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Wildlife Management Implications for Sexually Segregated Ungulates: Lessons from Kashmir Markhor

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Abstract
Sexual segregation occurs when the habitats used by males and females of a species differ markedly. Sexual segregation in ungulates sets up special challenges for conservation and management. Abstract This paper explores the consequences of sexual segregation with regard to the conservation of the endangered Kashmir Markhor (*Capra falconeri cashmerieinsis*) in Chitral Gol National Park (CGNP), Pakistan. Traditional conservation strategies have led to stable populations, but often use a "one-size-fits-all" approach that ignores ecological and behavioural differences between sexes, resulting in wastefulness. This paper seeks to examine ecological drivers of sexual segregation, assess current management practices, and use this information to provide the foundation for a sex-specific conservation framework. Inspired by experiences with other ungulate species living in isolation, including bighorn sheep and mountain goats, the lessons channel the crucial information necessary for effective on-the-ground conservation of the Kashmir Markhor in their rugged mountain habitat, informing habitat management, resource availabilities, and monitoring programs.

Introduction

Although sexual segregation is common in ungulates, it is attributed to ecological, physiological, and behavioural differences between the sexes. These variations frequently appear as differences in habitat, foraging habits and social groups but the reasons for sexual segregation and the potential conservation and management implications of this behaviour remain poorly understood (Main & Coblentz, 1996). Sexual segregation should be considered in a niche framework and this creates a problem with conservation, where similar treatments of genders would overlook the individual requirements of each sex (Bowyer, 2004). Sexual segregation is marked in the Kashmir markhor of the Hindukush as an emblematic species (Ahmad et al., 2018). During the course of the year, males and females frequently occupy different habitats, as females are restricted to zones of low elevation with dense vegetation to protect their cubs, whereas males prefer high elevation habitats with low but rich forage (Schaller & Khan, 1975). The Markhor belongs to the IUCN endangered classes, with the Markhor population in Chitral Gol National Park rebounding to stable numbers after conservation efforts (Peerzada et al., 2010.; Weinberg et al., 1997), but these efforts have largely been geared towards the sexes as individuals rather than a whole which is often ineffective. Here, we review the ecological underpinning of sexual segregation in the Kashmir Markhor, evaluate the flaws with broad-spectrum wildlife management and suggest a refined approach involving sex-specific dimensions.

Methodology

We use a narrative review approach synthesising information from the peer-reviewed literature, governing reports, and documents from conservation projects. We included data from academic databases Scopus and Web of Science, limited to studies from 1980 to 2023. We conducted a literature search using various keywords including, sexual segregation in ungulates, Kashmir

Markhor, and wildlife management strategies. Other research on sexually segregated ungulates like bighorn sheep *Ovis canadensis* Ruckstuhl, 1998), Red Deer *Cervus elaphus* (Garcia, 2016) andNorth American Elk *Cervus canadensis* (Stewart et al., 2015)was used for comparative purposes. We also analysed local studies and reports on CGNP management practices to situate what we found with CGNP local management practices and identify gaps. The lessons and successful practices extracted from the review would help to recommend sex-specific conservation measures for Kashmir Markhor.

Ecological and Behavioural Drivers of Sexual Segregation

Divergent ecological and reproductive strategies are hypothesized to drive sexual segregation in ungulates (K. E. Ruckstuhl, 1998). For female ungulates including Kashmir Markhor, predation risk minimization is a priority during spring when females are either birthing or lactating. These places typically have thick cover and intermediate forage accessibility, bestowing security to young. In contrast, males, unburdened by parental investment requirements, choose habitats that maximize food intake to sustain larger body sizes and more expensive mating strategies (Barboza & Bowyer, 2000). This is particularly the case in Chitral Gol National Park. Research shows that females gather in valley bottoms with dense vegetation and the males are high spaces with less vegetation. The spatial segregation decreases competition and predation risk but makes conservation challenging since it creates two habitats that require different management. For example, male habitats could be supported by enhancing forage but female habitats might require predator control or exclusion from anthropogenic stressors (Wolff & Horn, 2003).

Current Wildlife Management Practices in Chitral Gol National Park

Efforts at Chitral Gol National Park to conserve these populations of Markhor have been working, stabilizing the populations on the ground. A number of initiatives, including anti-poaching measures, community-based conservation initiatives and habitat restoration projects, appear to have contributed to population recovery (Arshad et al., 2012). Yet, the this may lead to a blanket approach, viewing the Markhor population as an across-the-board entity.

Habitat Management Deficiencies

In Chitral Gol National Park, habitat restoration efforts often target areas approachable to field teams, which are often lowland areas and dominated by female plants. These efforts will benefit females, but they ignore the males that are in remote high-altitude zones. In turn, males experience such habitat destruction and depletion of resources, needing sufficient nutritional intake during the rut (Ashraf et al., 2014).

Monitoring Challenges

Monitoring schemes in Chitral Gol National Park do not often separate the data by sex, causing assessments of population dynamics and habitat use to be highly incomplete. Not having access to sex-specific data makes it challenging to pinpoint the inherent challenges associated with each group, limiting the effectiveness of management mitigation measures (Ruckstuhl & Neuhaus, 2006).

Community Impacts

Habitats dominated by females are likely to be more heavily affected by human activities (grazing, firewood collection and tourism). These actions, in turn, worsen habitat destruction, enhancing competition for limited resources, and exposing wildlife to higher levels of predation during vulnerable periods, such as birthing season (Ashraf et al., 2014; Conradt et al., 1999).

Lessons from Other Segregated Ungulates

Research on other sexually segregated ungulates offers valuable insights for managing the Kashmir Markhor. For example, sex-specific habitat zoning has proven effective for bighorn sheep, reducing

human-wildlife conflicts and enhancing resource distribution (Anderson et al., 2022; Wood, 2020). Similarly, adaptive monitoring programs for mountain goats, which incorporate sex-specific data, have improved population assessments and informed targeted management strategies (Fuhlendorf & Engle, 2001). These lessons highlight the importance of tailoring conservation approaches to address the distinct needs of males and females.

Proposed Framework for Sex-Specific Wildlife Management

1. **Temporal Resource Management**

The seasonal requirements of different sexes of Kashmir Markhor vary considerably, implying that their management needs to be sex specific. During the birthing season, those safe and quiet places can be harder to find as increasingly more human contact occurs. Conserving these birthing grounds is vital for the young Markhor to survive and gives lactating females the opportunity to raise their young ones with reduced disturbance. It is also the time when Markhor natality rates are at their peak and therefore the predator control measures are equally important, as the young of the Markhor are very innocent and easy prey. Males, on the other hand, have separate dietary needs especially before and during their breeding season. Their sporadic male-biased distribution at higher elevations reflects both their physiological requirements and ecology; thus, management should target improvements to forage in these masculine dominated alpine landscapes. Such interventions are crucial when resources are balanced by sex and season, thereby averting population harm.

2. **Sex-Specific Habitat Zoning**

Zoning habitat by sex provides a pragmatic solution to such spatial and ecological divergence of male and female populations. For males in the most-highland preferred habitat types, more emphasis should be placed on forage quality to satisfy their dietary requirements. On the other hand, lowlands preferred by mating females need less human activity to be a safe place to give birth and rear young. This kind of allocation and management of habitats allows wildlife managers to reduce the competition among sportsmen and male and female for resources and maximize the efficiency of Habitat Use. Relating to Zoning: The zoning strategy also allows both sexes to thrive, in their specific environments that suit their specific needs, therefore reducing the risks of any stressors related to habitat.

3. **Targeted Monitoring Programs**

Thus, sex-specific monitoring protocols are needed to further investigate population dynamics, habitat use and resource selection. These should be population specific and rely on data collected from GPS collars and camera traps to generate convex hulls of male and female movement patterns, seasonal habitat use, and demographics. These programs provide specific management actions for each sex which adds an effective component to the conservation efforts because of the unique needs of each sex.

4. Connectivity Corridors

One of the greatest threats to the Kashmir Markhor is habitat fragmentation, an effect that is pronounced due to the segregated nature of the species i.e the sexes remain separated outside of the breeding season. The corridors for connectivity between male and female habitats are necessary in order to accomplish seasonal movements as well as for genetic diversity. Achieving these linkages needs to be done in a planned way to avoid human made obstacles like roads and settlements and preserve natural migration routes.

5. Managing the Dynamic Balance of Predators and Prey

One crucial part of managing sexually segregated species lies in balancing predator populations. Although predators are an important component of a healthy ecosystem, they can also exert excessive mortality on female Markhor and their offspring in lowland habitats. Reducing predator

densities to sustainable levels in the ecosystem allows for predation pressures to be alleviated without compromising the balance of the ecosystem.

6. Monitoring of Reproductive Health

Insights into the reproduction of both sexes is critical for population persistence. Calving success rates, the duration of lactation and the health of females should be monitored during the birthing season of Markhor females. Likewise, male fitness during and post-rut can be estimated using data on physical condition, as conditions reflect mate competitive ability and recovery from high energetic demands of reproduction. Reproductive health assessments provide important demographic correlates of population viability and ultimately inform adaptive management

7. Sex-Specific Risk Assessment

The main threats that male and female Markhor face are different, and therefore require different management responses. With their remote highland sites, males are especially threatened by wider environmental changes, such as pressure on land and food. In lowland areas, females are at greater risk of human encroachment and also predation. By recognizing and reducing these risks, conservation can ensure that their efforts are appropriate for the specific difficulties of each sex.

8. Climate-Resilient Strategies

Climate change will require proactive, sex-specific measures to ensure the Kashmir Markhor can long-term withstand the changing climate. An important intervention in the male-dominated highland regions is planting drought-resistant forage species and maintaining water availability. Efforts to conserve riparian habitat and maintain access to stable water sources are needed in female-preferred areas. These strategies increase resilience of habitats and aid population persistence by addressing climate-induced stressors.

9. Engagement of Community and Outreach

Local communities are key to the conservation of species which segregate by sex. Both genders play an ecological role and educational programs will need to reflect this interdependence within the ecosystem. Demonstrating the community and species-level return on sustainable practices can engage and promote stewardship. Our findings highlight the need for enhanced co-existence in those areas identified as having a high likelihood of overlap between overlapping human-wildlife conflict especially in regions where females favour the habitat for long-term conservation success.

10. Policy-Level Interventions

Policymakers need to incorporate sex-specific understanding into wildlife management since sexually segregated populations of tropical region can pose a unique management challenge. Policies need to earmark funds for gendered habitat conservation and targeted research. Macro-level policy changes that institutionalize these mitigation measures can also help ensure that conservation efforts are holistic and enduring.

11. Conflict Resolution in Human-Dominated Areas

Kashmir Markhor is subjected to human-wildlife conflict, especially where livestock grazing overlaps female habitats. Mitigating such conflicts require creating controlled grazing areas, compensation plans for livestock losses, and also having local communities involved in participatory conservation actions. Such measures lower competition for resources and enable cohabitation of men and beasts.

12. Restoring of Keystone Habitats

Many of the strategies used to manage wildlife involve restoring key habitats. So in the case of males, that means restoring high-elevation grasslands to create healthy forage. Female habitats need

restoration of riparian zones and high-water-availability areas. Restoration efforts should be tuned to the ecological requirements of each sex in order to exert maximal effects.

13. Inter-Sex Interaction Management

Highly stressful inter-sex interactions occur during the rutting season, where resources need to be guaranteed and stress minimised. Pressuring either sex during this time is counterproductive as successful breeding will stabilize later populations through temporary zoning and supplemental feeding.

14. Technological Integration

Technological advancements provide important assets for the control and monitoring of sexually segregated species. Soil moisture satellite images, GPS locations, and camera traps allow for detailed measurements of habitat use, movement, and population dynamics. AI-enabled solutions suggest predictive analytics that incorporates data from multiple sources to help managers uncover patterns, recognize trends, and predict future challenges.

15. Adaptive Management Through Behavioural Monitoring

Further examination of Markhor behaviour on a long-term basis is necessary to understand how individuals react to environmental changes and seasonal transitions. Examining intra- and inter-sexual interactions allows insight into habitat utilization, social behaviour, and reproductive strategy. Conservation efforts that are based on these insights use adaptive management plans such that they remain flexible and responsive to changes in the system.

Conclusion

The biology of sexual segregation poses specific challenges for wildlife management that depart from a universally uniform conservation strategy. In Chitral Gol National Park, identifying solutions for these challenges requires an understanding of the differences in ecological and behavioural needs between male and female Kashmir Markhor. The simultaneous inclusion of sex-specific habitat management, directed monitoring, and citizen science can substantially improve effectiveness and sustainability of conservation outcomes. The need for this is reinforced by lessons from other segregated ungulates, which may provide a model for managing sexually isolated populations globally.

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