Indian Journal of Ecology (2023) 50(1): 272-275
DOI: https://doi.org/10.55362/IJE/2023/3890

Manuscript Number: 3890
NAAS Rating: 5.79

Estimating Occupancy and Abundance of Endangered Kashmir Musk Deer (*Moschus cupreus*) in Uttarkashi, Uttarakhand.

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***Abstract*:** The present study aimed to assess the occupancy and abundance of musk deer in Uttarkashi using camera traps from October 2018 to October 2019. Musk deer was detected in 9 out of 24 grids yielding a naïve occupancy estimate of 0.29. By using the null model, the estimates of the site occupancy was 0.39 and detection probability was 0.19. The overall abundance of musk deer was 28.40 in the study area, with an average density of 4.73/100 km^2. This study is the first attempt to estimate occupancy and abundance using camera traps, providing baseline information for future management and conservation strategies within the landscape.

***Keywords*:** Occupancy, Elusive, Camera trap, Habitat degradation, Threatened

Mammals which occur in low densities at high altitudes, are globally threatened due to habitat loss and anthropogenic disturbances (Woodroffe 2000, Sharief et al 2020). Monitoring the population of these mammals is pivotal for their long-term viability and is essential from both ecological and management perspectives. For effective conservation and management planning, especially for those species which are under increasing threat or on the verge of extinction. It is imperative to identify their habitats and estimate their abundance. Among these species, musk deer (*Moschus* spp.) is a globally threatened species and needs top priority conservation action (Singh et al 2020). Recent studies have highlighted that Kashmir musk deer (*Moschus cupreus*, hereafter KMD) is coverings parts of Afghanistan, Pakistan, India, and Nepal (Singh et al 2020). The species is distributed in continuous to fragmented patches of forested and alpine scrub habitats in the western Himalayas, which is experiencing a rapidly changing climate (Syed and Ilyas 2016, Singh et al 2020). Worldwide, the population of musk deer have dramatically dwindled to half of the original size in three generations (approximately 21 years) primarily because of poaching and habitat degradation (Green 1986, Homes 2004, Timmins & Duckworth 2015). Therefore, musk deer have been categorized as endangered (Timmins and Duckworth 2015) in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2015). In addition to poaching, the other prevailing threats to musk deer are habitat destruction and degradation (Yang et al 2003, Ilyas 2014). Habitats in the Himalayas are threatened by anthropogenic pressures such as intensive livestock grazing, fuelwood cutting, and fodder collection (Vinod & Sathyakumar 1999, Ilyas 2014, Sathyakumar 2015). The suitable habitat for musk deer is mainly confined to protected areas with fragmented habitats and therefore demands the urgent need for protection and conservation efforts. Information is documented on various aspects of the ecology of musk deer (Green 1986, Sathyakumar 1994, Vinod & Sathyakumar 1999, Syed 2014, Ilyas 2014, Sathyakumar & Rawat, 2015, Singh et al 2018, Wangdi et al 2019). However conservation and management planning need information on species' different life history traits, especially population estimation. Hence the present study assessed the occupancy and abundance of KMD in Uttarkashi using camera traps. It has been documented that camera trapping is particularly useful by allowing population densities of the species to be estimated when the identification of individuals is possible (Singh et al 2014b). In some mammals, including musk deer, individuals cannot be identified positively because of the lack of a distinct spot or stripe pattern; however, abundance estimates can be made with occupancy surveys that rely on a species being detected, or not, at a particular site (MacKenzie et al 2002). Occupancy yields unbiased maximum likelihood estimates of numerous variables relevant to a wide variety of conservation and management applications research. (Mackenzie et al 2006, Singh et al 2015). The objective was to estimate the site occupancy and abundance of KMD in Uttarkashi district using remotely triggered cameras and to provide information

for managers to formulate effective conservation and habitat management strategies for the concerned species.

MATERIAL AND METHODS

Study area: For the most part, the district Uttarkashi is known as a sacred town situated on the banks of Bhagirathi, and located at 30.73°N 78.45°E with an average elevation of 1165 m. Uttarkashi is rich in biological resources, biodiversity, and other religious, cultural, and eco-tourism places. Besides, several mammal species occur in this prestine valley, such as Asiatic black bear, Brown bear, Musk deer, Common leopard, Snow leopard, Blue sheep, Himalayan tahr, and Serow. Moreover, the district also harbours the population of the Himalayan monal and many other important bird species. Whereas the floral resource of the district contains western Himalayan broadleaf woods at its most reduced heights, changing to western Himalayan subalpine conifer backwoods and western Himalayan alpine shrub and meadows at its most noteworthy rises. Trees exhibited in the lower parts are pine, deodar cedar, oak, and deciduous species.

Methodology: The study area was divided into 5×5 Km grids to maximize our effort so that all logistically accessible grids could be covered. The field surveys were conducted from 2018 to 2019 in all the ranges of Uttarkashi. A team of researchers visited the selected grids to detect/non-detection of musk deer. A total of 55 camera traps were deployed in selected grids. Camera traps were placed at knee height from the ground on animal trails or a few meters away from animal trails. The camera-trap was designed to evaluate the site occupancy and abundance of KMD in Uttarkashi. During the study, ultra-compact SPYPOINT FORCE-11D trail cameras (SPYPOINT, GG Telecom, Canada, QC) were used. In addition, we conducted seven continuous camera-trapping replicate surveys between October 2018 to October 2019.

Occupancy estimation: The single season occupancy analysis for estimating the site occupancy probability (ψ) and detection probability (ρ) of musk deer using a likelihood-based method was adopted(MacKenzie et al 2002) . Analysis was carried out using the PRESENCE v.2.12.25 software package (Proteus Wildlife Research Consultants, New Zealand; http://w. proteus.co.nz;Hines 2006). The detection/non-detection of musk deer was recorded over 12 months, from October 2018 to October 2019. Those surveys were divided into seven sampling occasions of around 15 days each. The data from all the camera trap locations at the respective sites was pooled and constructed standard detection histories for each site (Mackenzie et al 2002). Detection histories of musk deer was constructed for each site over the seven sampling occasions. Modelled occupancy and detection probability, applying single-season occupancy model on the pooled data set, keeping occupancy and detection probability constant ψ (.) ρ (.).

Abundance and density estimation: Estimation approaches developed for occupancy surveys incorporate detection probability directly into the estimation process (MacKenzie et al 2002) and thus deal appropriately with this fundamental component of animal abundance estimation. This was assumed that the detection of individuals was independent, individuals were equally detectable across the whole sampling site, and the site-specific abundance of individuals followed a Poisson distribution. The Royle–Nichols model provides estimates of the (λ) and r, representing the average abundance per site and innate species detectability, respectively (Royale and Nicholas 2003). The overall density will depend on the number of grid cells used by individuals was considered (Thorn et al 2011). This approach and divided abundance (λ) by the area of the sampling unit (n=24; area=600 km^2) to estimate the average KMD density of the sites in the study area was adopted. Royle–Nichols heterogeneity constant model λ(.),r(.) to estimate the abundance and associated parameters KMD was used.

RESULTS AND DISCUSSION

Sampling effort of 2819 camera trap nights yielded 10 independent detections of musk deer in 24 sites which were above >2500 m elevation. KMD was detected in 7 out of 24 sites (naïve occupancy=0.29) during the study period. The estimated site occupancy was 0.39with a detection probability of 0.19 (i.e., probability of detection of KMD on each survey) using the null model ψ (.) ρ (.) in which occupancy and detection probability are kept constant. Using Royle- Nicholas heterogeneity null model λ(.), r(.) keeping abundance and detection probability constant, evaluated the abundance of KMD in Uttarkashi. The abundance was λ=0.51KMD/site with a detection probability of r=0.12 (Fig.2). The overall abundance was 28.40KMD in the study area. The estimated density was 4.73/100 km^2 (Table 1).

KMD is one of the least studied mammal in India, and less attention has been given to this dwindled species since the last few years despite its endangered status. This study provides insights into the occupancy and abundance of musk deer and the feasibility of using detection/non-detection surveys to assess the musk deer's population status in Uttarkashi. The species occupies distinct habitats and has fragmented distribution in Uttarkashi, with an estimated density equal to 4.73/100 sq km. The null model indicates the estimated site occupancy of KMD is greater than naïve

occupancy. The occupancy estimates suggest that the KMD is rare in the study area, and the low detection probability further indicates that it is not easily detected. Low estimates of detection probability across the sites suggested that KMD is difficult to detect in the study sites even though the site is occupied by the species. Density estimates (number/sq km) for musk deer in the subalpine forests of Shokharakh in Kedarnath Wildlife Sanctuary were 3.2/sq km in 1979-81 3.7 in 1989-91 (Sathyakumar 1994). The musk deer abundance in pellet group density was 58.8 9 pellet groups/ha (Ilyas

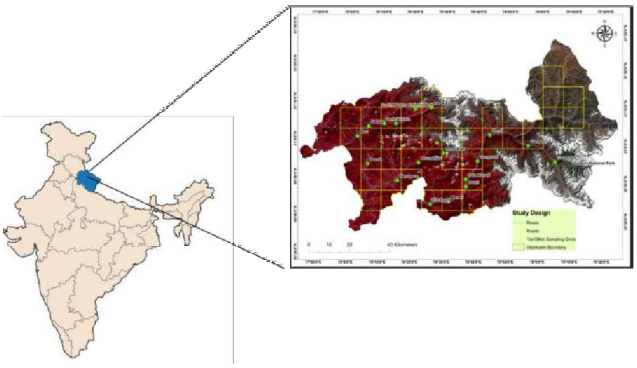

Fig. 1. Study area with camera trap locations in Uttarkashi

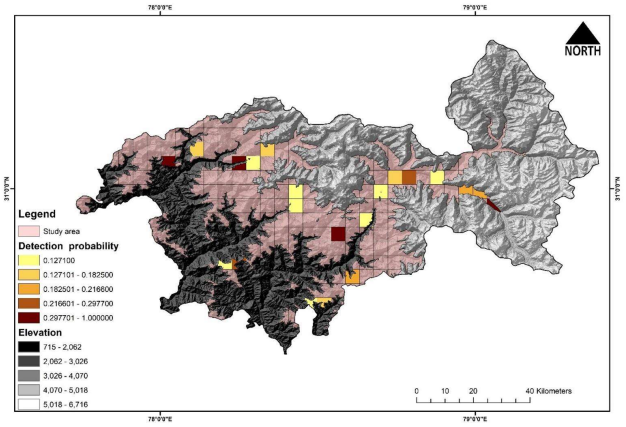

Fig. 2. Detection probability of Kashmir musk deer in Uttarkashi, Uttarakhand

Table 1. Occupancy and abundance estimation of Kashmir musk deer in Uttarkashi (above 2500 m)

Parameters	Estimation
Sampled area	600 km^2
Overall abundance	28.40±12.58
Naïve site occupancy	0.29
Site occupancy predicted/estimated	0.39±0.11
Detection probability of Musk deer	0.19±0.06
Density	4.73/100 km^2

2014). The current study indicate that KMD was not always detected at a site because the detection probability was low (0.19). The presence of KMD was captured in the alpine scrub and subalpine oak fir habitat at an elevation above 2500 m which is corroborated with the previous findings of Sathyakumar 1994, Green 1987, Ilyas 2014. However, despite the adoption of some conservation measures, the poaching of KMD continues virtually unchecked, and trading still persists on a large scale. Sathyamkumar (1994) documented that degradation and loss of musk deer habitat is due to the removal of understorey vegetation by extensive livestock grazing which has led to decreasing musk deer density in the Western Himalayas. Conservation of this rare animal is of utmost importance today, as it is fast heading towards total extinction. More effort to detect this species, the finding of this paper can be used as baseline information for making future management and conservation strategies for the species in Uttarkashi. The long term monitoring to assess KMD occupancy, population estimation and habitat utilization pattern within potential areas in Uttarkashi using different sampling methods is recommended.

ACKNOWLEDGEMENT

The authors extend thanks to the Principal Chief Conservator of Forest/ Chief Wildlife Warden Department of Forest, Government of Uttarakhand, for providing research permission for conducting the study. Authors also thanks to National Mission for Himalayan Studies for the funding support under Grant No. NMHS/2017-18/LG09/02/476.

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Received 17 September, 2022; Accepted 10 January, 2023