* was 62.53 (± 23.47 SD) m: 56.09 (± 20.30 SD, n = 11) m for single individuals, 64 (± 20.74 SD, n = 5) m for two individuals and 100 m (n = 1) for three individuals in a group. Linear regression showed an insignificant relation ($r^2 = 0.188$, Y-intercept = 46.33 ± 8.49, $P = 0.08$) between FID and freezing duration.

Localized defecation of *T. quadricornis* was found with three other mammals, i.e. *B. tragocamelus*, *R.*

Table 5. Threat responses and flight initiation distance (FID) of four-horned antelope *Tetracerus quadricornis* in the tropical deciduous forest, western India (M = male, Fe = female, Fw = fawn, Un = unidentified).

Group size	Composition	Threat response activities	Sighting frequency	Freezing duration (Sec.)		FID (m)	
				$\bar{X}$ ± SD	Overall $\bar{X}$ ± SD	$\bar{X}$ ± SD	Overall $\bar{X}$ ± SD
One	Fe	Freeze + Run	5	149.2 ± 137.6	140.7 ± 50.80	45.40 ± 26.09	56.09 ± 20.30
		Run + Freeze + Run	1	90		70	
	M	Freeze + Run	1	220		60	
	Un	Freeze + Run	1	80		60	
		Run	2	155 ± 205.1		60 ± 00	
		Walk + Hide	1	150		80	
Two	M + Fe	Walk + Hide + Run	1	20	124 ± 168	50	64.00 ± 20.74
		Run + Freeze + Run	1	100		15	
		Freeze + Run	1	30		50	
	M + Un	Freeze + Run + Freeze + Run	1	50		60	
	2Un	Freeze + Resume feeding activity + Run	1	420		100	
Three	M + Fe + Fw	Walk + Stop + Walk + Stop + Walk	1	180	180	100	100

unicolor and *P. pardus* in four compositions (Fig. 3) and was not significantly different (Kruskal-Wallis H = 4.219, $P = 0.233$) among sanctuaries. The highest number of association (76.47 %, n = 65) was with *B. tragocamelus*. Similarly, direct observations also revealed *T. quadricornis* association with six other mammals (Fig. 3), but the highest frequency was with *S. dussumieri* (37.50 %) and *B. tragocamelus* (16.67 %). These frequencies differed significantly among sanctuaries (Kruskal-Wallis H = 12.72, $P < 0.01$). *T. quadricornis* was also found to glean four plant parts belonging to 13 tree species dropped by *S. dussumieri* during 28 sightings in the study (Table 4).

Discussion

During the study, *T. quadricornis* was sighted mostly solitary (Table 3) and group size ≤ 4, as also depicted in literature (Leslie & Sharma 2009, Baskaran et al. 2011). Karanth & Sunquist (1992) observed maximum group size of two individuals in Nagarhole National Park (India), while Berwick (1974) reported maximum four individuals' group in the Gir National Forest (India). Similarly, in Panna National Park, 69 % sightings were of solitary individuals while 24 % in groups of two individuals (Sharma et al. 2005). In Mudumalai Tiger Reserve, observation of solitary individuals accounted 58 %, two individuals 28 %, three individuals 6 % and four individuals 2 % with a mean of ≤ 1.50 (Baskaran et al. 2009, 2011).

The results of activity budget in our study were found in accordance with the studies of Baskaran et al. (2011) and Sharma et al. (2009), wherein, feeding and walking were accounted highest in tropical deciduous forests of Mudumalai Wildlife Sanctuary and Panna National Park. Contrarily, Pokharel (2015) reported that *T. quadricornis* performed more alert (40 %) and licking (26 %) behaviours in climax Sal *Shorea robusta* and mixed deciduous forests of lowland Nepal, followed by walking (21 %), looking at subject (8 %), drinking (2 %) and browsing (1 %). The differences in licking and alertness is likely due to changes in geospatial habitat, succulent forage (Dalke et al. 1965), taste of the salt (licking is usually done to compensate for sodium Na deficiencies; Carbyn 1975), presence of other elements such as calcium, magnesium and potassium in the licked soil or rocks (Emmons & Stark 1979, Klaus 1998, Tobler et al. 2009) and predator pressure at the licking sites (Carbyn 1975). However, predator density was not assessed in study areas. In our study, resting was observed highest with rumination during the mid-day hours under the thickets and tall grasses, as they provide perfect camouflage to the species and shade, possibly to avoid extreme noon temperature and to degrade food into small particles through cud-chewing, which ultimately enhances nutrient assimilation after a continuous feeding (Pan et al. 2003, Hamel & Cote 2008).

The highest observations of *T. quadricornis* were with southern plains gray langur *S. dussumieri* (54.56 %), blue bull *B. tragocamelus* (34.86 %) and sambar *R. unicolor* (27.26 %) in order of preference (Fig. 3). Ungulates' association with primates offers foraging benefits, predator avoidance and predator detection advantages (Stensland et al. 2003, Desbiez et al. 2010), that ultimately allows individual to spend less time being vigilant (Desbiez et al. 2010). Panther *P. pardus* is the locally dominant predator of these species in the study area (Waite et al. 2007, Koli & Bhatnagar 2011) and polyspecific group, wherein all species predated by the same species, can be more efficient in the detection of a predator if different species use varied senses to scan predator than when apart (Newton 1989). *S. dussumieri* may also have an advantage of height from the ground. The alarm call is overtly relayed from one to another species; langur alerts ungulates more frequently than vice versa. In case of African ungulate-primate association, low vigilance has been reported in ungulates, with the company of monkeys and they use habitat with high predation risk in presence of primates (Washburns & Devore 1961, Strushsaketr 1967). Contrary to this, Nagel & Lohri (1973) observed that chital alerted langurs more often than vice versa. Besides these advantages, *T. quadricornis* was also observed to glean four plant parts of 13 tree species, which were dropped by *S. dussumieri* in the study area (Table 4). *S. dussumieri* drops on an average four kilograms fresh vegetation/day in the tropical forest of India mainly due to its selective feeding (Chhangani et al. 2002), or drop by mistake or by shaking branches during movement and leaps (Newton 1989). It is also assumed that dropping foliage attracts ungulates (Choudhury 1966). The ungulate-primate association has been also reported in many other species of Asia (Newton 1989, Majolo & Ventura 2004). The encounter of other animals (Fig. 3), besides *B. tragocamelus*, *S. dussumieri* and *R. unicolor* with the *T. quadricornis*, were seen as chance encounters or they were opportunistic generalist foragers in the study area.

During the study, localized defecation of *T. quadricornis* was found along with two ungulates (i.e. *B. tragocamelus* and *R. unicolor*) and one mammal species (i.e. *P. pardus*) but in varying degree (Fig.

3). These three ungulates (i.e. *T. quadricornis*, *B. tragocamelus*, and *R. unicolor*) are sharing similar spatial and feeding niche in the study area, therefore localized defecation was possibly for territoriality, intra- and inter-specific communication, but a single case with panther's scat was likely to maintain dominance and hierarchy upon the prey.

As per literature (Leslie & Sharma 2009, Sharma et al. 2009), *T. quadricornis* is shy, evades detection and usually hides, freezes, and lays down rather than fleeing instantly when encountered by a predator from a significant distance, but in a front encounter, it sprints in the opposite direction of threat. During the study, we observed that threat responses vary at different social composition levels in *T. quadricornis* (Table 5). The FID and freezing duration were noted to differ with the number of individuals in the company (from one to two, but both were found highest in one case of three individuals' in the company. However, a precise conclusion could not be made with this limited data set. Threat response in ungulates usually affects by the quality of disturbance site, availability of alternative sites, types of threat stimuli, group size, social organization and presence of hunting (Stankowich 2008). Increasing individuals in the company were found to be warier and they fled relatively at the greater distance than when single (Aastrup 2000). Sexes in ungulates have large consistent effects on the decision to flee; males are less wary than female, especially when they are guarding young, which are vulnerable to predation (Stankowich 2008). This was found in accordance at one occasion with three individuals in our study (Table 5), where freezing time and FID were noted highest most likely due to the presence of fawn with male and female, and running was not included in the flee decision.

Thus, from this study, we recommend that morning and evening hours are the optimum time for *T. quadricornis* census in the tropical deciduous forest of western India as they are most active at these times.

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