Original Article
DOI: https://doi.org/10.70749/ijbr.v3i4.380

INDUS JOURNAL OF BIOSCIENCE RESEARCH
https://induspublishers.com/IJBR
ISSN: 2960-2793/ 2960-2807

Spatial and Temporal Dynamics of Sexual Segregation in Kashmir Markhor *Capra falconeri cashmiriensis* in Chitral Gol National Park

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ARTICLE INFO

Keywords

Aggregation, Chitral Gol National Park, Kashmir Markhor, Seasonal Variation, Segregation, Spatial Behavior, Wildlife Ecology.

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Declaration

Authors' Contribution: All authors equally contributed to the study and approved the final manuscript.
Conflict of Interest: No conflict of interest.
Funding: No funding received by the authors.

Article History

Received: 14-01-2025, Revised: 20-03-2025
Accepted: 07-04-2025, Published: 22-04-2025

ABSTRACT

The study explores the spatial patterning and social grouping of Kashmir Markhor (*Capra falconeri cashmiriensis*) populations in Chitral Gol National Park, Pakistan, through systematic scoring of the Social Segregation and Aggregation Statistic (SSAS) during different seasons and across various habitat types. This research is particularly significant given the vulnerable status of the Kashmir Markhor and the need for informed conservation strategies. Data were collected through point and focal animal sampling every fortnight over a span of two years in diverse park habitats. The study revealed variation in behavior across habitats, with aggregation behavior dominating in the forested areas. This behavioral tendency may reflect the species' preference for cover and resources in densely vegetated landscapes. The Kruskal-Wallis H-test indicated no significant differences in SSAS values across winter, spring, summer, and autumn, suggesting that the spatial behavior of markhor remains consistent across seasons. These results provide a comprehensive overview of how seasonal and habitat-related factors influence social behavior in this endangered species. Such insights are crucial for wildlife managers and conservationists working to protect and maintain healthy populations of the species in the wild. These findings are valuable for managing vulnerable Markhor populations by enhancing understanding of their social structure and movement patterns in Chitral Gol National Park. The study contributes meaningfully to the ecological literature on ungulate social behavior and offers guidance for future research aimed at long-term conservation planning in protected mountainous ecosystems.

INTRODUCTION

Social aggregation and segregation constitute a central tenet in the ecological study of wildlife especially in self-regulating ungulate populations inhabiting harsh and resource-limited environments [4]. One of the major determinants of social organization is the level or the degree to which individuals and or groups aggregate, which is in relation to ecological and biological factors [2]. Such patterns can be formed by resource availability, risk of predation and other environmental differences; and determine how species assemblages and resilience evolve with changing environments [15]. For endangered species like the Kashmir Markhor (*Capra falconeri cashmiriensis*), conservation management relies on an understanding of social structure which can be gleaned from segregation and aggregation studies [12].

Research on ungulates has shown that factors such as seasonality, altitude, and habitat type impact sexual segregation and aggregation patterns[14]. Patterning of such behavior is normally in alignment with the research on ungulates previous studies [18]. However, such patterns are specific to the species and the habitat occupied leading to the need for such studies to be carried out to understand behavioral changes as a result of the ecological shifts.[7] With respect to the Kashmir Markhor, the steep and rugged terrain of Chitral Gol National Park and the resources growing in seasons create a proper environment to study sexual segregation and aggregation pattern [13]. This study seeks to assess the sexual segregation of Kashmir Markhor in Chitral Gol National Park in relation to seasonal, altitudinal and habitat type variations. The results should be of relevance to the development of management plans for Chitral Gol

National Park and, subsequently, achieve the objectives of range management and species protection.

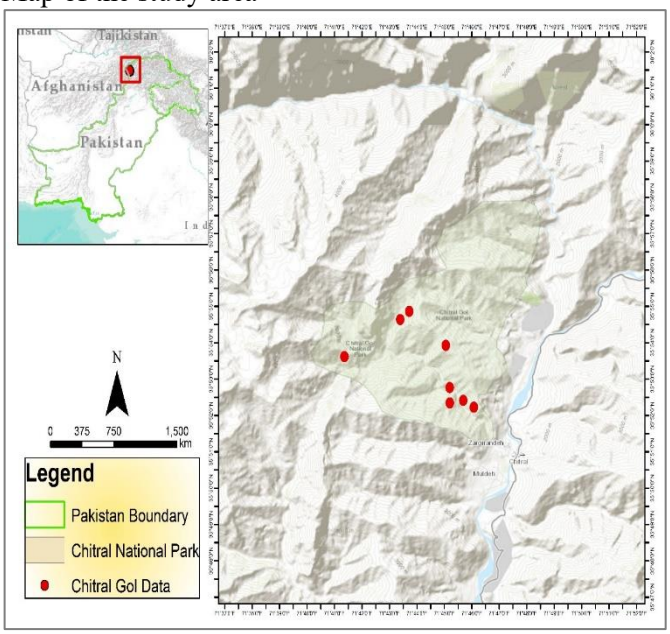
MATERIALS AND METHODS

Study Area

The focus of the research was Chitral Gol National Park located in the northern region of Chitral District of Pakistan. This park which was established for the purpose of protecting the biodiversity of the region has got a variety of plants and animals including the Kashmir Markhor (*Capra falconeri)* which has been classified as vulnerable by the International Union for Conservation of Nature (IUCN) [17]. The park includes mountainous land, different types of vegetation, as well as mixed forests and grasslands which are characteristic of the areas for Markhor's habitation [19].

Figure 1

Map of the study area



Study Animal

The Kashmir Markhor, a beautiful wild goat, is only found in the mountain regions of the Himalayas, Karakoram and Hindu Kush. As a flagship species of conservation, the Markhor is listed as "Near Threatened" by the International Union for Conservation of Nature (IUCN) [17]. Habitat loss, competition with livestock, and poaching are some subsistence practices that put the species at risk of extinction [11]. Chitral Gol National Park (CGNP), located within the boundaries of the Hindu Kush region of Pakistan, is a key area for this specie, as it contains one of the densest populations of Kashmir Markhor in the area. [19].Kashmir Markhor is a species of wild goat which inhabits the northern parts of Pakistan including Chitral and is known by its greatly twisted horns. The Kashmir Markhor is of great importance as a study animal as it is active and interacts in a social context. Based on the environmental and ecological parameters Markhor is known to show up with both aggregative as well as segregative spatial patterns making it quite a relevant animal for the current study. More research on the behavioural ecology of Kashmir Markhor would help understanding of the behvior and biology of this iconic species.

Data Collection

Point Sampling and Focal Animal Sampling

In order to gather data on the aggregation and segregation behavior of the Kashmir Markhor a combination of point sampling and focal animal sampling methods were employed. This method enabled the proper understanding on Markhor's space utilization throughout the seasons. There were fortnightly observations between October 04, 2019, and 07 March, 2021 to gather 112 observations in different habitats and altitudes. Focal animal sampling was designed to observe a particular group of animals in relation to their visibility and how active they were.

Sampling Protocol

Observation Points: The sampling exercise utilized a number of strategically placed fixed observation points located in the Chital Gol National Park's management zoning. These points enabled Markhor group visual across various dry habitats.

Habitat Types: The analysis comprised of different habitat types found in the park such as Dry Baloot Forest, Dry Deodar forests, Chilghoza forests, and Deodar and Oak species mixed forest.

Statistical Analysis

To determine the extent to which male and female Kashmir Markhor spatially overlap or stay apart, the Sexual Segregation and Aggregation Statistic (SSAS) was calculated using the Conradt's formula of SSAS [8].

$$SSAS = 1 - \frac{N}{X \times Y} \times \sum_{i=1}^{k} \frac{X_i \times Y_i}{N_i}$$

A value of 1 indicates complete segregation while 0 indicates a total aggregation of males and females. This measure supplies a valid and uniform method for the examination of the degree of the global and local (seasonal, altitudinal and habitat) patterns of population segregation, enabling to explore seasonal, altitudinal and habitat specific changes in the ungulate behavior.

Mean Sexual Segregation and Aggregation Statistics (SSAS) values, standard deviations, and frequency distributions for each season and habitat type were calculated with a view to comprehend spatial patterns of markhor. For comparison of SSAS values across the four studied seasons, a Kruskal-Wallis H test was administered after checking the normality of the data to determine whether differences across winter, spring, summer and autumn were significant. The null hypothesis (H_0) claimed that SSAS values did not significantly vary during the different seasons while the

alternative hypothesis (H_1) stated that there are seasons that have insignificant variation in SSAS values but at least one of the seasons shows a significant difference in its SSAS values. Similarly, Kruskal-Wallis H test was also administered to determine the difference in SSAS in various habitats of the park as well.

Data Analysis Software: The statistical analysis for the entire data set was executed using R, and p value of 0.05 was considered significant.

Ethical Considerations

All ethical principles concerning wildlife research and fieldwork were adhered to during the study. Researchers disclaimed their presence to avoid disturbing the animals and their environment. Appropriate human distance contact was observed for observing animal behaviour while all data processed and collected was qualitatively without human interference.

Limitations of the Study

Although valid information about SSAS of the Kashmir Markhor was obtained through the point and focal animal sampling methods, the level of detail achieved was restricted due to short time of observation and the spatial accessibility of some peripheral regions of the park.

RESULTS

The research focused on the analysis of Social Segregation and Aggregation Statistic (SSAS) in Kashmir Markhor across altitudinal zones, seasonal and habitat variation. Descriptive and inferential statistics were applied to the explored relationships between patterns in SSAS values and various ecological factors. A detailed summary of the results is presented below.

1. Social Segregation and Aggregation Statistic Across Seasons

Seasonal analysis of the Sexual Segregation and Aggregation Score (SSAS) shows interesting trends in the level of aggregation of Kashmir Markhor in Chitral Gol National Park. Mean SSAS scores imply that the greatest level of segregation is in the summer (M = 0.633), and spring is the second highest (M = 0.521), which also indicate decreased association between the sexes in these seasons. In contrast, winter (M = 0.129) and autumn (M = 0.192) relatively exhibit lower values for SSAS, implying higher degree of intermixing and more aggregation. These results indicate that sexual segregation and aggregation, in this case, have a seasonal pattern but may also be related to ecological conditions such as the distribution and availability of resources and mating strategies.

Considering that the p-value of Kruskal-Wallis H-Test (p=0.20, test statistics 4.63) is greater than the significance level (0.05), it can be concluded that there are no statistically significant differences among the SSAS values of the different seasons (Winter, Spring, Summer, Autumn). Therefore, aggregation and segregation behaviour does not differ greatly during these seasons

Figure 2

Social Segregation and Aggregation Statistics (SSAS) Across Various Season

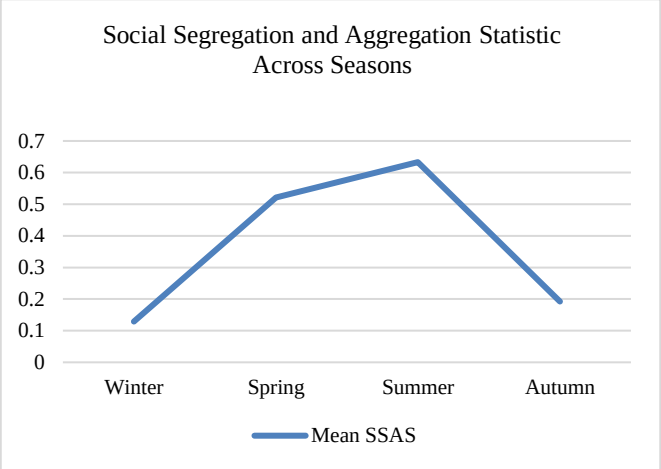


Figure 02. Social Segregation and Aggregation Statistics (SSAS) Across Various Season

Table 01. Social Segregation and Aggregation Statistics (SSAS) Across Various Season

	Mean SSAS	Standard Deviation	Kruskal-Wallis H-Test
Winter	0.129	0.180	Test Statistic: 4.63
Spring	0.521	0.179	p-value: 0.201
Summer	0.633	0.166	
Autumn	0.192	0.016	
Rut Season	0.124	0.0185	

2. Social Segregation and Aggregation Statistics (SSAS) Across Altitudinal Ranges

The analysis of SSAS values across elevation gradients demonstrates a positive association between height and aggregation behavior in Kashmir Markhor. More specifically, the mean SSAS also kept increasing according to altitude, from 0.316 at an altitude of between 6,000-7,000 feet to 0.642 at altitudes above 10,000 feet. This trend suggests that high altitudes offer conditions that encourage segregation. The significant p-value (0.013) suggests that SSAS values are statistically different across altitude ranges. The SSAS values give

an indication of the scope of segregation with the 6,000 – 7,000 ft range being the most segregative. This indicates factors at the lower altitude may be conducive to segregation.

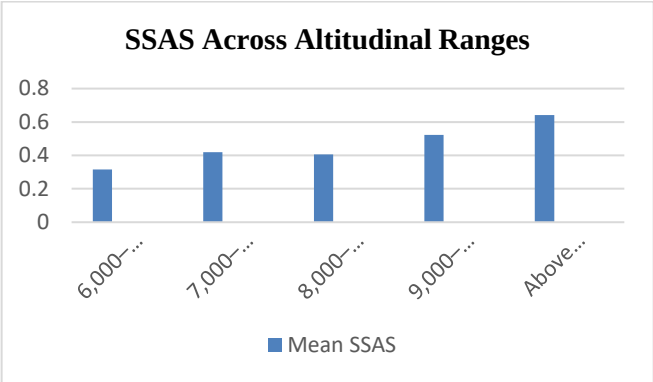


Figure 03. Social Segregation and Aggregation Statistics (SSAS) Across Altitudinal Ranges

Table 02. Social Segregation and Aggregation Statistics (SSAS) Across Altitudinal Ranges

	Mean SSAS	Standard Deviation	Kruskal-Wallis H-Test
6,000–7,000	0.316	0.0702	**Test Statistic:** 12.56
7,000–8,000	0.419	0.1647	**p-value:** 0.013
8,000–9,000	0.406	0.0570	
9,000–10,000	0.522	0.1788	
Above 10,000	0.642	0.1857	

3. Social Segregation and Aggregation Statistics (SSAS) Across Various Habitat Types

The evaluation of the different values of the SSAS across the different types of habitats of the Kashmir Markhor shows varying levels of aggregation with respect to the behaviour in the region. From the results, the Chilghoza forests have the highest mean SSAS value of 0.655 hence segregation is most pronounced among markhor in the park. Other habitat types show a segregation degree relatively lower than that of Chilgoza forests with Deodar with oak mixed forests at 0.397, Dry Baloot Forest at 0.414, and Dry Deodar Forest at 0.546. The Forest Associated with Herbs shows the lowest mean SSAS value of 0.257, which would suggest this habitat has a more aggregated spatial distribution. This further implies that within the Kashmir Markhor, certain types of habitats do promote specific spatial and social distributions which often seem to differ in levels of habitat type aggregation. This pattern may reflect differences in resource availability, predation risk, or habitat structure.

The p-value less than alpha of the study (0.004) establishes the fact that SSAS scores are ranked through the comparison of habitation types in scores. Aggregative patterns are also to be found in the mean SSAS of the "Forest Associated with Herbs" habitat while all other habitats exhibit higher segregation.

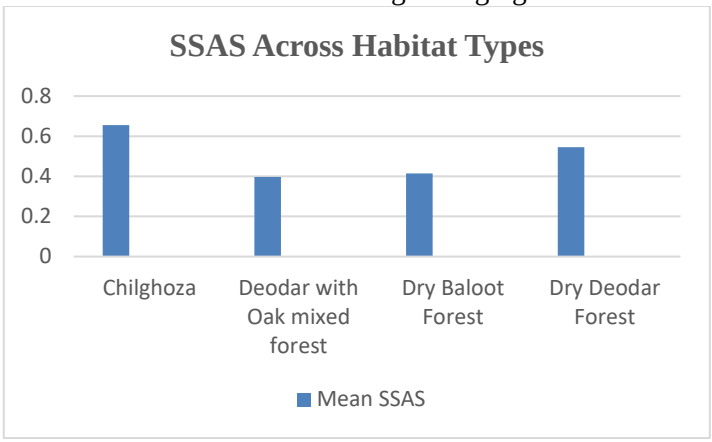


Figure 04. Social Segregation and Aggregation Statistics (SSAS) Across Various Habitat Types

Table 03. Social Segregation and Aggregation Statistics (SSAS) Across Various Habitat Types

Habitat	Mean SSAS	Standard Deviation	Kruskal-Wallis H-Test
Chilghoza	0.655	0.310	Test Statistic: 15.32
Deodar with Oak mixed forest	0.397	0.137	p-value: 0.004
Dry Baloot Forest	0.414	0.175	
Dry Deodar Forest	0.546	0.249	
Forest Associated with Herbs	0.257	0.023	

DISCUSSION

The aim of this research was to comprehend the segregating and aggregating actions (SSAS) of the Kashmir Markhor (*Capra falconeri cashmirieinsis*) in the different seasons, areas, and types of habitats found in the Chitral region of the Hindukush. This work synthesises descriptive and inferential statistics in

relation to the ecology and behaviour of this endangered species.

The F statistic value of p = 0.201 implies that interrelationships of aggregation and segregation are similar across all four seasons with the rutting season as a notable exception. This agrees with the findings of Prieto et al. 2004 [16], where it was noted that many ungulate species remain constant in behaviour throughout the seasons, save for the breeding season when aggression tendencies are common as they equally battle for breeding mates. According to the work of Bowyer (2022) [5], such behaviour is termed neutral due to the availability on autumn feed resources which weaken competition. In contrast, the variable social structures evident in winter, spring and summer may be a reflection of food resource availability, and this agrees with the behavior of ibex and mountain ungulates as noted by Bruch et al. (2008) [7] .

Kashmir Markhor also have similar grouping tendencies in winter compared to other ungulates from temperate regions. This can be attributed to the rut season where individuals come in aggregation in search of potential mates, and larger herd size maximize mate searching in the season Isvaran (2005) [10].

The findings confirmed that significant variations exist in SSAS across altitudinal ranges (p = 0.013) with strongest differences in the resonances exceedingly below the level of sea (6000-7000) feet. Altitudes affect vegetation type, predator activity and density, human activity and settlement, all of which affect the dynamics of the group and tend to support the hypothesis. Herfindal et al. (2019) [9] researched the case of alpine ungulates and found lower altitudes with higher levels of human being activity and predators to create segregation. At additional elevations (greater than 9000ft) SSAS values were level, showing strong tendencies of segregation. Bro-Jørgensen (2016)[6] noted that ungulates in considerable high zones tighten their groups to lessen predation and enhance heat regulation in cold weather. However, one reason as to why Kashmir Markhor were less intensely aggregated in high slopes could be attributed to the presence of widely spread, yet high quality forage in the alpine regions [3].

The research also established patterns of SSAS for various habitat types. The analysis showed differences in SSAS values held in different regions, with markhor exhibiting more segregation in certain habitats while others tendencies to aggregative behaviour. The patterns imply that the Kashmir Markhor's spatial distribution is affected by various parameters such as vegetation, other animals, and physical factors of the area. There were similar comments by Ahmad et al. (2016)[1]who reported that populations of Markhor tend to concentrate in areas of difficult accessibility so that they may reduce human disturbance and for them to feed well during certain times of the year.

Implications for Conservation

The current study will help in drafting conservation measures for markhor in critical areas like Chitral Gol National Park. The winter and summer seasons suggest a systematic framework that governs the Kasmir Markhor SSAS. Habitat management and protection measures preservation of sustainably resilient and complex ecosystems within the boundaries of the park should be the focus as the ecosystem changes more greatly affect the bristle bottle neck than the seasonal changes of even the winter changes. The segregation that is seen in part of some park might be core habitats that are essential for the survival of the species and should be kept away from human activities that may destroy the habitat and the resources.

CONCLUSION

This investigation social segregation and aggregation of Kashmir Markhor in Chitral Gol National Park and indicates that the seasonal changes do not substantially affect the spatial behavior of the species. On the contrary, several features of the habitat seem to exercise more influences towards patterns of aggregation and segregation. These facts broaden the existing knowledge concerning the ecology of Kashmir Markhor and stress the importance of stable and diversified biotopes for the conservation of this vulnerable species. The results shed light on the ecological parameters which drive segregation and aggregation in this species and may inform the sustainable management of rangelands in the area. Future studies should aim to identify how other ecological variables such as predation and competition with other species may act together with habitat characteristics in affecting SSAS patterns in populations of Markhor.

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