

## Population Dynamics and Diurnal Budget of Behavioral Activities of BlackBuck (*Antilope cervicapra*) at three protected areas in Cholistan Desert, Pakistan

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### Abstract

Our present study investigated the ecological density, herd distribution and Diurnal Budget of Behavioral Activities amongst Free Ranging and Semi-captive Blackbucks (*Antilope cervicapra*) at Lal Suhanra National Park (RD25), Sheikh Mohammad Bin Zayed Al- Nahyan Conservation Centre Black Buck Enclosure and sections of Dodhlan Forest during three seasons (Summer, Monsoon and Winter) for year 2019-2023. By the end of study period, Ecological density at Lal Suhanra National Park (0.10 individuals/ha), Sheikh Mohammad Bin Zayed Al- Nahyan Conservation Center Black Buck Enclosure (0.45 individuals/ha) and Dodhlan Park, Fort Abbas (0.28 individuals/ha) were calculated, while Male to Female ratios were observed to be 2/1, 3/4 and 2/3 respectively. Unpredictably higher, percent increase in the blackbuck population during the year 2020 at Lal Suhanra National Park (16.06%), Sheikh Mohammad Bin Zayed Al- Nahyan Conservation Centre Black Buck Enclosure (15.85%), and Dodhlan Park in Fort Abbas (38.46%), indicated a positive impact of COVID-19-related lockdown measures. A definite pattern of behavioral activities was observed during specific parts of the day which varied across different seasons. Amongst all blackbuck age groups, foraging activity was most pronounced during monsoon ( $P < 0.0001$ ), while resting was least prominent during the same season. Foraging activities peaked from late morning to midday and again just before dusk, while afternoon hours were predominantly spent resting. Peaks in all behavioral activities varied with seasonal changes. Throughout the seasons, adult blackbucks exhibited longer durations of foraging, while fawns were frequently observed engaging in miscellaneous activities compared to other age groups.

**Keywords:** Budget of Behavioral Activities, Diurnal, Foraging, Lal Suhanra National Park, Percent increase in population, Semi-captive Blackbucks

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### Introduction

The Blackbuck (*Antilope cervicapra*), member of the 'Bovidae' family and the *Antilopinae* subfamily (Bhaskar, Kanaparathi, and Sakthivel 2021). It inhabits regions spanning across the Indian Subcontinent and certain parts of Middle-East, demonstrating adaptability in diverse landscapes, including open grasslands, bushlands, scrublands, and dry thorn habitats (Jana and Karanth 2023).

National-level policies are increasingly focusing on the conservation and sustainable management of Blackbuck, given its importance for ecotourism and the need for species preservation (Chandel et al. 2022). Unfortunately, the charm of hunting, driven by the species' delicious and nutritious meat, poses a significant threat to Blackbuck populations (Sinha and Singh 2020). Recreational hunting, often for amusement, is contributing to the decline of Blackbuck numbers. Instances of poaching, particularly to keep Blackbuck as pets due to their aesthetic appeal, are observed, especially among privileged sectors (Sinha and Singh 2020). Beyond its economic aspects, Blackbuck's unique morphological features make it an attractive subject for researchers, biologists, and the general public (Bolacali et al. 2017). Additionally, the species plays a crucial role in maintaining the balance of wild grasses and shrubs through its feeding habits, indirectly contributing to ecosystem equilibrium (Chandel et al. 2022). Notably, through their digestive system, Blackbuck disperses a substantial quantity of seeds, aiding in the natural growth of these plants when the defecated seeds reach the ground (A. Das et al. 2013). However, despite its ecological significance, the current population of the Indian Blackbuck remains a mere fraction of its historical numbers, predominantly due to unrelenting hunting, habitat degradation, and the introduction of invasive species (Chandel et al. 2022).

Beyond its ecological role, the preservation of the Blackbuck holds chief importance in fostering tourism development within the country (Sinha and Singh 2020). Supporters, including tourists, researchers, and animal devotees, are captivated by the Blackbuck, thereby facilitating the dissemination of cultural appreciation. This fascination extends beyond its visual allure; the Blackbuck becomes a focal point for hunting pursuits, driven by the tempting appeal of its delectable meat (Bist et al. 2021). Delving into the ecological intricacies, numerous factors contribute to the reduction of the Blackbuck's habitat, encompassing widespread agricultural pressure, hunting, invasive species, and cattle grazing (Hertaeg et al. 2021). These cumulative challenges have led to the fragmentation of its habitat, confining the species to isolated grassland areas. Investigating the behavioral activities of blackbucks is crucial for conservation as it provides essential insights into their ecological roles, adaptation strategies, and responses to environmental changes. Understanding these behaviors is fundamental for developing targeted conservation measures, ensuring the species' survival, and promoting biodiversity in their habitat. Therefore, this study aimed to quantify population fluctuations in the Rangelands of Pakistan (Cholistan desert) across recent years, provide a detailed analysis of population dynamics, and identify the effect of diurnal, seasonal or demographic variations on their behavioral activities.

## Material and Methods

### Ethical Consideration

This study was approved from the Islamia University Bahawalpur, Department of Wildlife and Forestry, Thesis Committee (Synopsis Approval no: 389/AS&R). This research was observational in nature and was conducted in complete compliance with the established guidelines stated in Pakistan's Prevention of Cruelty to Animals Act (1890), Punjab Wildlife Protection, Preservation, Conservation and Management Act (1974).

### Study Area

This research was undertaken in the Cholistan Desert, situated in the southern most regions of Punjab, Pakistan. Spanning an extensive land area of 25,800 km<sup>2</sup>, this desert is home to a population of 500,000 people residing in the districts of Bahawalnagar, Rahim Yar Khan, and Bahawalpur. It is a semi-arid desert, predominantly comprising sandy terrain, with the remaining land mass consisting of alluvial flats and small sand dunes. Summer typically corresponds to the months of May to August, monsoon season occurs from July to September, and winter spans from November to February. The average monthly rainfall in Cholistan is approximately 180mm, with the peak precipitation occurring in July and August, while droughts are a common occurrence. Water collection primarily relies on seasonal natural pools or artificially constructed pools known as Toba or Kund. Subsoil water, located at a depth of 30–40 meters, is often saline and unsuitable for the growth of the majority of plants. Our present study was conducted at three specific locations established by the Government for reintroduction and conservation of Blackbucks in Cholistan region. Blackbucks were investigated at Lal Suhanra National Park (RD25), Sheikh Mohammad Bin Zayed Al- Nahyan Conservation Centre Black Buck Enclosure and sections of Dodhlan Forest, Fort Abbas bordering the Indo-Pak border during three seasons (Summer, Monsoon and Winter) (Altaf 2022; Hussain and Altaf 2023)

### Assessment of Ecological Density

A precise enumeration of animals was carried out using binoculars to gauge the total population of blackbucks at Lal Suhanra National Park (RD25), Sheikh Mohammad Bin Zayed Al- Nahyan Conservation Centre Black Buck Enclosure and Dodhlan Forest, Fort Abbas. Concurrently, assessments were made for both population density and ecological density. Population density was defined as the overall number of animals per unit area they inhabit, while ecological density pertained to the total number of individuals within the specific habitat area available to the species (Pant et al. 2019).

Crude Population Density (D) = Total no. of individuals in an Area / Total Area(ha)

Ecological Density (ED) = Total no. of Individual / Area of the Actual Habitat (ha)

The data for different demographic groups within herds was collected between July 2019 and July 2023. Percentage increase within populations as opposed to preceding years was also determined to evaluate overall growth in number of blackbucks across the three afore mentioned sanctuaries.

### Assessment of Social Behavior

Data was collected amongst free ranging and semi-captive blackbuck herds for the assessment of diurnal social behavior (Renu, Chourasia, and Saran 2017). Behavior including, foraging, walking,

standing, resting and other miscellaneous activities were monitored for different age groups in a herd throughout the day. To this end, author of this manuscript selected 48 adult females, 28 adult males, 16 sub-adult females, 16 sub-adult males and 16 fawns to be observed during the three seasons. May, September and December months were investigated during summer, monsoon and winter seasons respectively for daytime activities.

### ***Methodology for selection and observation of Blackbuck***

During the current investigation, data were collected on the fundamental diurnal activities of blackbucks. Throughout the study, field binoculars and a GPS system integrated with a mobile device were employed for observing animals in their natural habitat. High-resolution photographs of blackbucks were captured using a dedicated camera. Behavior of selected blackbucks of specific age and sex were documented using the focal animal sampling method. Once an animal was identified in the binoculars, it was observed at 10-minute intervals for continuously 5 minutes. Observation sites that were least probable to create any potential disturbance to the blackbucks were identified. As a result, majority of the observations were conducted within a range of 50-200 meters from the focal animal or individual (Renu, Chourasia, and Saran 2017).

### ***Observation of behavioral activities in Blackbuck***

The recorded activities were grouped into distinct categories, including foraging, walking, standing, resting, and miscellaneous behaviors. Both grazing and browsing were included into Foraging activity, whereas any movement leading to a change in location was referred as Walking. However, any meaningful and intentional activity aimed towards grazing or browsing for fodder (moving or standing with head down), was identified as foraging. Activities involving, being static at a place or mating were denoted as Standing. Only duration of idly lingering at a particular spot, scanning the horizons, was deemed as time spent while standing. Recumbent animals were considered resting (either sternal or lateral). A various range of activities namely, scratching, rubbing, sparring, grooming, urination-defecation, aggression, display of dominance, territory marking, and alertness to the observer were termed as Miscellaneous activities. If multiple behaviors occurred simultaneously, all were recorded for time durations. Data collection involved observing chosen males, females, subadult males, sub-adult females, and fawns. The activities of blackbucks in all age and sex categories were examined on an hourly basis during an activity period of 6:00 am to 6:00 pm (Renu, Chourasia, and Saran 2017). Sightings of black bucks, throughout the months were divided into three seasonal periods, i.e., Summer, winter and monsoon. The data obtained from these observations were analyzed for; Diurnal, Seasonal and Demographics (age and sex) variations.

### ***Identification of Age and Sex of black bucks selected for observation***

Sex determination (male and female) was based on the presence of horns; meanwhile, individual age was categorized into three groups: adults (more than 45 cm), yearlings (sub-adults 30–45 cm), and fawns (less than 30 cm) (Tahir, Afzal, Sohail, Sobia, et al. 2022). Adults observed with fawn(s) were classified as females, as young ones typically stay close to their mothers, while others were identified as males (Fig. 1).



**Figure 1.** Demographics of a Black Buck Herd. (A) Adult Male (B) Adult Female (C) Sub- Adult Male (D) Sub-Adult Female (E) Fawn (F) Sub-Adult Female with An Adult Female

### Statistical Analysis

All the parametric values were represented as Mean  $\pm$  SD. Percentage increase in population of blackbucks in sanctuaries was calculated. Duration of time (minutes) spent while foraging, walking, resting, standing and other miscellaneous activities were analyzed for hourly, seasonal and demographic variation using One-Way ANOVA. Post-hoc Tukey's test was used to perform multiple comparisons for behavioral activities in different seasons and between different herd groups (Adult Male, Adult Female, Sub-Adult Male, Sub-Adult Female and Fawn). All analyses were performed using Statistical Software Program (SPSS for Windows, Version 20.0, USA) and GraphPad Prism (Version 8.4.3). Statistical Significance was indicated when  $P < 0.05$ .

## Results

### Ecological Density of Black Bucks

Lal Suhanra National Park, Sheikh Mohammad Bin Zayed Al- Nahyan Conservation Centre Black Buck Enclosure and Dodhlan Park, Fort Abbas were surveyed during July 2019 and July 2023 to physically determine the population density and population distribution of blackbucks in these sanctuaries. By the end of study period, it was observed that Male to Female ratio at Lal Suhanra National Park, Sheikh Mohammad Bin Zayed Al- Nahyan Conservation centre Black buck enclosure and Dodhlan Park, Fort Abbas were 2/1, 3/4 and 2/3 respectively (Table 1).

**Table 1. Recent population status of Blackbuck at different sanctuaries in Cholistan Desert, Pakistan**

Location	Year	Male		Female		Fawn	Total	Male: Female Ratio	Percentage Increase (Preceding Year)
		Adult	Sub-Adult	Adult	Sub-Adult				
Lal Suhanra National Park	2019	115	131	40	41	28	355	3/1	
	2020	127	143	49	53	40	412	8/3	16.06
	2021	117	134	83	88	52	474	3/2	15.05
	2022	138	158	70	72	57	495	2/1	4.43
	2023	140	160	78	78	61	517	2/1	4.44
Sheikh Mohammad Bin Zayed Al- Nahyan Conservation Centre Black Buck Enclosure	2019	223	9	258	46	32	568	3/4	
	2020	237	25	280	66	50	658	3/4	15.85
	2021	243	30	290	75	57	695	3/4	5.62
	2022	253	37	296	82	64	732	3/4	5.32
	2023	255	44	302	87	70	758	3/4	3.55
Dodhlan Park, Fort Abbas	2019	8	0	14	3	1	26	1/2	
	2020	9	2	12	6	7	36	3/5	38.46
	2021	11	6	13	5	7	42	1/1	16.67
	2022	12	7	14	5	7	45	1/1	7.14
	2023	11	4	14	8	9	46	2/3	2.22

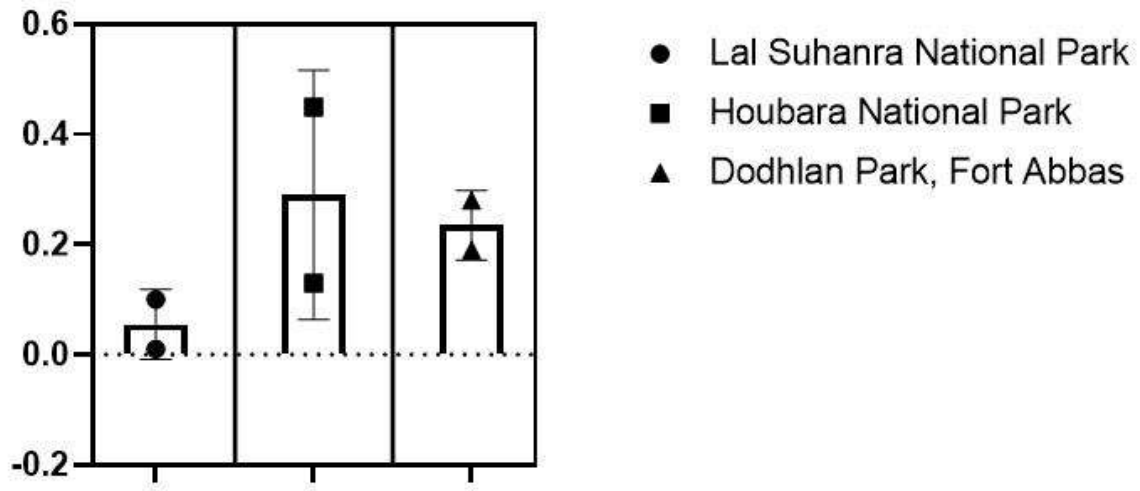
A relatively higher Percent increase in population was observed for the Year 2020 at Lal Suhanra National Park (16.06%), Sheikh Mohammad Bin Zayed Al- Nahyan Conservation Centre Black Buck Enclosure (15.85%) and Dodhlan Park, Fort Abbas (38.46%) (Table 1). In summary, by 2023, there were 140, 255 and 11 Adult Males at the three sanctuaries respectively. Similarly, Adult female numbers were observed to be 78, 302 and 14 respectively. Whereas, Sub-Adult populations of Males and Females constituted a smaller proportion of total herd (Table 1). However, Fawns were lowest in number with only 61, 70 and 9 individuals at all three sanctuaries respectively.

Land survey was essential for the present study as the researcher intended to determine the crude and ecological densities of Blackbuck populations in all three sanctuaries. It was reported that the Crude Density (D) was 0.01 (Lal Suhanra National Park), 0.13 (Sheikh Mohammad Bin Zayed Al-Nahyan Conservation Centre Black Buck Enclosure) and 0.19 (Dodhlan Park) while Ecological Density was 0.10 (Lal Suhanra National Park), 0.45 (Houbara National Park) and 0.28 (Dodhlan Park) (Table 2).

**Table 2. Estimation of Crude and Ecological Density of Blackbuck population at different sanctuaries in Cholistan Desert, Pakistan**

<b>Location</b>	<b>Total number of individuals</b>	<b>Total Area (ha)</b>	<b>Crude Density (D)</b>	<b>Area of the actual habitat (ha)</b>	<b>Ecological Density (E.D)</b>
<b>Lal Suhanra National Park</b>	517	65790.37	0.01	4985	0.10
<b>Sheikh Mohammad Bin Zayed Al-Nahyan Conservation Centre Black Buck Enclosure</b>	758	5999.60	0.13	1678	0.45
<b>Dodhlan Park, Fort Abbas</b>	46	242.82	0.19	166	0.28

A scatter plot with bars has been employed to illustrate the gap between crude and ecological densities at Lal Suhanra National Park, indicating that only a small portion of allocated land is habituated by blackbucks (Fig. 2).



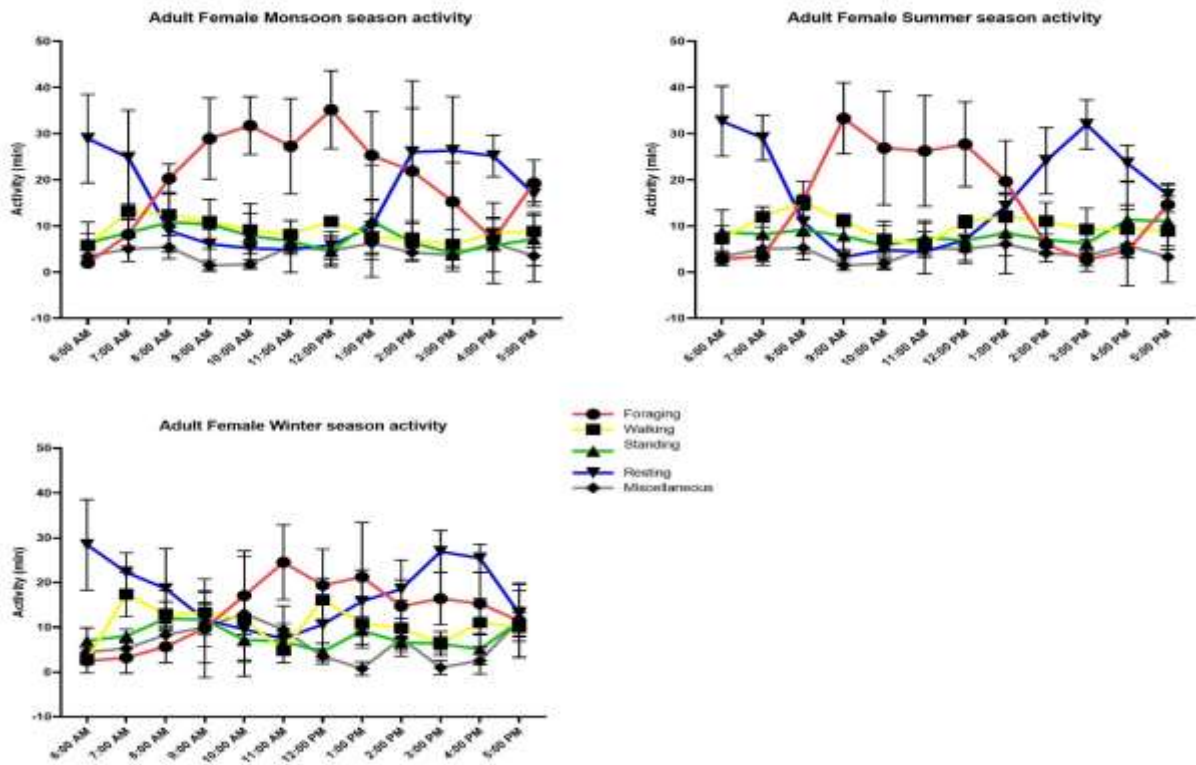
**Figure 2.** A Scatter plot with bars illustrating relationship between Crude and Ecological densities of Blackbuck sanctuaries in Cholistan, Desert

## Behavioral Activities

### a) Diurnal Variations

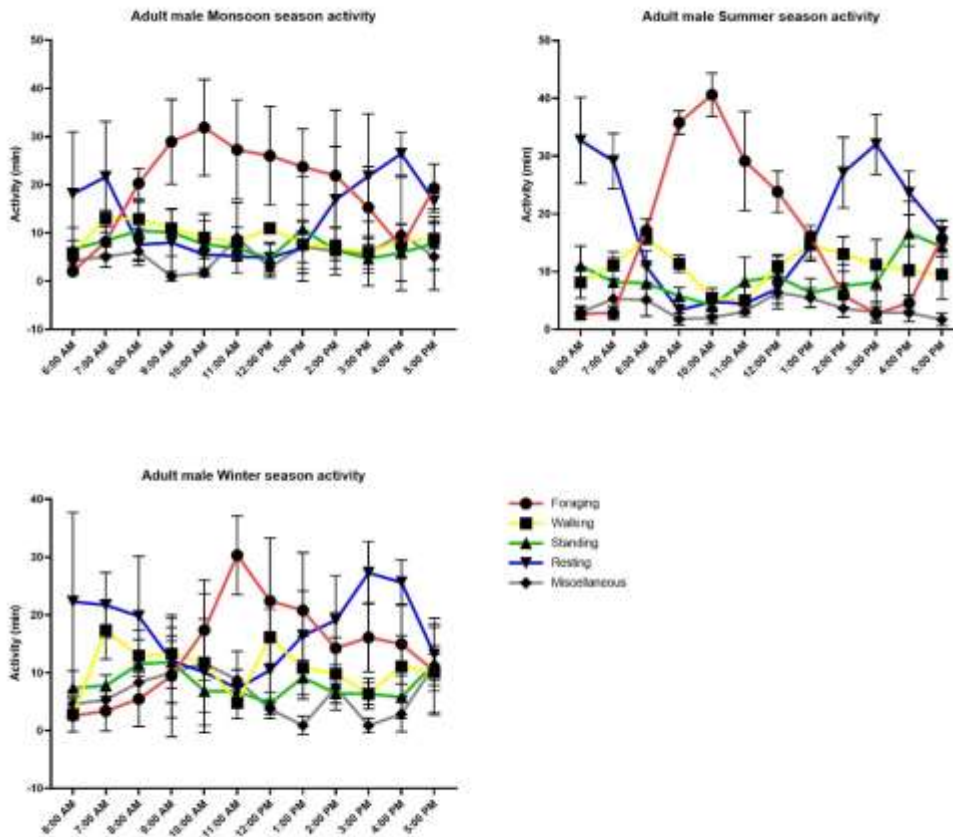
One-Way ANOVA was employed to determine if within a group, this hourly variation differed significantly. For this purpose, behavioral activities namely, foraging, walking, standing, resting and other miscellaneous ones were noted in terms of minutes on an hourly basis during three different seasons and for all the demographic groups in the herd (Adult Male, Adult Female, Sub-adult male, Sub-adult female and fawn). In case of adult females, during monsoon months Mean hourly foraging activity ranged between 2.00 to 35.21 minutes during the 6:00 AM to 6:00 PM time periods. Whereas, mean resting durations lasted between 4.91 to 28.94 minutes. All behavioral activities were observed to be significantly different ( $P < 0.0001$ ). Walking was most pronounced during summer, around 8:00 AM ( $15.13 \pm 1.65$ ) and then again by around 1:00 PM ( $12.17 \pm 4.67$ ). However, during Winter Season Adult females spent the greatest amount of time resting during the earlier hours of the day, specifically around 6:00 AM ( $28.44 \pm 10.10$ ), 7:00 AM ( $22.29 \pm 4.36$ ) and 8:00 AM ( $18.63 \pm 8.97$ ) (Fig. 3).





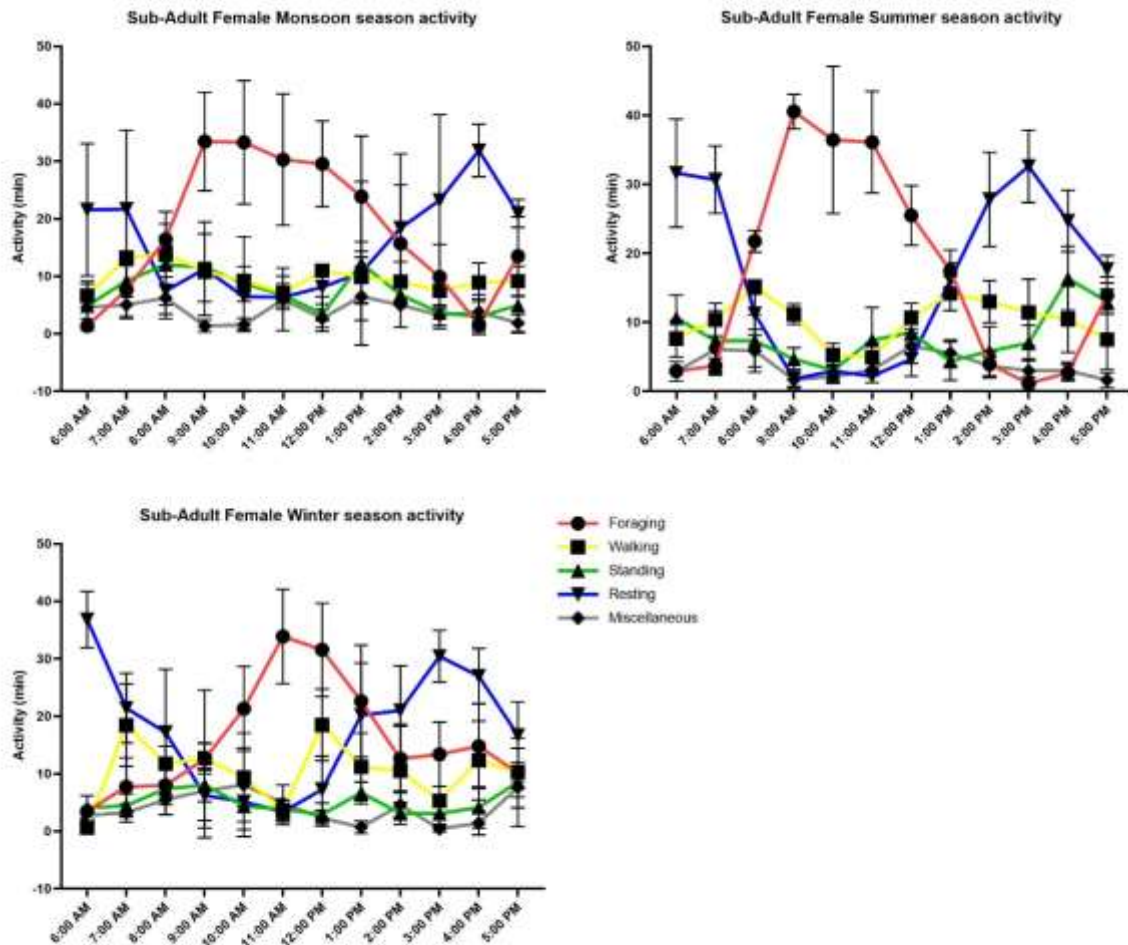
**Figure 3.** Effect of diurnal variations on behavioral activities of an Adult Female Blackbuck during Monsoon, Summer and Winter

Adult males during monsoon season experienced relatively higher foraging ( $19.29 \pm 5.02$ ) and resting ( $16.61 \pm 1.62$ ) durations around 5:00 PM. While during summer season, only their miscellaneous activities were observed to be non-significant in a diurnal period, foraging activity spiked at around 10:00 AM ( $40.61 \pm 3.75$ ) and resting was predominantly observed around 6:00 AM ( $32.71 \pm 7.44$ ). Whereas, in Winter the greatest duration for foraging was observed much later in the day i.e., at 12:00 PM ( $22.43 \pm 10.88$ ) (Fig. 4).



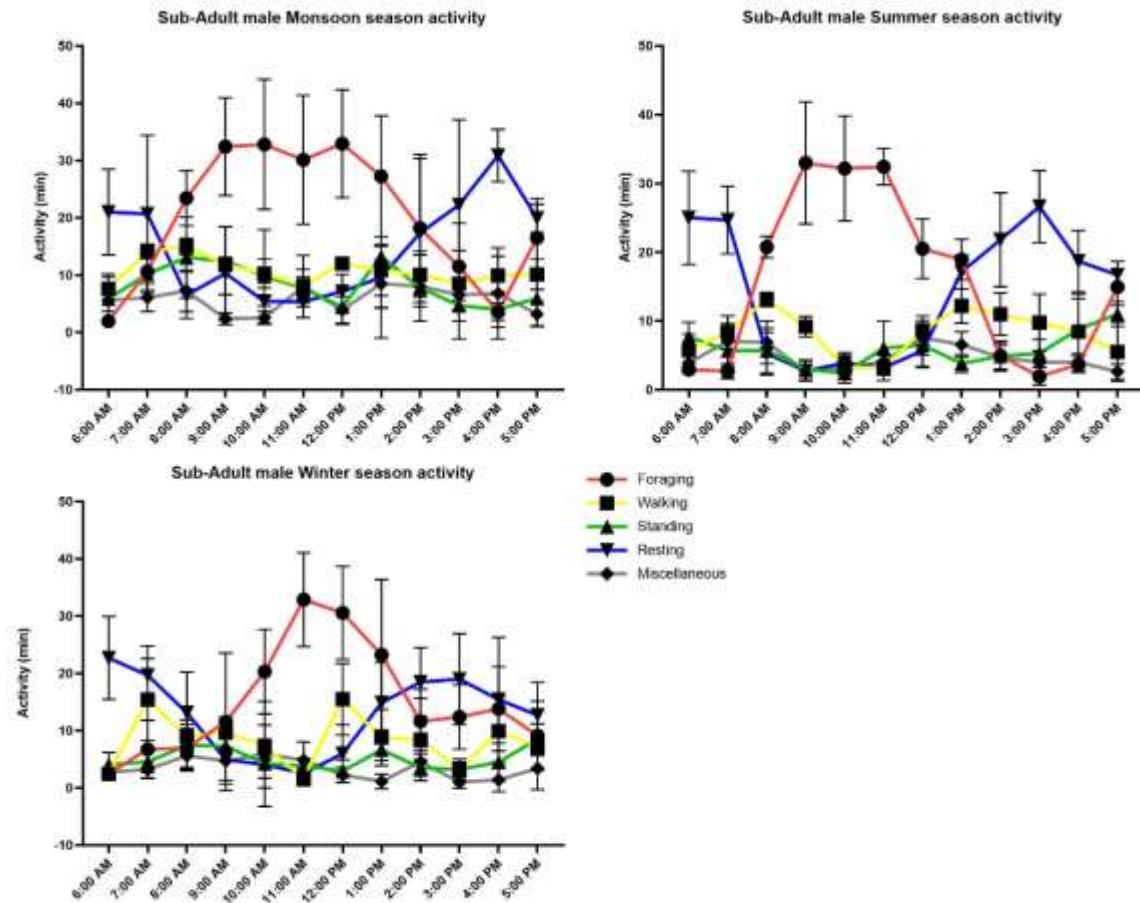
**Figure 4.** Effect of diurnal variations on behavioral activities of an Adult Male Blackbuck during Monsoon, Summer and Winter.

When compared within a group, walking ( $P=0.0990$ ), standing ( $P=0.6828$ ) and miscellaneous ( $P>0.9999$ ) activities were non-significant for Sub-Adult Females during Monsoon Season. While, foraging and resting activities were significantly different across the 12-hour monitoring period ( $<0.0001$ ). As opposed to other demographic groups of the herd, duration for miscellaneous behavior were much lower amongst sub-adult females. Peak foraging activity was observably higher during summer ( $40.56\pm 2.50$ ), while comparably lower during monsoon ( $33.44\pm 8.54$ ) and winter ( $33.88\pm 8.19$ ) (Fig. 5).



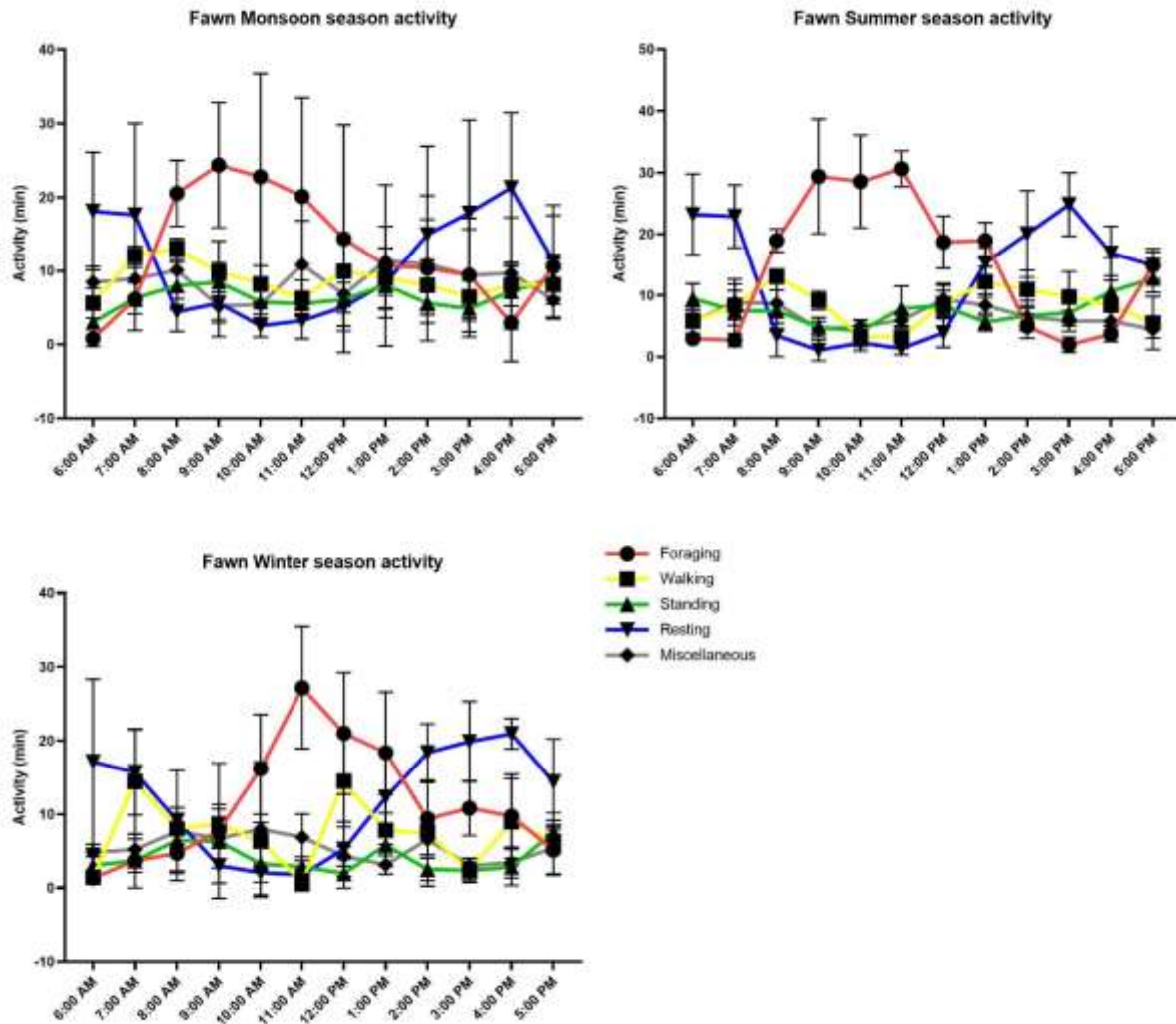
**Figure 5.** Effect of diurnal variations on behavioral activities of Sub-Adult Female Blackbuck during Monsoon, Summer and Winter

Similarly, Resting and foraging activities were statistically significant ( $P < 0.0001$ ) during monsoon season, in Sub-Adult Males. During summer season, peak resting values were observed a bit lower than that of Monsoon, whereby highest value was observed around 3:00 PM ( $26.63 \pm 5.24$ ). Resting was most pronounced during winter season amongst Sub-Adult males, specifically at 6:00 AM ( $22.69 \pm 7.23$ ) and 7:00 AM ( $19.69 \pm 5.12$ ). During winter an anomalously large peak in walking activity was observed around 12 PM amongst (Fig. 6).



**Figure 6.** Effect of diurnal variations on behavioral activities of a Sub-Adult Male Blackbuck during Monsoon, Summer and Winter

Amongst fawns, overall activity budget was much lower than other demographic groups of the herd. During monsoon first peak hours of foraging, walking, standing, resting and other activities were observed during 9:00 AM ( $24.38 \pm 8.48$ ), 8:00 AM ( $13.00 \pm 1.41$ ), 9:00 AM ( $8.50 \pm 5.55$ ), 6:00 AM ( $18.13 \pm 8.02$ ) and 8:00 AM ( $10.13 \pm 3.93$ ) respectively. The line graph with plot symbols illustrated that foraging activity was most pronounced in fawn between 7:00 AM and 2:00 PM, without any significant dips. However, peak foraging period was limited during winter seasons between 9:00 AM to 2:00 PM (Fig. 7).



**Figure 7.** Effect of diurnal variations on behavioral activities of Fawn Blackbuck during Monsoon, Summer and Winter

**Seasonal Variations**

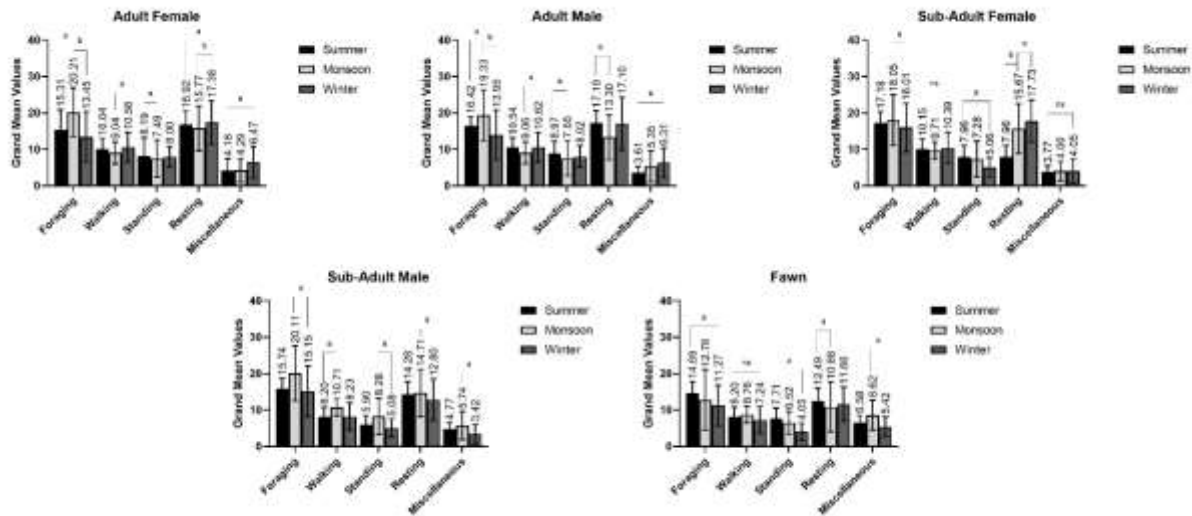
Behavioral activities namely, foraging, walking, standing, resting and other miscellaneous activities were evaluated for seasonal variations as well. In Adult Females, observations for all behavioral activities differed statistically ( $P < 0.0001$ ) (Table 3).

**Table 3. Behavioral Activities of Adult Female, Adult Male, Sub-Adult Female, Sub-Adult Male and Fawn during Summer, Monsoon and Winter Seasons represented as Grand Mean  $\pm$  SD values and analyzed for seasonal variations using One-Way ANOVA and Post-hoc Tukey's multiple comparisons test**

Herd Demographics	Behavioral Activities	Summer	Monsoon	Winter	P Value
Adult Female	Foraging	15.31 $\pm$ 5.59 <sup>b</sup>	20.21 $\pm$ 6.66 <sup>a</sup>	13.45 $\pm$ 6.91 <sup>c</sup>	<0.0001
	Walking	10.04 $\pm$ 3.04 <sup>b</sup>	9.04 $\pm$ 3.01 <sup>c</sup>	10.58 $\pm$ 4.07 <sup>a</sup>	<0.0001
	Standing	8.19 $\pm$ 5.07 <sup>a</sup>	7.49 $\pm$ 5.05 <sup>b</sup>	8.00 $\pm$ 2.87 <sup>a</sup>	0.0403
	Resting	16.92 $\pm$ 3.59 <sup>a</sup>	15.77 $\pm$ 6.15 <sup>b</sup>	17.38 $\pm$ 6.01 <sup>a</sup>	<0.0001
	Miscellaneous	4.18 $\pm$ 3.25 <sup>b</sup>	4.29 $\pm$ 3.27 <sup>b</sup>	6.47 $\pm$ 4.35 <sup>a</sup>	<0.0001
Adult Male	Foraging	16.42 $\pm$ 2.65 <sup>b</sup>	19.33 $\pm$ 6.98 <sup>a</sup>	13.95 $\pm$ 6.88 <sup>c</sup>	<0.0001
	Walking	10.54 $\pm$ 2.64 <sup>a</sup>	9.06 $\pm$ 3.00 <sup>b</sup>	10.62 $\pm$ 4.11 <sup>a</sup>	<0.0001
	Standing	8.97 $\pm$ 3.20 <sup>a</sup>	7.55 $\pm$ 4.79 <sup>b</sup>	8.02 $\pm$ 2.97 <sup>b</sup>	<0.0001
	Resting	17.19 $\pm$ 3.44 <sup>a</sup>	13.30 $\pm$ 6.23 <sup>b</sup>	17.10 $\pm$ 7.24 <sup>a</sup>	<0.0001
	Miscellaneous	3.61 $\pm$ 1.70 <sup>c</sup>	5.35 $\pm$ 4.29 <sup>b</sup>	6.31 $\pm$ 4.06 <sup>a</sup>	<0.0001
Sub-Adult Female	Foraging	17.18 $\pm$ 3.18 <sup>b</sup>	18.05 $\pm$ 6.92 <sup>a</sup>	16.01 $\pm$ 6.64 <sup>b</sup>	0.0097
	Walking	10.15 $\pm$ 2.74 <sup>a</sup>	9.71 $\pm$ 2.37 <sup>a</sup>	10.39 $\pm$ 4.29 <sup>a</sup>	0.1836
	Standing	7.96 $\pm$ 3.17 <sup>a</sup>	7.28 $\pm$ 4.97 <sup>a</sup>	5.06 $\pm$ 2.59 <sup>b</sup>	<0.0001
	Resting	17.01 $\pm$ 3.58 <sup>a</sup>	15.67 $\pm$ 6.86 <sup>b</sup>	17.73 $\pm$ 5.81 <sup>a</sup>	<0.0001
	Miscellaneous	3.77 $\pm$ 1.76 <sup>a</sup>	4.00 $\pm$ 2.62 <sup>a</sup>	4.05 $\pm$ 3.25 <sup>a</sup>	0.661
Sub-Adult Male	Foraging	15.74 $\pm$ 3.09 <sup>b</sup>	20.11 $\pm$ 7.55 <sup>a</sup>	15.15 $\pm$ 6.92 <sup>b</sup>	<0.0001
	Walking	8.20 $\pm$ 2.64 <sup>b</sup>	10.71 $\pm$ 2.37 <sup>a</sup>	8.23 $\pm$ 3.71 <sup>b</sup>	<0.0001
	Standing	5.90 $\pm$ 2.62 <sup>b</sup>	8.28 $\pm$ 4.97 <sup>a</sup>	5.08 $\pm$ 2.47 <sup>b</sup>	<0.0001
	Resting	14.28 $\pm$ 3.51 <sup>a</sup>	14.71 $\pm$ 6.52 <sup>a</sup>	12.80 $\pm$ 5.74 <sup>b</sup>	0.0085
	Miscellaneous	4.77 $\pm$ 1.76 <sup>b</sup>	5.74 $\pm$ 3.84 <sup>a</sup>	3.42 $\pm$ 2.69 <sup>c</sup>	<0.0001
Fawn	Foraging	14.69 $\pm$ 3.16 <sup>a</sup>	12.78 $\pm$ 8.31 <sup>b</sup>	11.27 $\pm$ 5.59 <sup>b</sup>	<0.0001
	Walking	8.20 $\pm$ 2.64 <sup>a</sup>	8.76 $\pm$ 2.26 <sup>a</sup>	7.24 $\pm$ 3.71 <sup>b</sup>	<0.0001
	Standing	7.71 $\pm$ 2.85 <sup>a</sup>	6.52 $\pm$ 3.08 <sup>b</sup>	4.05 $\pm$ 2.32 <sup>c</sup>	<0.0001
	Resting	12.49 $\pm$ 3.57 <sup>a</sup>	10.88 $\pm$ 6.84 <sup>b</sup>	11.66 $\pm$ 4.64 <sup>b</sup>	0.0324
	Miscellaneous	6.58 $\pm$ 1.94 <sup>b</sup>	8.62 $\pm$ 4.09 <sup>a</sup>	5.42 $\pm$ 2.69 <sup>c</sup>	<0.0001

\*Values are represented as Mean  $\pm$  SD. Different superscripts (a, b, c) within a row indicate statistical significance when P<0.05

In case of adult males, walking activity was non-significant between summer and winter (P=0.9575). Whereas, for standing activity, Monsoon and Winter durations were non-significant (P=0.2833). It was observed that unlike Adult males and females, foraging times differed only during monsoon and winter seasons (P=0.0069) in Sub-Adult females. Moreover, none of the seasons differed significantly for walking activity (Fig. 8). Except in fawns, mean duration of foraging were observably highest during monsoon season.



**Figure 8.** Interleaved Bar Chart illustrating the effect of Seasonal variations on Behavioral Activities of Adult Female, Adult Male, Sub-Adult Female, Sub-Adult Male, Fawn Blackbuck during Monsoon, Summer and Winter. Statistical significance is indicated by different superscripts (a, b, c) when P<0.05

**Demographic Variations**

When cumulative mean for each of the behavioral activities were summated, it was observed that during summer foraging activity ranged between 176.25±15.43 to 206.19±20.87 minutes, while that of resting ranged between 149.94±19.54 to 206.29±17.20 minutes. Behavioral activities namely, Foraging (P<0.0001), Walking (P<0.0001), Standing (P=0.0996), Resting (P<0.0001) and Miscellaneous (P<0.0001) ones were significantly different in monsoon season as well (Table 4).

**Table 4.** Total duration of Daily Behavioral Activities for Adult Female, Adult Male, Sub-adult female, Sub-adult male and Fawns during Summer, Monsoon and Winter Seasons represented as Cumulative Mean ± SD and analyzed for variations using One-Way ANOVA and Post-hoc Tukey's multiple comparisons test

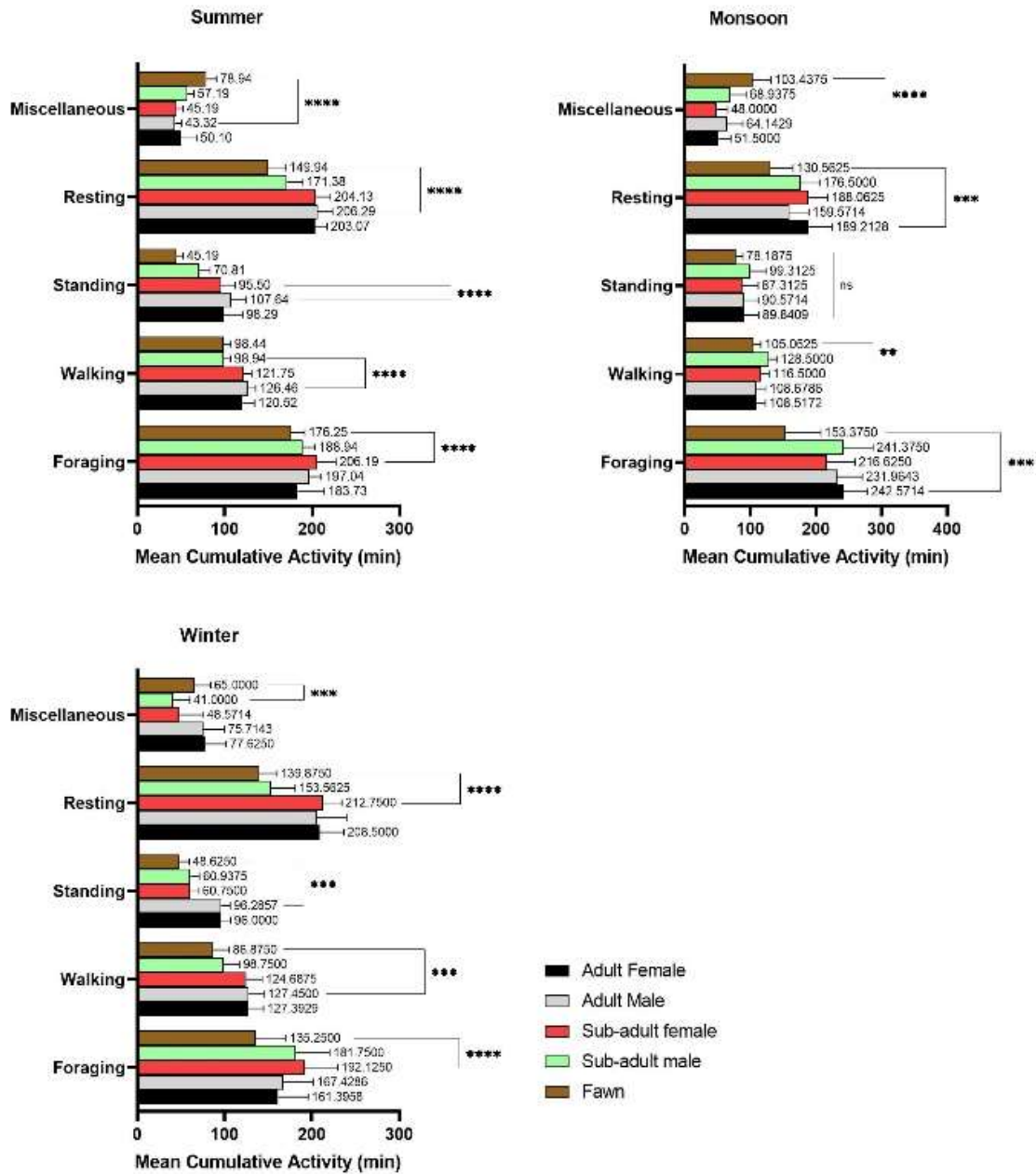
Behavioral Activities	Adult Female	Adult Male	Sub-adult female	Sub-adult male	Fawn	P Value
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
<b>Summer</b>						
<b>Foraging</b>	183.73±30.18 <sup>b</sup>	197.04±13.44 <sup>b</sup>	206.19±20.87 <sup>a</sup>	188.94±14.47 <sup>b</sup>	176.25±15.43 <sup>c</sup>	0.0008
<b>Walking</b>	120.52±13.60 <sup>a</sup>	126.46±8.99 <sup>a</sup>	121.75±9.18 <sup>a</sup>	98.94±7.97 <sup>b</sup>	98.44±8.59 <sup>c</sup>	<0.0001
<b>Standing</b>	98.29±22.14 <sup>b</sup>	107.64±16.79 <sup>a</sup>	95.50±16.40 <sup>b</sup>	70.81±12.24 <sup>b</sup>	45.19±7.27 <sup>c</sup>	<0.0001

<b>Resting</b>	203.07±14.01 <sup>a</sup>	206.29±17.20 <sup>a</sup>	204.13±17.09 <sup>a</sup>	171.38±18.15 <sup>b</sup>	149.94±19.54 <sup>c</sup>	<0.0001
<b>Miscellaneous</b>	50.10±17.69 <sup>c</sup>	43.32±7.37 <sup>c</sup>	45.19±7.27 <sup>c</sup>	57.19±7.27 <sup>b</sup>	78.94±11.61 <sup>a</sup>	<0.0001
<b>Monsoon</b>						
<b>Foraging</b>	242.57±36.30 <sup>a</sup>	231.96±38.73 <sup>a</sup>	216.63±42.83 <sup>a</sup>	241.38±45.69 <sup>a</sup>	153.38±53.85 <sup>b</sup>	<0.0001
<b>Walking</b>	108.52±14.29 <sup>c</sup>	108.68±14.53 <sup>c</sup>	116.50±11.70 <sup>b</sup>	128.50±11.70 <sup>a</sup>	105.06±10.78 <sup>c</sup>	<0.0001
<b>Standing</b>	89.84±22.51 <sup>a</sup>	90.57±21.34 <sup>a</sup>	87.31±24.19 <sup>a</sup>	99.31±24.19 <sup>a</sup>	78.19±10.01 <sup>b</sup>	0.0996
<b>Resting</b>	189.21±35.10 <sup>a</sup>	159.57±29.55 <sup>b</sup>	188.06±29.99 <sup>a</sup>	176.50±28.89 <sup>b</sup>	130.56±34.30 <sup>c</sup>	<0.0001
<b>Miscellaneous</b>	51.50±18.46 <sup>b</sup>	64.14±24.02 <sup>b</sup>	48.00±16.66 <sup>b</sup>	68.94±24.22 <sup>b</sup>	103.44±27.37 <sup>a</sup>	<0.0001
<b>Winter</b>						
<b>Foraging</b>	161.40±34.36 <sup>b</sup>	167.43±33.97 <sup>b</sup>	192.13±37.33 <sup>a</sup>	181.75±38.52 <sup>a</sup>	135.25±35.12 <sup>c</sup>	<0.0001
<b>Walking</b>	127.39±17.32 <sup>a</sup>	127.45±17.79 <sup>a</sup>	124.69±18.23 <sup>a</sup>	98.75±18.34 <sup>b</sup>	86.88±18.44 <sup>b</sup>	<0.0001
<b>Standing</b>	96.00±11.08 <sup>a</sup>	96.29±10.17 <sup>a</sup>	60.75±10.11 <sup>b</sup>	60.94±10.40 <sup>b</sup>	48.63±10.66 <sup>c</sup>	<0.0001
<b>Resting</b>	208.50±28.06 <sup>a</sup>	205.21±34.47 <sup>a</sup>	212.75±21.44 <sup>a</sup>	153.56±27.63 <sup>b</sup>	139.88±20.35 <sup>c</sup>	<0.0001
<b>Miscellaneous</b>	77.63±24.29 <sup>a</sup>	75.71±24.28 <sup>a</sup>	48.57±27.40 <sup>b</sup>	41.00±19.25 <sup>c</sup>	65.00±19.25 <sup>b</sup>	<0.0001

\*Values are represented as Mean ± SD. Different superscripts (a, b, c) within a row indicate statistical significance when P<0.05

In case of foraging during summer multiple comparisons between, Adult Female and Sub-adult female (P=0.0071), Adult Male and Fawn (P=0.0324), Sub-adult female and Fawn (P=0.0026) yielded significant outcomes. Whereas during monsoon season, Adult Female and Fawn (P<0.0001), Adult Male and Fawn (P<0.0001), Sub-adult female and Fawn (P=0.0003), Sub-adult male and Fawn (P<0.0001) comparisons were also significantly different. Moreover, in winter scenario, foraging activities were significantly different amongst, Adult Female and Sub-adult male (P<0.0001), Adult Female and Fawn (P<0.0001), Adult Male and Sub-adult male (P<0.0001), Adult Male and Fawn (P<0.0001), Sub-adult female and Sub-adult male (P=0.0007), Sub-adult female and Fawn (P<0.0001) as well (Fig. 9).





**Figure 9.** Cumulative Mean values for a 12hr period are represented through Interleaved Bar Charts illustrating the effect of Age and Sex on Behavioral Activities during Monsoon, Summer and Winter. Significant differences ( $P < 0.05$ ) amongst demographic groups have been indicated by GP style: 0.1234 (ns), 0.0332 (\*), 0.0021 (\*\*), 0.0002 (\*\*\*\*),  $< 0.0001$  (\*\*\*\*)

## Discussion

Once widespread across the Indian subcontinent, Blackbucks have undergone a substantial reduction in their habitat, resulting in their extinction in Bangladesh and Pakistan. In Pakistan, the species now exists mostly in captive or semi-captive conditions, with regional extinction in its native distribution. Whereas, globally the conservation status has fluctuated from "Vulnerable" to "Least Concern" since 2016 (Tahir, Afzal, Sohail, Abid, et al. 2022; Mirza and Waiz 1973; R. Meena, Saran, and Chourasia 2017). In line with previous investigators, the researcher of this manuscript consistently monitored habitats using both walking and bicycling throughout the research duration (U. K. Das and Sudhakar 2015; Renu, Chourasia, and Saran 2017; M. Meena and Kumar Jaipal 2020). Aided by binoculars, the author diligently recorded blackbuck gatherings and used a count clicker to document individuals within different age groups. Due to seasonal variation, the authors observed blackbucks predominantly assembling in specific foraging grounds during the monsoon, while they were more easily sighted in the expansive arid grasslands and shrubs off the desert during winter (Choudhary and Chisty 2022). Blackbucks are legally protected in South Asian countries; however, threats from poachers and ecological disasters have restricted their population to only a few protected areas. Therefore, ongoing monitoring and conservation efforts for preserving the blackbuck population are imperative (P. Khanal 2002; Tahir, Afzal, Sohail, Sobia, et al. 2022).

In our recent study, Lal Suhanra National Park, Sheikh Mohammad Bin Zayed Al- Nahyan Conservation Centre Black Buck Enclosure, and Dodhlan Park in Fort Abbas were surveyed during 2019-23 to physically ascertain the population density and distribution of blackbucks in these sanctuaries. Male-to-female ratios observed during current study, aligned with prior investigations by Khanal, (2002). Moreover, similar growth rates were reported in the Protected Blackbuck Conservation Area (PBCA) during non-covid years. Whereas, another investigation indicated that among adults, the male-to-female ratios were 1:2.3 (M. Meena and Kumar Jaipal 2020). Contrastingly, in the Hisar region of India, a case study spanning 2017 to 2019 (Delu et al. 2023) revealed that male-to-female sex ratio was reportedly 1:4, demonstrating a significant resurgence in protected areas, particularly in Vishnoi-dominated regions in Rajasthan and Haryana, India (Tahir, Afzal, Sohail, Sobia, et al. 2022; Khalil et al. 2020; P. Khanal 2002; Jyoti and Rai 2021). However, in our current study researchers reported that both the Adult and sub-adult populations of females constituted a much smaller proportion of the total herd. Despite the improvement of Lal Suhanra National Park's allocated land from 77,480 acres in 1972 to its present size of 162,568 acres and reduced competition for grazing from domestic livestock through fencing, the blackbuck population in Cholistan desert has stagnated over the last decade. A similar issue was reported in Nepal, where authors noted a decline in population from 190 individuals, attributing it to inbreeding (P. Khanal 2002). The spatial detectability and density distribution of Blackbucks are intricately linked to environmental factors (Choudhary and Chisty 2022). Due to extremely harsh climate conditions and abundant shrub coverage, the Crude Density (D) at Lal Suhanra National Park, Houbara National Park, and Dodhlan forest was reported to be 1, 13, and 19 individuals/km<sup>2</sup> respectively, while a Protected Blackbuck Conservation Area (PBCA) in Nepal set up similarly in the 1970s, reported a crude density of Blackbucks at 12.38 individuals/km<sup>2</sup> in the total area covering 5.25 km<sup>2</sup> (L. Khanal and Chalise 2011; P. Khanal 2002). Authors have posited that due to the sheer size of Lal Suhanra National Park, its crude density for blackbucks could be misleading. Most of the fenced landmass is uninhabitable by blackbucks, and they are mostly concentrated in specific habitats in the sanctuary (Mirza and Waiz 1973). Previously,

research surveying PBCA in Nepal encountered a comparable issue and identified the specific patch of the sanctuary inhabited by blackbucks, thereby reporting a much higher ecological density of 32.82 individuals/km<sup>2</sup> in Pataha phanta (P. Khanal 2002). The authors of this manuscript report similar findings, whereby when population densities were calculated specifically for core habitats at Lal Suhanra National Park, it improved from 1 to 10 individuals per km<sup>2</sup>.

Understanding how blackbucks allocate their time among various activities is essential for gaining insights into their life cycle (Sankaran and Ahrestani 2016b) and establishing a foundation for comprehending their ecology and behavior (Jhala and Isvaran 2016). Blackbucks are unique as they can both be browsers as well as grazers (Frank et al. 2021). Their diet is composed of cereals, grasses and bushes (Farooq et al. 2022). Researchers have postulated that in addition to climate, time of the day, provision of food, and group size affected the foraging behavior (Farooq et al. 2022). Succinctly, larger herds would often devote greater amount of time foraging as limited feed resources would be available to them. Moreover, blackbucks living in harsher terrains might also have to traverse longer distances for food and water (Bhaskar, Kanaparthi, and Sakthivel 2021). Several challenges including, high sensitivity of wild animals to human interaction, poor visibility through thick forest and low population density (Renu, Chourasia, and Saran 2017) were commonly experienced in prior and current investigations. Animals fleeing upon spotting the observer, caused a serious limitation towards data collection. However, in present settings, authors were aided by the predominantly arid nature of the study area in this regard. Therefore, author had a relatively clearer line of sight during daylight hours (Choudhary and Chisty 2022). Furthermore, while approaching these herds, researcher employed a bicycle or just walked on foot so that they may not flee after hearing the sound of an automotive. Similar to previous publications, authors observed that feeding was the most time-consuming activity (Renu, Chourasia, and Saran 2017).

Prior investigations have established that diurnal animals follow peculiar feeding patterns whereby, feeding activities peak in early morning hours and are usually followed by a resting phase during midday (Frank et al. 2021). Subsequently, feeding activities resume in these animals during late afternoon hours (A. Das et al. 2013). Diurnal activity patterns are polyphasic, including foraging, resting, standing, and walking, with a bimodal distribution and seasonal variations (Farooq et al. 2022). Several studies have suggested that behavioral activities might also be influenced by demographics namely age and sex of animal (Baskaran et al. 2011). Therefore, author of this manuscript endeavored to investigate and statistically analyze five distinct groups in a blackbuck herd, namely adult male, adult female, sub-adult male, sub-adult female and fawns. Their diurnal activities were tabulated during three seasons, summer, monsoon and winter. Patterns of feeding, resting, walking, standing and other activities followed a definite schedule and peaked at specific hours of the day during particular seasons. In present circumstances, authors mainly observed a biphasic incremental or detrimental change in durations for most activities. Though there have been instances of blackbucks foraging at night, but most prior studies have considered the hours with daylight as the activity hours (Baskaran et al. 2011). Therefore, our present study was justified in conducting observations only during the day time when foraging was most prevalent. In similarly, designed prior investigations a bimodal distribution of activity was observed for all ages of Blackbucks involving a morning peak of foraging starting from 08:00 AM and extending till 10:00 AM. After a short respite, a second peak in activity was also reported during evening hours, between 4:00 and 6:00 PM (Renu, Chourasia, and Saran 2017). Our findings were consistent with these earlier reports, as during 6:00 AM and 5:00 PM hours, authors of this manuscript observed similar peaks in early morning and during later in the day. However,

considering the harsher climate of present study area and rougher topography, the feeding frenzy ensued up until later in the day, mainly till 12:00 PM. Similarly, the second foraging peak came bit later in the day than what was reported earlier (Renu, Chourasia, and Saran 2017). This variation from prior data could certainly be rationalized by the difference in weather of Cholistan desert, whereby most diurnal animals rested for longer, during midday hours (Baskaran et al. 2011). Apart from the adult female's anomalous behavior regarding their peak foraging hours, remaining demographic groups behaved comparably to the prior findings (Renu, Chourasia, and Saran 2017; Baskaran et al. 2011; Farooq et al. 2022; Sankaran and Ahrestani 2016a). Moreover, authors have identified that females of herd, even the yearling ones, foraged for longer durations than male ones. This was especially true during breeding seasons, when males were often engaged in lekking behavior (Isvaran 2005). Additionally, peaks in diurnal foraging activity were preceded by walking activity. Irrespective of peak durations, analysis of cumulative mean durations for walking and standing in adults exhibited increased activity during both the summer and winter seasons as opposed to monsoon. Authors of this manuscript have posited that this may be attributed to the seasonal rutting periods which are much more frequent during drier months. Such deductions have been indicated by earlier publications as well (Renu, Chourasia, and Saran 2017). Authors observed a bell-shaped curve for foraging activity, which was inversely followed by resting (Renu, Chourasia, and Saran 2017). However, age played a significant role as fawns dedicated most of their time to resting and other miscellaneous activities. Seasonal changes critically affected these behavioral activities as well. It has been postulated that seasonal changes impacted vegetation availability and quality, affecting foraging habits (Choudhary and Chisty 2022). This has been apparent in our present study as well, whereby both adult male and female blackbucks spent the most amount of time invested in foraging during monsoon season followed by summer and then lastly winter (Farooq et al. 2022). This could be justified by the fact that forage is most abundant during monsoon, making it possible for all individuals of the herd to graze as much they desire. This rationalization would be especially true in present circumstances as the area of study was quite arid during summer and therefore foliage was limited during harsher months (Baskaran et al. 2011). Concurrently, author also observed seasonal movements by blackbuck, causing them to cover longer distances during summer and winter months due to scarcity of available fodder. This was evident from highest mean durations for walking during winter season in both adult male ( $10.62 \pm 4.11$ ) and female ( $10.58 \pm 4.07$ ) animals (Baskaran et al. 2011; Jhala and Isvaran 2016; Renu, Chourasia, and Saran 2017; Farooq et al. 2022). Blackbucks remained reproductively active throughout the year, however, lekking and rutting were most intensified by the end of winters. They have a 6-month gestation period so fawning in most females was reported during pre-monsoon and monsoon seasons (Isvaran 2005).

## Conclusion

At the conclusion of the research period in 2023, it was evident that the Male to Female ratios at Lal Suhanra National Park, Sheikh Mohammad Bin Zayed Al- Nahyan Conservation Centre Black Buck Enclosure, and Dodhlan Park in Fort Abbas were 2/1, 3/4, and 2/3, respectively. A relatively higher growth rate in the blackbuck population during the year 2020 at Lal Suhanra National Park (16.06%), Sheikh Mohammad Bin Zayed Al- Nahyan Conservation Centre Black Buck Enclosure (15.85%), and Dodhlan Park in Fort Abbas (38.46%), indicated a positive impact of COVID-19-related lockdown measures. Blackbucks exhibited a polyphasic diurnal nature whereby multiple behavioral activities, were intricately intertwined with foraging. Foraging activities peaked from late morning to midday and again just before dusk, while afternoon hours were predominantly

spent resting. Peaks in all behavioral activities varied with seasonal changes. Adult blackbucks exhibited longer durations of foraging, while fawns were frequently observed engaging in miscellaneous activities compared to other age groups. This study has endeavored to emphasize the significant impact of diurnal, seasonal, and demographic variations on the durations of different behavioral activities.

### **Recommendations and Future Perspectives**

When systematically implemented, these strategies could contribute to the long-term conservation and sustainable management of the blackbuck habitats in Cholistan Desert:

1. Establish and maintain outer boundaries around blackbuck habitats to minimize conflicts with local livestock, enforce sustainable grazing practices, and prevent illegal poaching.
2. Create wildlife corridors connecting fragmented habitats, promoting blackbuck movement and genetic diversity.
3. Engage local communities in habitat conservation through education programs, emphasizing mutual benefits for both communities and blackbucks.
4. Conduct ongoing research to monitor habitat changes and assess the effectiveness of conservation strategies, especially considering climate change impacts.
5. Develop conservation policies tailored to Cholistan Desert's unique ecology, incorporating climate-resilient planting and restoration techniques.
6. Collaborate with governmental bodies to establish and enforce regulations protecting critical blackbuck habitats.
7. Seek collaboration with international conservation organizations, research institutions, and experts to leverage global expertise and resources for joint research projects and funding to support habitat conservation initiatives

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