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COMMUNICATION

GROUP SIZE, CROWDING, AND AGE CLASS COMPOSITION OF THE THREATENED SAMBAR *RUSA UNICOLOR* (KERR, 1792) (MAMMALIA: CETARTIODACTYLA: CERVIDAE) IN THE SEMI-ARID REGIONS OF NORTHEASTERN RAJASTHAN, INDIA

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Group size, crowding, and age class composition of the threatened Sambar *Rusa unicolor* (Kerr, 1792) (Mammalia: Cetartiodactyla: Cervidae) in the semi-arid regions of northeastern Rajasthan, India

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Abstract: Grouping characteristics and population growth dynamics of Sambar were studied in Bir Jhunjhunu Conservation Reserve (BJCR) and Bairasar Johad (BJ) in Rajasthan, India from July 2018 to June 2019. Following the scan sampling method, a total of 117 sightings of Sambar (N= 488 individuals) were recorded in BJCR, and 106 in BJ (N= 389 individuals), during 24 fortnightly visits. The data revealed that besides solitary sightings of Sambar, groups ranging from 2–11 and 2–12 individuals were observed in BJCR and BJ, respectively. The overall mean group size and mean crowding of Sambar were 4.2±0.2 S.E. and 5.3 respectively in BJCR, and 3.7±0.2 S.E. and 5.0 respectively in BJ. The sex ratio was skewed towards females. The overall adult male: adult female: fawn ratio was 74.4: 100: 47.1 (N= 488 individuals) in BJCR while the ratio was 92.6: 100: 41.1 (N= 389 individuals) in BJ. As far as the social organization of Sambar is concerned, six types of herds were recorded in the present study. It is urged that sambar populations outside protected area also need simultaneous strategies for conservation attention.

Keywords: Population structure, sex ratio, ungulates.

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Author contributions: Deepak Rai and Kalpana conceived and designed the study. Kalpana collected the field data and prepare rough draft of the manuscript. Deepak Rai guided the research, analyzed the data and wrote the final draft of the manuscript.

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INTRODUCTION

Group size and population structure are basic aspects of mammal population monitoring and effective conservation planning (Bagchi et al. 2008; Debata & Swain 2019). Group size varies widely between and within species (Barrette 1991; Ramesh et al. 2012a) and the group size of ungulates is a reflection of resource distribution, habitat structure, home range, mating systems, intraspecific competition, and predation risk (Pulliam & Caraco 1984; Lagory 1986; Raman 1997; Simcharoen et al. 2014). For example, many ungulates show large group sizes when food resources are adequate, but when food is in limited supply they fragment into smaller groups (Karanth & Sunquist 1992; Bagchi et al. 2003; Ramesh et al. 2012b). Ungulates also tend to assemble in larger groups in open habitats, but not in dense scrubland. Thus observed group sizes indicate a balance between the benefits of group living, such as better foraging efficiency and safety from predators, and the costs, such as competition for food resources (Krebs et al. 1972).

Ungulates show a fission-fusion system of fluid group formation where individuals are free to leave or join a given group (Barrette 1991; Raman 1997). Depending on the various ecological factors involved, two measures of group size are commonly used: mean group size and typical group size. Mean group size is measured from an outsider's point of view, while typical group size is assessed from the perspective of group members (i.e., as crowding; Jarman 1974; Reiczigel et al. 2005; Reiczigel et al. 2008). The age structure of a population is represented in terms of the distribution of number of individuals from each age class which corresponds to fecundity, mortality, reproductive status and population increase of a particular species (Clutton-Brock et al. 1980). The reproductive potential of a species can be calculated from sex ratio of that species (Ramesh et al. 2012a,b).

Sambar *Rusa unicolor* (Kerr, 1792) is the largest deer species in southern and southeastern Asia. In the Indian subcontinent, the species is widely distributed and occurs in 208 protected areas (Sankar & Goyal 2004; Timmins et al. 2015). Sexes of *Rusa unicolor* are distinguished by size (males 225–320 kg; females <180 kg), the presence or absence of antlers (present only in males), and body coloration (generally lighter color of females and young than the males) (Jain et al. 2018). The males have longer hair on the upper surface of the neck and back. The wild population of this species is under stress due to loss of its natural habitats, anthropogenic activities such

as hunting, poaching, urban expansion and agriculture expansion (Chatterjee et al. 2014). The Sambar is listed as 'Vulnerable' as per the IUCN Red List (2008) due to an estimated decline of 30%–50% population over the past three generation (Timmins et al. 2015) and it is also listed in Schedule III of the Indian Wildlife Protection Act (IWPA) 1972.

Various ecological and behavioral aspects including group size as well as density of Sambar were studied in Kanha National Park (Schaller 1967; Poruse 1996), Bandipur National Park (Johsingh 1983), Mundanthurai (Johsingh & Sankar 1991), Nagarhole National Park (Karanth & Sunquist 1992), Mudumalai (Verman & Sukumar 1993, Ramesh et al. 2012a), Corbett National Park (Pant et al. 1999), Periyar Tiger Reserve (Harikumar et al. 1999), Pench Tiger Reserve (Biswas & Sankar 2002), Ranthambore Tiger Reserve (Bagchi et al. 2003), and Sariska National Park (Chatterjee et al. 2014). But few studies have been conducted on Sambar in northeastern Rajasthan. Hence the present study was conducted to obtain information on group size including crowding, population structure, variation in social organization and other ecological aspects with respect to Sambar, which will be helpful in planning effective conservation strategies for this threatened species.

MATERIALS AND METHODS

Study areas

The present study was carried out in two selected study sites, namely, Bir Jhunjhunu Conservation Reserve (BJCR), district Jhunjhunu and Bairasar Johad (BJ), village Bairasar Bara, district Churu of state Rajasthan from July 2018 to June 2019.

Bir Jhunjhunu Conservation Reserve, Jhunjhunu (BJCR)

The area lies between 28.158° N & 75.416° E alongside the Jhunjhunu-Chirawa state highway, and covers an area of 1,047 ha (Figure 1). As far as the floral diversity of the area is concerned, 440 plant species were identified (Dev & Singh 2016). In this study area, Sambar coexists with other mammals including Nilgai *Boselophus tragocamelus*, Chinkara *Gazella bennettii*, Desert Fox *Vulpes vulpes*, and the wildcat *Felis silvestris*, and around 95 bird species (Shekhawat & Bhatnagar 2014).

Bairasar Johad (BJ), village Bairasar Bara

Bairasar Johad, village Bairasar Bara (28.88°N & 75.641°E) is part of tehsil Rajgarh of district Churu

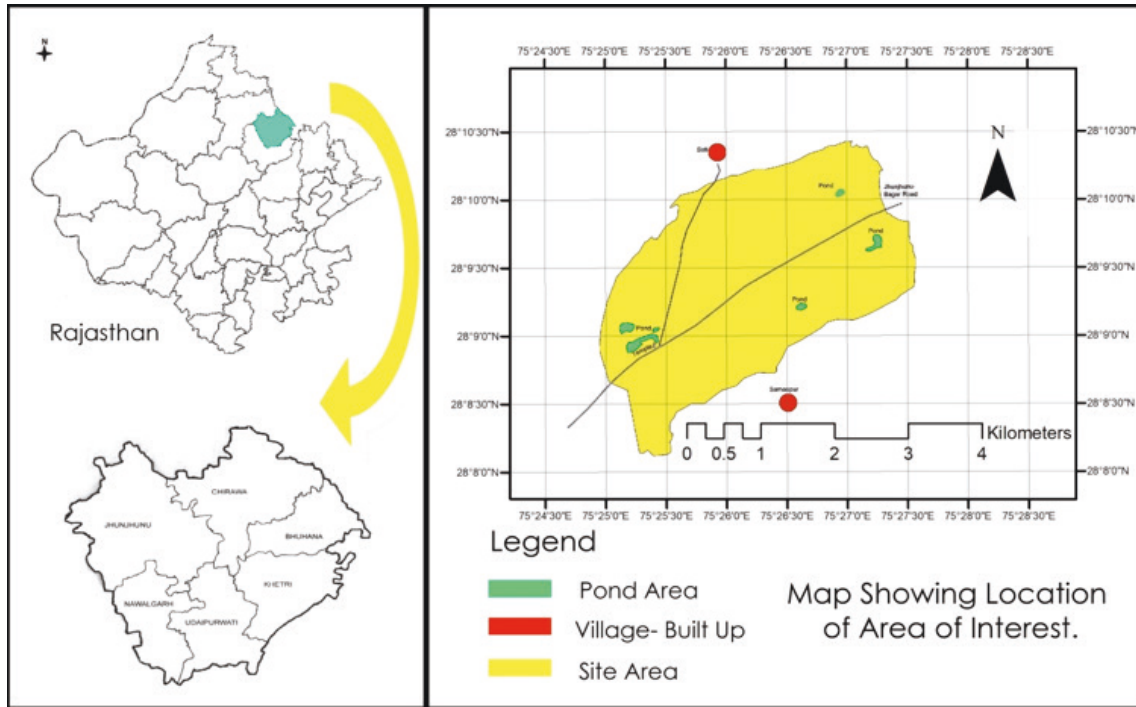


Figure 1. Bir Jhunjhunu Conservation Reserve (BJCR) in district Jhunjhunu, Rajasthan (India) (Rai & Kalpana 2019).

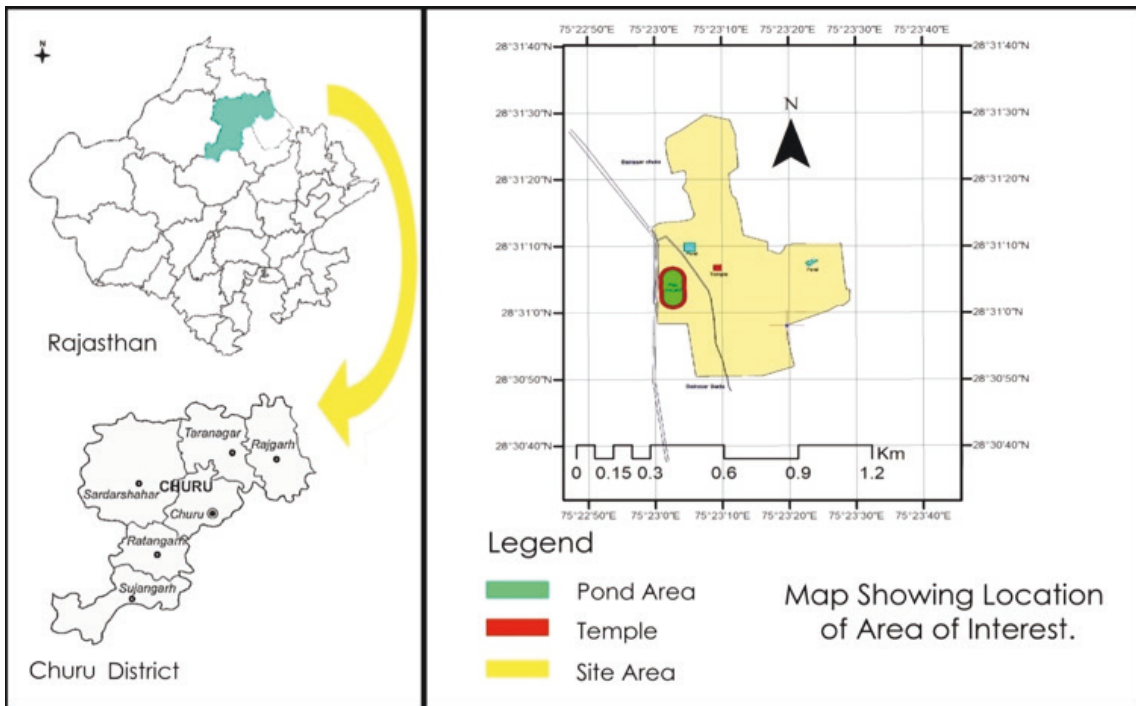


Figure 2. Bairasar Johad (BJ), village Bairasar Bara in district Churu, Rajasthan (India) (Rai & Kalpana 2019).

(Rajasthan) and is bordered by the Rajgarh-Jhunjhunu state highway (Figure 2). This region covers an area of about 14.72 ha. Dominant wild fauna found in the study area include Nilgai, Chinkara, and Sambar (Dev & Singh

2016).

Both the study sites are situated in the shekhawati region of India’s Thar desert. Climatic conditions are semi-arid, and there are three distinct seasons: summer

(March to June), monsoon (July to October), and winter (November to February). Summers are very hot (up to 50°C) and winters cold (0°C) (Dev & Singh 2016). Annual rainfall varies 300–400 mm. Major soil types are sand, sandy loam and salt affected black soil. The study areas were divided into three major habitats: fallow land, scrubby forest, and agricultural fields. The vegetation of this semi-arid region falls under the category of tropical desert thorn species predominantly of xerophytes (Dev & Singh 2016).

Data collection and analysis

To obtain information on group size, population structure and herd composition of Sambar, 24 fortnightly visits were conducted from July 2018 to June 2019 in accordance with Chopra & Rai (2009) and Rai & Jyoti (2019). Data collection was done using the scan sampling method (Altmann 1974) from random observation points. The time of observation was divided into three diurnal phases: morning (0630–1100), noon (1100–1500), and evening (1500–1800). The observations were made in different phases during different visits on a periodic basis.

On each sighting of Sambar, the following information was recorded: sex, age class, group size as well as number of groups. A group was defined following Schaller (1967) as a number of the individuals in different age classes exhibiting cohesive activity (movement in the same direction) and close proximity to each other (less than 30 m apart).

Age class composition was based on earlier studies (Schaller 1967) and recorded individuals were categorized as: adult male (>1 feet antlers), sub-adult male (spike and <1 feet antlers), adult female (morphological characters), sub-adult female (height of individuals above the adult female belly and morphological characters), and fawn (size equal and less to the height of mother's belly).

Groups of Sambar were categorized as: (i) lone territorial male/female; (ii) unimale-unifemale group consisting of one adult male & one adult female; (iii) female group consisting of adult female(s), sub-adult female(s), & fawn(s); (iv) bachelor group consisting of adult male(s) & sub-adult male(s); (v) harem consisting of one adult male, adult female(s), sub-adult female(s), & fawn(s); and (vi) mixed group consisting of adult(s) & sub-adult(s) of both sexes and fawn(s) (Image 1).

The ratio of adult male: adult female: fawn was calculated. Mean crowding and mean group size was calculated by using the program Flocker1.0 (Reiczigel & Rozsa 2006; Reiczigel et al. 2008) and obtained data was also cross checked by using the following formulae as

per Jarman (1982) who used typical group size instead of mean crowding.

$$\text{Mean group size of Sambar} = \frac{\text{Number of Sambar seen}}{\text{Number of sightings}}$$

$$\text{Mean crowding} = \frac{\sum_{i=0}^n (x_i)^2}{N}$$

where,

x_i = number of individuals in the i^{th} group/sighting

n = number of groups

N = total number of individuals

Statistical analysis of the data was done by using Mann-Whitney test (U) to determine the significant differences in mean group size of Sambar between two seasons and Kruskal Wallis test (K) between all the three seasons using SPSS 16.0 packages.

RESULTS AND DISCUSSION

During the field surveys from July 2018 to June 2019 in Bir Jhunjhunu Conservation Reserve, 117 sightings of Sambar comprising 488 individuals were recorded varying from a minimum of one to a maximum of 11 individuals per group sighting during 24 fortnightly visits (Figure 3). Similarly, in Bairasar Johad, a total of 106 sightings of Sambar comprising of 389 individuals were observed with group size varying of 1–12 individuals per group sighting (Figure 4). As far as the variation in number of group sightings per periodic visit was concerned, a minimum of three to a maximum of six group sightings were made during the visits. The overall mean group size observed was 4.17 ± 0.20 S.E. and mean crowding was 5.34 in Bir Jhunjhunu Conservation Reserve. Similarly, the overall mean group size and mean crowding value was 3.67 ± 0.21 S.E. and 5.04, respectively, in Bairasar Johad (Table 1). The highest mean group size was observed during summer season and the lowest mean group size was observed during monsoon season in both of the study sites. The highest mean crowding was recorded during the summer season in Bir Jhunjhunu Conservation Reserve while in Bairasar Johad the highest mean crowding was recorded in winter season. It probably coincides with scarcity of food resources in the study areas during summer and winter seasons. Lowest value of mean crowding was observed in monsoon season when group size of Sambar increased due to adult male joining female group during breeding season. Therefore, variation in group size was lower in monsoon season. Earlier, similar observations on group size have been observed by Bagchi et al. (2008).

Mann Whitney U test and Kruskal Wallis test results

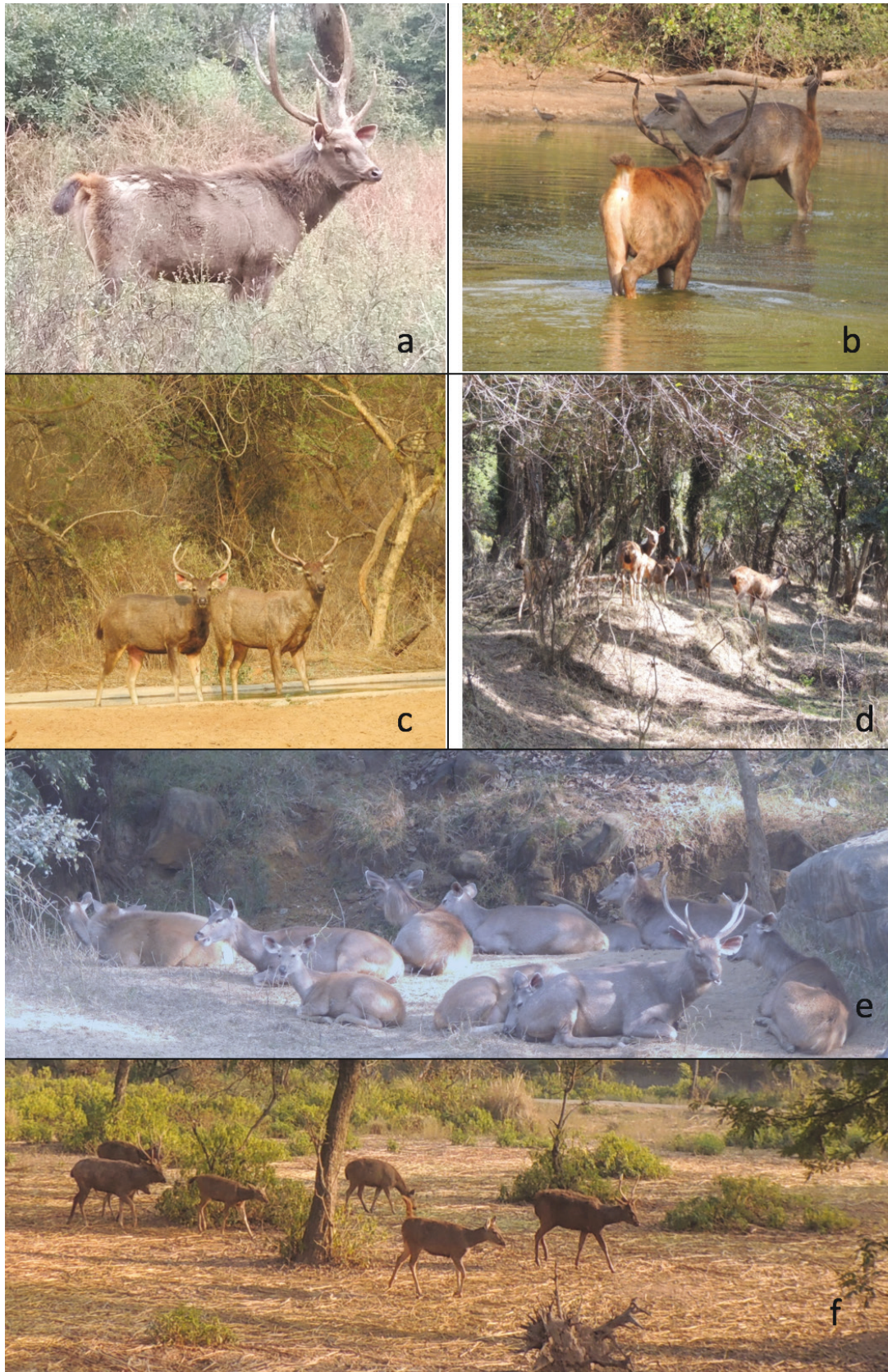


Image 1. Different types of herds of Sambar recorded during field visits at Bir Jhunjhunu Conservation Reserve, Jhunjhunu (a, b & d) and Bairasar Johad (c, e & f): a—lone territorial male (LTM) | b—unimale-Unifemale (UM-UF) | c—bachelor herd (BH) | d—female herd (FH) | e—harem herd (HH) | f—mixed herd. © Deepak Rai.

Table 1. Seasonal grouping patterns of Sambar in Bir Jhunjhunu Conservation Reserve (BJCR) and Bairasar Johad (BJ) Rajasthan from July 2018 to June 2019.

Season	NG	LGO	NA	MC	MeC	MGS±S.E.	MeGS	Group size (% of Groups)			
								1	2–5	6–10	>10
Bir Jhunjhunu Conservation Reserve											
Monsoon, 2018 (July to October)	39	8	149	4.88	5.00	3.82±0.32	4.00	17.95	58.97	23.08	0
Winter, 2018-2019 (November to February)	40	11	160	5.38	5.00	4.00±37	4.00	17.5	60.00	20.00	2.50
Summer, 2019 (March to June)	38	9	179	5.70	6.00	4.71±0.35	5.00	13.16	44.74	42.10	0
Annual (2018-2019)	117	11	488	5.34	5.00	4.71±0.20	4.00	16.24	54.70	28.20	0.85
Bairasar Johad, village Bairasar Bara											
Monsoon, 2018 (July to October)	35	7	123	4.46	5.00	3.51±0.31	4.00	20.00	65.71	14.28	0
Winter, 2018-19 (November to February)	37	12	141	5.84	6.00	3.81±0.46	3.00	21.62	54.05	18.92	5.40
Summer, 2019 (March to June)	34	8	125	4.71	4.00	3.68±0.33	3.50	14.70	64.70	20.59	0
Annual (2018-2019)	106	12	389	5.04	5.00	3.67±0.21	3.00	17.87	61.32	18.92	1.89

NG—Number of groups | NA—Number of animals | LGO—Largest group observed | MC—Mean crowding | MeC—Median crowding | MGS—Mean group size | MeGS—Median group size | SE—Standard error.

revealed that the group size of sambar were not significantly different between the two seasons and three seasons in both study sites ($p > 0.05$ in all cases) due to frequent observation of group size range of 1–5 individuals. The mean group size was in accordance with the previous studies conducted in different parts of India (Table 2). Sambar were most frequently observed in groups of 2–5 individuals, followed by 6–10, while the lowest numbers of sightings were for groups of more than 12 individuals (Table 1). Largest group sightings of 11 individuals and 12 individuals were recorded in fallow land in Bir Jhunjhunu Conservation Reserve and Bairasar Johad, respectively, as solitary animals were more vulnerable to predators in open areas than in the forested habitat due to more time spent in alertness than foraging activity (Estes 1974; Barrette 1991). In contrast, smaller groups were recorded in scrubby forest areas, possibly due to difficulties in maintaining contacts with others owing to low visibility, as reported by Lagory (1986). The obtained results were in accordance with Schaller (1967) and Ramesh et al. (2009), which revealed that size of the group is correlated with habitat openness, i.e., open or fallow land. Forage abundance also influenced group size, as the largest groups were observed in winter in both study sites owing to more clumped distribution of food. Conversely, when food is evenly dispersed and locally sparse, large groups breaks up into smaller foraging units (Jarman 1974). According

to previous studies, predation has been proposed as a factor influencing grouping behavior in Sambar, but our study area did not have any large carnivores except for a few feral dogs that posed threats to fawns (Khan et al. 1995; Raman 1997).

For population studies the mean group size is useful when population is normally distributed because mean group size is an observed-centered measurement that gives equal weightage to all groups but in clumped distribution of population, crowding phenomenon is more useful because crowding is a more animal-centered index of group size which gives the measures of the group size that the average individual finds itself in (Reiczigel et al. 2005). Similar studies based on crowding phenomenon had been reported for Sambar in Mudumalai Tiger Reserve, Western Ghats (Ramesh et al. 2012a) and some mega herbivores including Gaur *Bos Gaurus*, Elephant *Elephas maximus*, and Chital *Axis axis* (Bagchi et al. 2008; Debata & Swain 2019).

Data regarding the population structure of Sambar revealed that, of the 488 individual sightings of Sambar recorded in Bir Jhunjhunu Conservation Reserve (July 2018 to June 2019), 18.5% were adult males, 18.7% sub-adult males, 24.8% adult females, 26.4% sub-adult females, and 11.7% fawns. Similarly, in Bairasar Johad, of 389 individual sightings, 22.6% were adult males, 19.3% sub-adult males, 24.4% adult females, 23.7% sub-adult females, and 10.0% fawns (Figure 5; Table 3).

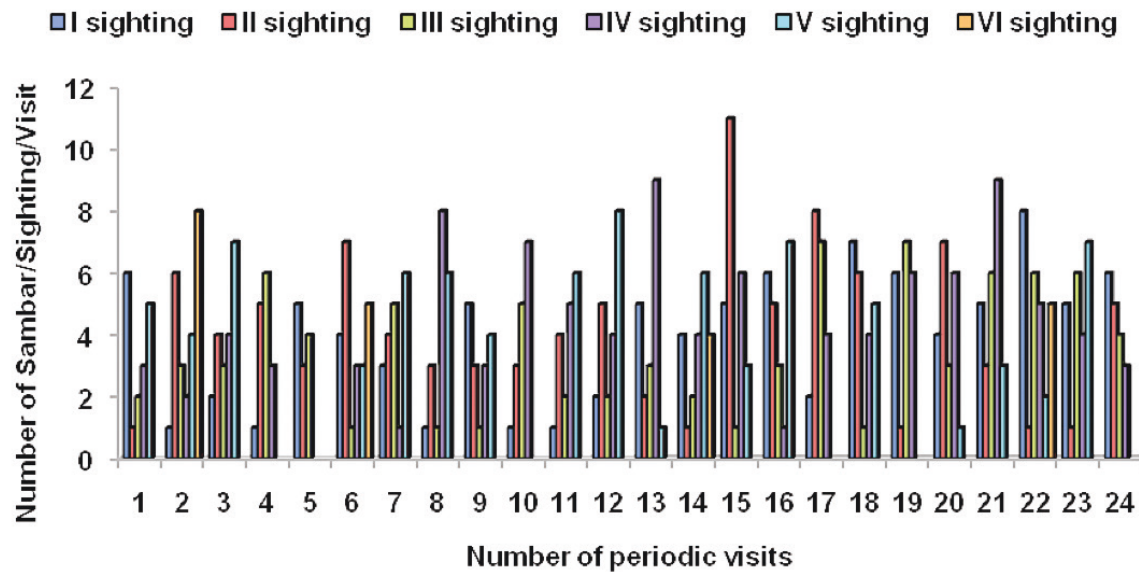


Figure 3. Number of Sambar group sightings/visit and number of individuals/group sighting in Bir Jhunjhunu Conservation Reserve (BJCR), Jhunjhunu during July 2018 to June 2019.

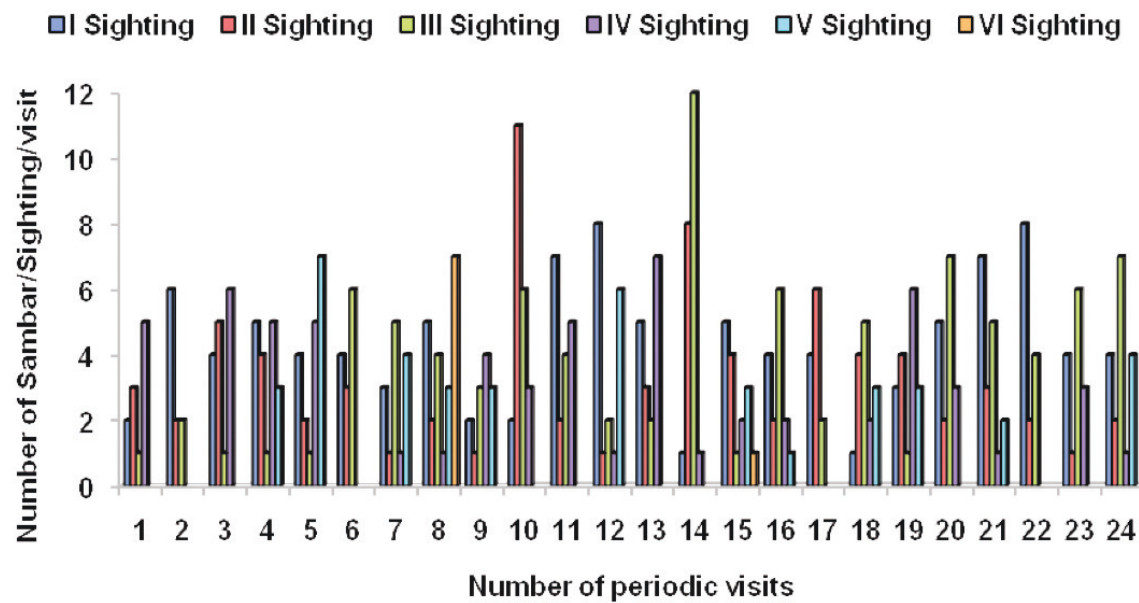


Figure 4. Number of Sambar group sightings/visit and number of individuals/group sighting in Bairasar Johad (BJ) in village Bairasar Bara during July 2018 to June 2019.

Newborn fawns were also observed throughout the year, with a peak fawning period from March to June in both study sites. The overall adult male: adult female: fawn ratio was 74.4: 100: 47.1 (N= 488 individuals) in Bir Jhunjhunu Conservation Reserve, while in Bairasar Johad the ratio was 92.6: 100: 41 (N= 389 individuals) (Table 4). A sex ratio skewed towards females was recorded in both study areas, which may be due to the illegal hunting of adult males. The absence of predators in the

study area may also have made males more susceptible to mortality from intra-male competition. A Sambar sex ratio skewed towards females was also reported in Nagarahole and Mudumalai national parks by Karanth & Sunquist (1992) and Ramesh et al. (2012a), respectively, and a similar imbalance was detected in other species, including Gaur, Elephant, Chital, and Blackbuck (Ramesh et al. 2012a,b; Rai & Jyoti 2019).

Singh (1995) mentioned that a single dominant male

Table 2. Mean Group size and Sex ratio of Sambar *Rusa unicolor* from different protected areas of India.

Study site	Mean group size	Adult male: Adult female	Source
Bir Jhunjhunu Conservation Reserve	4.71	0.9: 1	Present Study
Bairasar Johad	3.67	0.7: 1	Present Study
Bandipur National Park	-	0.3: 1	Johnsingh 1983
Nagarahole National Park	1.7	0.4: 1	Karanth & Sunquist 1992
Gir National Park	-	0.5: 1	Khan et al. 1995
Pench Tiger Reserve	1.7	-	Biswas & Sankar 2004
Sariska National Park	4.00	0.1: 1	Chatterjee et al. 2014
Ranthambhor National Park	3.7	-	Bagchi et al. 2004
Mudumalai National Park	3.6	0.4: 1	Ramesh et al. 2012a

tiger breeds with 2–3 females in its territory at 2–4 years gap for each tigress. Further, the male doesn't participate in parental care and better males in the hierarchy wait to replace him in the population, and therefore, survival of an equal or higher proportion of males in a tiger population is an ecological burden. On this account, certain biological characteristics related to sex ratio of wildlife may be comparable among herbivore and carnivore populations, where male of the species displays dominance hierarchy and has the most prominent role only to sire the progeny with one or more females, seasonally or at longer intervals.

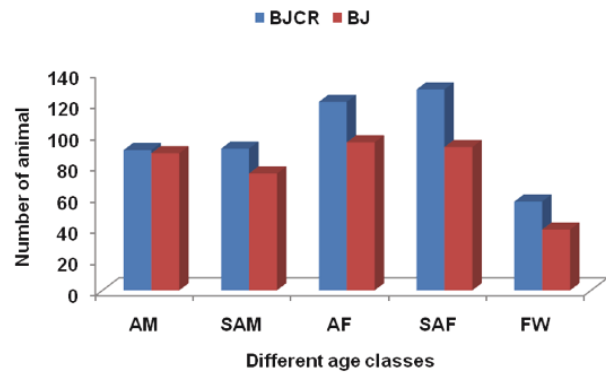


Figure 5. Population structure (different age classes) of Sambar recorded in Bir Jhunjhunu Conservation Reserve (BJCR) Jhunjhunu and Bairasar Johad (BJ) village Bairasar Bara, Rajasthan from July 2018 to June 2019. AM—Adult male | SAM—Sub-adult male | AF—Adult female | SAF—Sub-adult female | FW—Fawn.

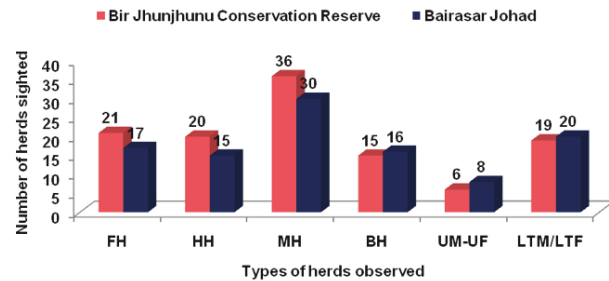


Figure 6. Different types of herds of Sambar observed in Bir Jhunjhunu Conservation Reserve (BJCR) and Bairasar Johad (BJ) Rajasthan from July 2018 to June 2019. FH—Female herd | HH—Harem herd | MH—Mixed herd | BH—Bachelor herd | UM-UF—Unimale-Unifemale | LTM—Lone territorial male/female.

Table 3. Age structure of Sambar in Bir Jhunjhunu Conservation Reserve (BJCR) and Bairasar Johad (BJ) Rajasthan from July 2018 to June 2019.

Season(s)	AM		SAM		AF		SAF		FW		Total
	No.	%	No.	%	No.	%	No.	%	No.	%	
Bir Jhunjhunu Conservation Reserve, Jhunjhunu											
Monsoon, 2018 (July–October)	29	19.46	33	22.15	32	21.48	40	26.84	15	10.07	149
Winter, 2018–19 (November–February)	25	15.62	24	15.00	46	28.75	45	28.12	20	12.50	160
Summer, 2019 (March–June)	36	20.11	34	18.99	43	24.02	44	24.58	22	12.29	179
Annual data	90	18.44	91	18.65	121	24.79	129	26.43	57	11.68	488
Bairasar Johad, village Bairasar Bara											
Monsoon, 2018 (July–October)	27	22.50	27	22.50	29	23.58	30	24.39	10	8.13	123
Winter, 2018–19 (November–February)	33	23.40	28	19.86	36	25.53	30	21.28	14	9.93	141
Summer, 2019 (March–June)	28	22.40	20	16.00	30	24.00	32	25.6	15	12.00	125
Annual data	88	22.62	75	19.28	95	24.42	92	23.65	39	10.02	389



Table 4. Sex ratio of Sambar in Bir Jhunjhunu Conservation Reserve (BJCR) and Bairasar Johad (BJ) Rajasthan from July 2018 to June 2019.

Season(s)	Adult male	Adult female	Fawn	Number of individuals classified
Bir Jhunjhunu Conservation Reserve, Jhunjhunu				
Monsoon, 2018 (July–October)	90.62	100	46.87	76
Winter, 2018–19 (November–February)	54.35	100	43.48	91
Summer, 2019 (March–June)	83.72	100	51.16	101
Overall Annual	74.38	100	47.10	268
Bairasar Johad, village Bairasar Bara				
Monsoon, 2018 (July–October)	93.10	100	34.48	66
Winter, 2018–19 (November–February)	91.66	100	37.83	83
Summer, 2019 (March–June)	93.33	100	50.00	73
Overall Annual	92.63	100	41.05	222

The observed seasonal variation in the number of newly born fawns in this study was considered to be an index of the breeding cycle. Maximum numbers of newly born fawns were observed during the summer, which indicates that the peak rutting season was in winter (November to December) when all male Sambar were carrying hard antlers. Antler cycles are convenient indicators of the reproductive status of male deer (Sankar & Goyal 2004). In Sambar the development of hard antlers in males, sore patch, territoriality wallowing and courtship behavior may indicate their rutting period.

As far as the type of herd is concerned, along with 19 lone territorial males, 36 mixed herds, 15 bachelor herds, 20 harem herds, 21 female herds, and six unimale-unifemale pairs were recorded in Bir Jhunjhunu Conservation Reserve. While in Bairasar Johad, along with 20 lone territorial males, 30 mixed herds, 16 bachelor herds, 15 harem herds, 17 female herds, and eight unimale-unifemale pairs were observed (Figure

Table 5. Seasonal variations in the herd sighting of Sambar, range of number of individuals seen/sighting and the mean number of individuals seen/ sighting±S.E. in Bir Jhunjhunu Conservation Reserve (BJCR) and Bairasar Johad (BJ) from July 2018 to June 2019.

Season	Type of Herds seen	Total sightings (N)		Range of group size seen/sighting		Mean group size seen/sighting±S.E.	
		Bir Jhunjhunu	Bairasar Johad	Bir Jhunjhunu	Bairasar Johad	Bir Jhunjhunu	Bairasar Johad
Monsoon, 2018 (July–October)							
	LTM/LTF	7	7	1	1	1±0	1±0
	MxH	13	11	2 to 8	3 to 7	5.46±0.47	4.54±0.38
	BH	6	4	2 to 4	2 to 4	3.50±0.56	3.00±0.57
	HH	5	5	4 to 5	3 to 6	4.40±0.24	4.80±0.58
	FH	7	6	2 to 6	2 to 7	4.00±0.63	4.33±0.71
	UF-UM	1	2	2	2	2±0	2±0
Winter, 2018–2019 (November–February)							
	LTM/LTF	7	8	1	1	1±0	1±0
	MxH	10	8	3 to 9	3 to 12	5.80±0.64	6.50±1.00
	BH	4	7	2 to 5	2 to 5	3.50±0.64	3.00±0.43
	HH	6	5	5 to 11	4 to 11	5.66±1.11	7.00±1.14
	FH	10	5	2 to 6	2 to 5	4.10±0.40	3.40±0.50
	UF-UM	3	4	2	2	2±0	2±0
Summer, 2019 (March–June)							
	LTM/LTF	5	5	1	1	1±0	1±0
	MxH	13	11	3 to 9	4 to 8	6.61±0.34	5.54±0.43
	BH	5	5	2 to 5	2 to 4	4.20±0.58	2.60±0.40
	HH	9	6	3 to 7	3 to 5	5.11±0.42	3.75±0.47
	FH	4	4	2 to 4	2 to 7	4.25±0.62	3.85±0.63
	UF-UM	2	2	2	2	2±0	2±0
Annual (2018–19)		117	106	1 to 11	1 to 12	4.17±0.20	3.66±0.21

LTM—Lone territorial male/female | UM-UF—Unimale-Unifemale | MxH—Mixed herd | BH—Bachelor herd | HH—Harem herd | FH—Female herd.

6). Seasonal variations in the herd sighting of Sambar, range of number of individuals seen/sighting and the mean number of individuals seen/sighting \pm S.E. was also calculated in Bir Jhunjhunu Conservation Reserve and Bairasar Johad (Table 5). Variation in herd size in relation to social behavior and rutting behavior indicates that aggregation during rutting season facilitates social interaction and breeding opportunities. Based on the seasonal variation in habitat utilization and forage abundance, the obtained results of crowding revealed the clumped distribution of Sambar in both the study areas. Therefore, based on the changed distribution pattern of Sambar, evaluation of effectiveness as well as revision of conservation strategies are needed for long term survival of Sambar populations in unprotected and protected areas.

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