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

Deepak Rai & Kalpana

26 July 2021 | Vol. 13 | No. 8 | Pages: 18975–18985
DOI: 10.11609/jott.5784.13.8.18975-18985
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

**Deepak Rai** & **Kalpana**

**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.
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 (Johnsingh 1983), Mundanthurai (Johnsingh & 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 (Biswa & 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 Boselaphus 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.

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 (Johnsingh 1983), Mundanthurai (Johnsingh & 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 (Biswa & 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 Boselaphus 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.
(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,

\[
x_i = \text{number of individuals in the } i^{th} \text{ group/sighting}
\]

\[
n = \text{number of groups}
\]

\[
N = \text{total number of individuals}
\]

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.
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).

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 |    |     |     |     |     |          |      | 1            2–5  6–10 >10 |
| 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, 2018-19 (November to February) | 40 | 11  | 160 | 5.38| 5.00| 4.00±0.37| 4.00 | 17.50  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 |    |     |     |     |     |          |      | 1            2–5  6–10 >10 |
| 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.
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                |
| Nagarhole 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           |

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 |
|------------------------------------|------|------|-------|------|------|------|-------|------|------|------|-------|
| 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 Bala|      |      |       |      |      |      |       |      |      |      |       |
| 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 | 90.62      | 100          | 46.87| 76                              |
| Monsoon, 2018 (July–October)       | 54.35      | 100          | 43.48| 91                              |
| Winter, 2018–19 (November–February)| 83.72      | 100          | 51.16| 101                             |
| Summer, 2019 (March–June)          | 74.38      | 100          | 47.10| 268                             |
| Overall Annual                     |            |              |      |                                 |
| 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 harems, 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 harems, 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        | Bir Jhunjhunu                      |                                   |
|                                 |                    | Bajrasar Johad       | Bajrasar Johad                     |                                   |
| Monsoon, 2018 (July–October)    | LTM/LTF            | 7                   | 7                                 | 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                           | 4.04±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                                 | 3 to 9                            | 3 to 12                          | 5.80±0.64                        | 6.50±1.00                        |
|                                 | MxH                | 10                  | 8                                 | 3 to 9                            | 3 to 12                          | 3.50±0.64                        | 3.00±0.43                        |
|                                 | BH                 | 4                   | 7                                 | 2 to 5                            | 2 to 5                           | 5.66±1.11                        | 7.00±1.14                        |
|                                 | HH                 | 6                   | 5                                 | 5 to 11                           | 4 to 11                          | 4.10±0.40                        | 3.40±0.50                        |
|                                 | FH                 | 7                   | 4                                 | 2 to 6                            | 2 to 7                           | 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.
Group size, crowding, and age class composition of threatened Sambar

6. 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. 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.

REFERENCES

Altmann, J. (1974). Observational study of behavior: sampling methods. Behavior 49: 227–265. https://doi.org/10.1163/156853974X00534

Bagchi, S., S.P. Goyal & K. Sankar (2003). Habitat separation among ungulates in dry tropical forests of Ranthambhore national park, Rajasthan. Tropical Ecology 44(2): 175–182.

Bagchi, S., S.P. Goyal & K. Sankar (2008). Social organisation and population structure of ungulates in a dry tropical forest in western India (Mammalia, Artiodactyla). Mammalia 72: 44–49. https://doi.org/10.1515/MAMM.2008.008

Barrette, C. (1991). The size of Axis deer fluid groups in Wilpattu National Park, Sri Lanka. Mammalia 55: 207–220. https://doi.org/10.1515/mamm.1991.55.2.207

Biswa S. & K. Sankar (2002). Prey abundance and food habit of tigers (Panthera tigris tigris) in Pench National Park, Madhya Pradesh, India. Journal of Zoology 256: 411–420. https://doi.org/10.1017/S0952836902000456

Chatterjee, D., K. Sankar, Q. Qureshi, P.K. Malik & P. Nigam (2014). Ranging pattern and habitat use of sambar (Rusa unicolor) in Sariska Tiger Reserve, Rajasthan, Western India. OSN Newsletter 26: 60–71.

Chopra, G. & B. Rai (2009). A study on the ecology of Nilgai (Boselaphus tragocamelus Pallas) and its status as an unconventional pest of agriculture in and around Beer-Sonty reserve forest, Haryana, India. Journal of Applied and Natural Science 1(2): 245–249. https://doi.org/10.31018/jans.v1i2.81

Clutton-Brock, T.H., S.D. Albon & P.H. Harvey (1980). Antlers, body size and breeding group size in Cervidae. Nature 285: 565–567.

Debata, S. & K.K. Swain (2019). Group size and population structure of vulnerable Gaur in an isolated tropical deciduous forest of eastern India. Proceedings of the National Academy of Sciences 89(1): 89–94. https://doi.org/10.11609/jpap.98.5.110953-110955

Dev, K. & P. Singh (2016). Mammalian diversity of Shekhawati region in arid zone of Thar Desert, India. International Journal of Biological Sciences 3: 16–22.

Estes, R.D. (1974). Social organization of the African boids, pp. 166–205. In: Geist, V. & F. Walther (eds.). The Behaviour of Ungulates and its Relation to Management - Volume I. International Union for Conservation of Nature and Natural Resources, Morges, Switzerland, 940pp.

Harikumar, G., B. Thomas, K.J. Joseph & V.J. Zacharias (1999). Population dynamics of Sambar Cervus unicolor, in Periyar Tiger Reserve. Indian Forester 125(10): 995–1003.

IUCN (2008). IUCN Red List of threatened species. Version 2008. www.iucnredlist.org.

Jain, P., A. Bhasin, G. Talukdar & B. Habib (2018). Distribution and population status of Sambar Rusa unicolor (Mammalia: Cetartiodactyla: Cervidae) from Aravalli landscape with a note on its first record from Aravalli Hills of Haryana, India. Journal of Threatened Taxa 10(10): 12337–12362. https://doi.org/10.11609/jott.4011.10.12357-12362

Jarman, P.J. (1974). The social organisation of antelope in relation to their ecology. Behaviour 48: 216–267. https://doi.org/10.1163/156853974X00345

Johnsingh, A.J.T. (1983). Large mammalian prey-predators in Bandipur. Journal of the Bombay Natural History Society 80: 1–57.

Johnsingh, A.J.T. & K. Sankar (1991). Food plants of chital, sambar and cattle on Mundanthurai Plateau, Tamil Nadu, South India. Mammalia 55: 57–66. https://doi.org/10.1515/mamm.1991.55.1.57

Karanth, K.U. & M.E. Sunquist (1992). Population structure, density and biomass of large herbivores in the tropical forests of Nagarathole, India. Journal of Tropical Ecology 8: 21–35. https://doi.org/10.1017/S0266467700006040

Khan, J.A., R. Chelliam & A.J.T. Johnsingh (1995). Group size and age-sex composition of three major ungulate species in Gir Lion Sanctuary, Gujarat, India. Journal of the Bombay Natural History Society 92: 295–302.

Kerr, R. (1792). The animal kingdom, or zoological system of the celebrated Sir Charles Linnaeus; Class I. Mammalia; containing a complete systematic description, arrangement, and nomenclature, of all the known species and varieties of the Mammalia, or animals which give suck to their young; being a translation of that part of the Systema Naturae, as lately published, with great improvements, by Professor Gmelin of Goettingen. J. Murray & R. Faulder, London, UK.

Krebs, J.R., M.H. MacRoberts & J.M. Cullen (1972). Flocking and feeding in the Great tit Parus major- an experimental study. Ibis 114: 507–530. https://doi.org/10.1111/j.1477-9299.1972.tb00852.x

Lagory, K.E. (1986). Habitat, group size, and the behavior of white-tailed deer. Behaviour 98: 168–179. https://doi.org/10.1163/156853974X000955

Pant, A., S.G. Chavan, P.S. Roy & K.K. Das (1999). Habitat analysis for sambar in Corbett National Park using remote sensing and GIS. Journal of Indian Society Remote Sensing 27(3): 133–139.

Poruse, M.C. (1996). Wildlife Habitat Analysis for Sambar in Kanha National Park Using Remote Sensing. Journal of Indian Society Remote Sensing 17(14): 919–935.

Pulliam, H.R. & T. Caraco (1984). Living in groups: is there an optimal group size? pp. 122–148. In: Krebs, J.R. & N.B. Dviers (eds.). Behavioral Ecology: An Evolutionary Approach. 2nd Edition. Blackwell Scientific Publication, Oxford, 493pp.

Rai, D. & J. Royti (2019). Crowding, Group size and Population structure of Blackbuck, Antilope cervicapra (Linnaeus, 1758) in semi-arid habitat of Haryana, India. Journal of Threatened Taxa 11(9): 14194–14203. https://doi.org/10.11609/jott.4011.10.12357-12362

Rai, D. & Kalpana (2019). Opinion survey on the ecology of Sambar, Rusa unicolor (Artiodactyla, Cervidae) and its status with respect to crop damage in districts Jhunjhunu and Churu, Rajasthan (India). Journal of Applied and Natural Science 11(2): 468–477. https://doi.org/10.31018/jans.v11i2.2092

Raman, T.R.S. (1997). Factors influencing seasonal and monthly changes in the group size of chital or axis deer in southern India. Journal of Bioscience 22: 203–218. https://doi.org/10.1007/BF02704733

Ramesh, T., V. Snehalatha, K. Sankar & Q. Qureshi (2009). Food habits and prey selection of tiger and leopard in Madumalai Tiger Reserve, Tamil Nadu, India. Journal of Scientific Transactions Environment and Technovation 2: 170–181.

Ramesh, T., K. Sankar, B. Qureshi & R. Kalle (2012a). Group size, sex and age composition of Chital (Axis axis) and Sambar (Rusa unicolor) in a deciduous habitat of Western Ghats. Mammal Science 77: 53–59. https://doi.org/10.1016/j.mamsce.2011.09.003

Ramesh, T., K. Sankar, B. Qureshi & R. Kalle (2012b). Group size and population structure of megaherbivores (Gaur Bos gaurus
and Asian Elephant *Elephas maximus* in a deciduous habitat of Western Ghats, India. *Mammal Study* 37: 47–54. https://doi.org/10.3106/041.037.0106

Reiczigel, J., Z. Lang, L. Rozsa & B. Tothmeresz (2005). Properties of crowding indices and statistical tools to analyze crowding data. *Journal of Parasitology* 91: 245–252. https://doi.org/10.1645/GE-281R1

Reiczigel, J. & L. Rozsa (2006). Flocker 1.0. Available at www.behav.org/flocker/ Accessed on 20 September 2018.

Reiczigel, J., Z. Lang, L. Rozsa & B. Tothmeresz (2008). Measures of sociality: two different views of group size. *Animal Behaviour* 75: 715–721. https://doi.org/10.1016/j.anbehav.2007.05.020

Sankar, K. & S.P. Goyal (2004). Ungulates of India. ENVIS Bulletin: Wildlife and Protected Areas 7(1): 163–170.

Schaller, G.B. (1967). *The Deer and the Tiger: A Study of Wildlife in India*. The University of Chicago Press, Chicago, USA, 384pp.

Shekhawat, D.S & C. Bhatnagar (2014). Guild, status, and diversity of avian fauna in the Jhunjhunu district, Rajasthan, India. *Journal of Asia-Pacific Biodiversity* 7(3): 262–267. https://doi.org/10.1016/j.japb.2014.06.001

Simcharoen, A., T. Savini, G.A. Gale, E. Roche, V. Chimchome & J.L. Smith (2014). Ecological factors that influence Sambar (*Rusa unicolor*) distribution and abundance in western Thailand: implications for tiger conservation. *Raffles Bulletin of Zoology* 62: 100–106.

Singh, L.A.K. (1995). Sex-identification technique and sex-ratio in tiger: doubts and clarifications. *Indian Forester* 21(10): 885–894.

Timmins, R.J., R. Steinmetz, B.H. Sagar, K.N. Samba, J.W. Duckworth, I.M. Anwarul & B.P.L. Chan (2015). *Rusa unicolor*. The IUCN Red List of Threatened Species. https://doi.org/10.2305/IUCN.UK.2015-2.RLTS.T41790A22156247.en

Varman, K.S. & R. Sukumar (1993). Ecology of sambar in Mudumalai Sanctuary, southern India, pp. 273–284. In: ‘Deer of China: biology and management: proceedings of the International Symposium on Deer of China’. Elsevier, New York.
