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Research article

Grouping dynamics of the northernmost population of blackbuck (*Antilope cervicapra*) in Krishnasaar Conservation Area, Nepal

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Abstract

Blackbuck, *Antilope cervicapra,* are group-living grazers found in a wide range of habitats, from dry grasslands to open forests. Krishnasaar Conservation Area (KrCA) in Bardia, Nepal is home to the northernmost population of blackbuck. This population lives in close proximity to humans. As a population in an extreme of the species' range and experiencing direct and indirect human influences, KrCA is suitable to study less explored facets of herbivore ecology and behavior. One such less explored behavior of herbivores is their grouping (herding) behavior. Grouping is commonly seen as an anti-predator response and could also be used in the context of anthropogenic threat. In this study we investigated herding behavior of blackbuck and ecological and anthropogenic factors that might influence the herding. To record the grouping behavior of blackbuck in the different habitat types, we used scan sampling methods for groups. A group was defined by including all individuals that are within 50 m of another individual. The influence of ecological and anthropogenic factors on herding pattern was assessed through simple regression modelling. We scanned animals for 89 hours and each hour had seven observations. The mean group size was 20.56 ±1.97 (mean ± SE). More than two-thirds of animals observed were female. We found larger herd sizes in the morning compared with herd sizes in the afternoon and evening. Our observations also showed that mixed herds were significantly larger in size than male-only, and female-only herds in both core and settlement zones. Our modelling of covariates predicted group type to be the single most influential factor influencing herd size. As herding behavior of animals reflect associated risk and resource factors, the finding of this work can be helpful in managing this isolated threatened population of blackbuck.

Keywords: Anthropogenic disturbance; Blackbuck; Group size; Herding behaviour; Scan sampling

1 | Introduction

Blackbuck, *Antilope cervicapra* (Linnaeus 1758) are generalist grazers often found living in groups in habitats ranging from dry grasslands to open forests (Ranjithsinh 1989; Isvaran 2005). Blackbucks are endemic to Indian subcontinent and were once distributed throughout the plains of the subcontinent. However, they are already extinct in Pakistan and Bangladesh (IUCN SSC Antelope Specialist Group 2017). The present distribution of the species is limited, with most populations occurring in India and with an isolated population in Nepal (IUCN SSC Antelope Specialist Group 2017). Along with this isolated population of blackbuck in Krishnasaar Conservation Area, (KrCA), Khairapur in Bardia district there is another soft-release population in Hirapur Phanta in Shuklaphanta National Park (Bist et al. 2021).

The population of blackbuck in KrCA is unique in several ways. First, it is the northernmost population of the species in the world (Jha & Isvaran 2022). Second, in KrCA, humans, livestock, and blackbuck have existed in proximity for decades now. In KrCA, around 250 blackbucks live alongside 10000 people in an area of approximately 17 km^2 (KrCA 2017). This geographical and ecological uniqueness of KrCA makes it suitable to study less explored facets of herbivore ecology and behavior compared with their ecology at other locations with similar habitats.

One such relatively less explored behavior of herbivores is their grouping (herding) behavior. Prey species across taxa possess a set of behaviors that reduces their chance of being preyed upon (Lima & Dill 1990; Caro 2005). Grouping (size of the herd) and vigilance (alertness) are two major and flexible anti-predatory behaviors in antelopes. Animals deploy these behaviors to minimize the chance of being predated (Makin et al. 2017). For example, animals will benefit from the dilution effect, collective group vigilance, and deterrence by maintaining a large group size (Beauchamp 2003; Schmitt et al. 2014). However, this will also increase intragroup competition (Bode et al. 2010). Therefore, animals will not always choose to stay in larger groups and will adjust the group size depending on the anticipated risk (Creel & Creel 2002).

There are many theories that explain the grouping mechanism and factors determining grouping in animals (Altmann 1974; Geist & Walther 1974; Eisenberg 1981). For example, prey-predator theory suggests that the probability of detecting a herd and the per capita possibility of prey being attacked together determine an individual's chances of encountering a predator (Bonar et al. 2020). In a larger herd, there is a high chance of being detected (Riipi et al. 2001) but a low per capita probability of being attacked, and vice versa in the case of a small herd (Hamilton 1971). In many species with fission-fusion grouping behavior, group sizes fluctuate either by merging of two or more groups or by the splitting of a single group into two or more sub-units (Smith 1993; Aureli et al. 2008; Bond et al. 2019). Such fluctuations and adjustments in group size might enable those species to respond to temporary fluctuations in factors relating to risks (Thaker et al. 2010) or resources (Holekamp et al. 2012). In relation to the grouping behavior of African antelopes and their ecology, it was hypothesized that the distribution of food resources in space, the feeding behavior of species, and their strategies to overcome predation largely influence group size (Jarman 1974). Studies like (Pays & Jarman 2008; Thaker et al. 2010) have shown that in open grassland, herbivores form larger groups to protect themselves from being predated. Similarly, in the areas of dense vegetative growth, those ungulates were found forming groups with few numbers of individuals. These studies reflect that resource and risk factors together influence grouping behavior by animals. However, most of these studies (Pays & Jarman 2008; Thaker et al. 2010; Bond et al. 2019) are from large parks where animals live with negligible direct human influence. However, most of the studies conducted thus far are from large parks in Africa where animals live with negligible direct human influence and there is little knowledge about animals' grouping behaviour in habitats from the global south where these animals have been living alongside growing human populations.

In KrCA, animals live in refugia of habitat in multi-use landscape (Jha & Isvaran, 2022). Therefore, it becomes important to know how animals perceive risks associated with humans. One of the ways in which animals respond to risk is through the size of the group the animals maintain. Knowing animal grouping behavior in response to human-induced risk will help us assess the impact of human presence in day-to-day life of blackbuck. Like in most antelopes, blackbuck also live in social groups. Isvaran (2007) suggests three major social groups in blackbuck (1) all-male groups that include all age classes males, (2) female groups that incorporate all age classes females and immature males, and (3) mixed-sex groups that include all age classes male and female. However, Isvaran (2007) inference is from population of blackbucks from different geographical and ecological regions. And the herding type and influencing factors that we observe at KrCA might be unique.

Therefore, in this interesting system we decided to simultaneously analyze the impacts of a broad spectrum of covariates that might be playing a role to decide what size of the herd the animal prefer to be in. The aim of this work is to characterize the grouping behavior of blackbuck and assess the influence of natural and anthropogenic factors i.e., time of the day, weather, age-sex composition, and location in shaping the herd size. We hypothesized that group size would reflect associated natural and anthropogenic risks.

2 | Materials and methods

2.1 | Study area

This study was conducted in Krishnasaar Conservation Area (KrCA) (28°7' and 28°39'N latitude and 81°3' and 81°4'E longitude). Krishnasaar is the Nepali name for blackbuck. Located in Gulariya municipality ~40 km east of Bardia National Park in western lowland Terai of Nepal it is home to the only wild population of blackbuck in Nepal. It lies between the old and new course of Babai river. The total area (16.95 km^2) is divided into Core Area (CA) with an area of 5.27 km^2 and Community Development Zone (CDZ) with the remaining area of 11.68 km^2 (Fig. 1). The CA, which is further reduced by 0.6 km^2 due to human settlement of 142 households, primarily comprises of grassland (2.57 km^2) and two forest patches (2.1 km^2). The CDZ is densely populated.

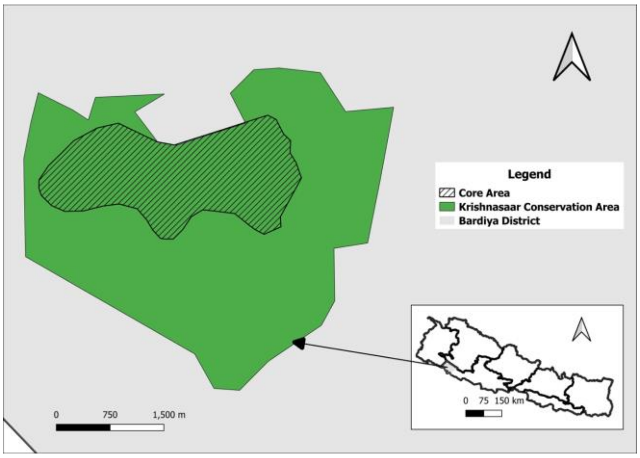

Figure 1. Krishnasaar Conservation Area and its location in the country

There are around 1669 households with a total population of 8789 living in CDZ. The total number of livestock recorded from those households was 2384. There are three distinct seasons: hot season (mid-February to mid-June), monsoon (mid-June to late September) and winter (October to mid-February). The mean annual rainfall at the site between 1976 and 2016 was 1005 mm and the mean annual temperature in 2015 was 31°C (KrCA 2017) (Fig. 1).

2.2 | Animals observation

We recorded the grouping behavior of blackbuck in the different habitat types and zones. Two distinct habitat types present in the core area of KrCA and included in this study were grassland habitat and Bombax forest habitat. Similarly, the core and settlement zones were two zones that we incorporated. The settlement zone was that region of the core which was within 100 m of either crop field or buildup area. We used scan sampling methods for groups (Altmann 1974). In this method of recording behavior, first, a group of animals is selected. The group was defined by including all individuals that are within 50 m of another individual (Clutton-Brock et al. 1982; Lingle 2001; Isvaran 2005). We mostly selected raised structures (view-towers) or stood at least 60–80 m distance from the herd to observe their behavior. Once we approached the site and defined the group, we waited 5-10 minutes before starting the observation to allow enough time for blackbuck to acclimatize to and ignore our presence. We then observed the total number of individuals in the group and their age and sex composition. Age composition was possible only in the case of males where the size of the horn and curl in the horn was used to distinguish males as immature male and adult males. We did not use coat color as a distinguishing feature as it can change from brown to black even in adult males (Isvaran 2005). We categorized individuals as fawn (sex not separated), immature male (from horns visible up to three curls in the horn), female (size larger than fawns but no presence of horns), and adult male (more than three curls in the horn). As the immature male's category only included those who had horns visible, those that did not might have been categorized as female. Therefore, the female category included adult females and immature of both sexes. All observations were diurnal and blackbuck groups were scanned between 05:05 AM and 06:15 PM in the month of December of 2019, and January, and February of 2020.

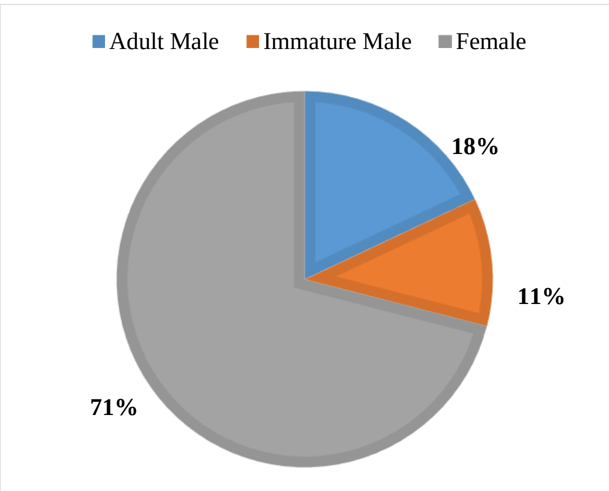

Figure 2. Percentage composition of different ages and sex of blackbuck being scanned.

An observation session of a group lasted for one hour. Every 10 minutes from the start of the session (zero minutes) to the 60th minute, we scanned the group and recorded the number of individuals in the group and the behavior of all individuals at that instant. Observations were done using a pair of binoculars (Nikon Action EX 8x40 8.2°). As predictor variables, we also noted the type of habitat (grassland, forest, cropland) the group was in, the location of the site (CA and CDZ) of observation, and weather conditions at the time of observation.

2.3 | Data analysis

The Instantaneous scan sampling method was employed to record the number of individuals in the group at every instant of observation. Each observation session of a group had seven scans (scans at zero minutes and 60 minutes with 10-minute interval. For each group observation session, the mean group size across the 7 scans was calculated and used to examine variation in grouping behavior across habitat types and zones.

For modeling grouping behavior of blackbuck in the different habitats, the response variable was mean group size which was a continuous variable. The predictor variables were habitat type (grassland, *Bombax* forest); location (core and settlement); group type (female only, male only, mixed); weather (no sun, partial sun, sunny); and time of the day (day, evening, morning). The selected predictors were primarily resource and risk factors based on what we already know about the herding behavior of blackbuck from previous works (Isvaran 2007; Rai 2019). As the response was a continuous variable with no zeroes, simple linear regression was used for modeling.

Based on our hypotheses and prior knowledge of blackbuck, we framed an *a priori* candidate set of 25 models including both the null and the global models, each representing a different ecological hypothesis. For statistical inference, we adopted a model selection using an information theoretic approach framework (Burnham & Anderson 1998).

3 | Results

We scanned animals for 89 hours in total. As each hour (independent observation session) had seven observations, we had altogether scanned 623 groups of animals which comprised 12811 individual samplings. The lowest number of individuals observed in the group was three whereas the largest herd was observed with

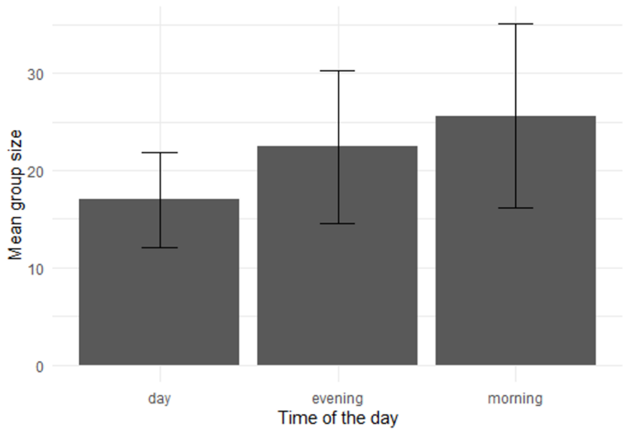

Figure 3. Variation in group size across time of the day. Means and 95% confidence intervals are shown.

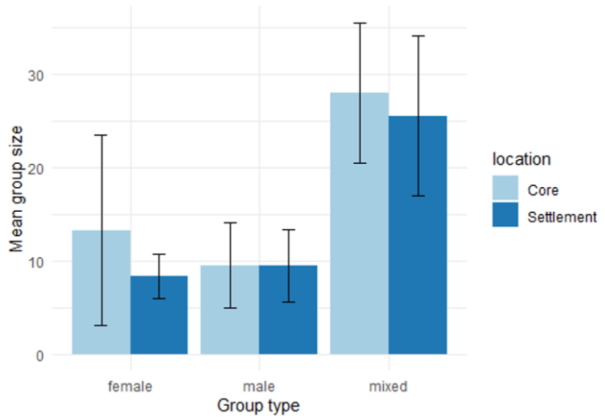

Figure 4. Variation in group sizes across group type in two different locations. Means and 95% confidence intervals are shown.

112 individual observations. The mean group size was 20.56±1.97 (mean ± SE).

As the youngest animals in the area were already between 8-9 months old (the last fawning month was 9 months before the field season started) we could not separate fawn from male and female during observation and a few individuals were unidentified and could not be placed under any of our age and sex categories. So, the animals whose grouping behavior was analyzed further were adult males (males with three or more curls in the horn), immature males, and females. Animals observed in more than two-thirds of the scans were females (Fig. 2).

During observations, we found size of social groups in blackbuck changing many times in a single day. We found both intra-sex and inter-sex grouping. However, sighting of same-sex or mixed herds was most frequent. Out of the total (n=89) herds that were scanned, more than half (n=55) were mixed herds. Single-sex herds, male-only (n=15) and female-only (n=19) were comparable in terms of frequency during the scan sampling sessions. Also, the typical herd size in the day was smaller when compared to those in the morning and evening (Fig. 3). Another interesting observation was with group size. We found mixed herds to be statistically detactably larger in size when compared to male-only or female-only herds in both the core and settlement zone (Fig. 4). There was no detectable difference between the use of core and settlement zone in any of the group types.

Our model which incorporated only group type was the best predictor of grouping in blackbuck (Table 1). Blackbuck group size varied largely with group type (model-averaged weight=0.99) (Table 2). Other predictors like time of the day (model-averaged weight=0.50), weather (model-averaged weight=0.23), location (model averaged weight=0.47, and habitat type (model-averaged weight=0.20) did not have much influence on group size in blackbuck.

4 | Discussion

Our results showed social groups in blackbuck to be fluid i.e., can change herd size many times in a day and best described as fission-fusion groups (Mungall 1978; Isvaran 2007). The number of individuals in the group considerably varied throughout the day resulting in frequent change in the group size. The mean group size we observed was 20.56±1.97 (mean± SE). The previous work conducted at the same site reported group size of blackbuck in winter to be 17.14 animals (Sharma 2019). However, older studies from the same site reported substantially smaller herd size. Khanal (2006) calculated average group size of 7.64 whereas Chand (1999) reported group size ranging between 4.4–6.9 animals. Nevertheless, some studies which focused on herding behavior of blackbuck in India found similar herd size as we report in this study. A study from Odisha, India

Table 1: Top-ranked five models from a model set comprising 25 models exploring variables affecting grouping behavior. Habitat type (Grassland, *Bombax* forest); Location (Core and Settlement); Group type (Female only, Male only, Mixed); Weather (No sun, Partial sun, Sunny); Time (Day, Evening, Morning).

Model	df	logLik	AICc	Delta AICc	Weight
Group type	4	-376.0	760.01	0.73	0.24
Group type + Time	6	-374.14	761.30	0.82	0.16
Group type + Time + Location + Weather	9	-370.64	761.55	1.07	0.14
Group type + Time + Location	7	-373.30	761.97	1.49	0.11
Group type + Location	5	-375.75	762.22	1.74	0.10

Table 2: Model averaged β coefficient, 95% confidence limits, and weights associated with different predictors of grouping behavior from a model set comprising 25 models.

	B Estimate	95% Lower CL	95% Upper CL	Weights
Intercept	11.53	-0.95	24.03	
Group type				0.99
Group type: male	-1.61	-13.27	10.04	
Group type: mixed	**15.99**	**6.89**	**25.09**	
Time				0.50
Time: Evening	9.23	-0.35	18.81	
Time: morning	9.87	-2.46	22.19	
Weather				0.23
Weather: Partial sun	-7.66	-20-67	5.37	
Weather: sunny	-13.15	-27.89	1.57	
Location				0.47
Location: settlement	-3.35	-11.63	4.92	
Habitat type				0.20
Habitat type: grassland	-0.88	-11.15	9.39	

Notes: CL, Confidence Limit; Habitat type (Grassland, *Bombax* forest); Location (Core and Settlement); Group type (Female only, Male only, Mixed); Weather (No sun, Partial sun, Sunny); Time (Day, Evening, Morning). Terms in bold indicate 95% confidence intervals that do not include zero.

reported a mean herd size of 19.49±0.03 (Mean ± SE) (Debata 2017). Also, Delu et al. (2023), Bharucha & Asher (1993) and Nair (1976) reported mean herd size of 26.29, 21 and 23 respectively. Therefore, we can say the mean group size of blackbuck at KrCA is both comparable and contradictory to other findings from the same site and other sites in India.

More than two-third of individuals we observed were female (71%) followed by adult male (18%) and immature male (11%). Sharma (2019) reported similar composition from the same site with almost two-third (66.25%) females and remaining males. Similarly, a study from Ranebennur Blackbuck Sanctuary, Karnataka, India also summarized sex composition as 70% of females and remaining males (Arockianathan & Balasundaram 2018).

Although we expected habitat types to influence herd size as habitat characteristics determine both risk (with grasslands being lower in risk than forests) and reward (with grasslands being more resource-abundant than forests), group sizes were not consistently related to habitat types.

We found that grouping type best explained the herd size in blackbuck. Mixed (male and female) herds were detectably larger than male-only and female-only herds. Interestingly, similar patterns in herding were observed by (Rai 2019) where they found that mixed herds were the largest in size compared to female-only or bachelor herds (male-only herds).

Herd size during day hours was smaller as compared to herd size in the morning or evening. One reason for this could be animals distributing themselves while foraging during day hours so as to reduce foraging competition. In contrast, they might aggregate in the evening to compensate for reduced visibility as compared to day hours through group vigilance and this aggregation of animals could last till the morning hours of the next day. The main determining factors for group size in blackbuck, like other large herbivores, are risk of predation, resource availability, and habitat structure (Isvaran 2007; Jha & Isvaran 2022). Although the relationships between group size and the weather had high uncertainty (the 95% CLs of the parameters included zero), the trends were in the expected direction based on the findings of other studies. Among weather types, blackbuck maintained the largest group size when it was completely foggy with no sun out, and the smallest when it was sunny. As group size is related to predation risk, a larger herd would have more dilution effect and more group vigilance which would be preferred by animals in a foggy day where visibility is low. An experimental study in coati (*Nasua narica*) that tested the impact of visibility and group size on vigilance rate also found group size to be negatively correlated with visibility (Burger & Gochfeld 1992).

Similarly, we found that the location of the herd (core and settlement) has little influence on the group size. This is contrary to what we had hypothesized. We expected herds near settlement would be larger as these sites could be associated with higher risks. However, animals did not perceive the location itself as the one with higher risks. This could be due to site familiarity. Animals at this site have lived for generations among humans and they might have gotten accustomed to being near crop fields or even human settlements. So, through generations of living together in a landscape, site familiarity might have made Blackbuck comfortable in sharing space with people and hence not perceiving those sites as one higher risk. Another reason for indifferent herding behavior between core and settlement could be prolong absence of direct threats like hunting or killing which associated with proximity to humans. In this landscape hunting has never been allowed in any form. Similarly, people living around KrCA consider blackbuck as integral part of the landscape and there are hardly any evidences of local community involvement in trapping or killing blackbuck (Pers. Com. With Conservation Officer of KrCA).

5 | Conclusions

The herding behaviour of an animal is a reflection of the animal's perception of risk and resources associated with its habitat. Knowing the sociality of animals is crucial in managing habitat. With the knowledge of the nature of the grouping of the animals, better habitat management strategies can be implemented. For example, this study found that there is a negligible difference in the use of the core zone and settlement zone by blackbuck. Blackbucks frequently use both zones. This information implies that while managing habitat both core and settlement zones should be given equal importance. More such studies to explore the herding behavior of animals should be encouraged so that the knowledge of animal-specific behavior can be used for designing and implementing effective habitat management protocols.

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Authors' contributions

Both the authors designed the study. R.R.J. collected field data; both authors analyzed the data and wrote the manuscript.

Conflicts of interest

Authors declare no conflict of interest.

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