Conservation of hangul, *Cervus hanglu* – paving the way ahead

Tanushree Srivastava and Karthikeyan Vasudevan*

Hangul Cervus hanglu is the only red deer species in India distributed in the Kashmir Himalaya. A population of only 200-odd is currently surviving in the wild due to a variety of threats since prehistoric times. Given the critical nature of this population, use of multifaceted approaches and technologies along with addressing the prerequisites to a successful conservation breeding programme, remains crucial to enhance the reproductive value of such endangered species. We expect that the information on genetic diversity, reproductive biology and dietary niche of wild population, generated through the ongoing work would speed up the species conservation efforts.

Keywords: Assisted reproductive technologies, *Cervus hanglu*, conservation breeding, endangered species, genetic diversity, reproductive biology.

THE red deer originated and spread in Central Asia, in the Tarim Basin, approximately two million years ago[1–3]. Hangul (*Cervus hanglu*) is the only red deer species in the Indian subcontinent[4] and is presently distributed in the Kashmir Himalaya (Figures 1 and 2). Until recently, hangul in Kashmir, India (*Cervus elaphus hanglu*) along with the Yarkand–Tarim (*Cervus elaphus yarkandensis*) and Bukhara (*Cervus elaphus bactrianus*) red deer populations of Central Asia were considered as subspecies of *Cervus elaphus*[3,5,6]. However, currently all the three subspecies have been merged into a single separate species named *Cervus hanglu*. Reported to be ranging from 3000 to 5000 at the beginning of the century, hangul has faced a drastic decline in its population in the last five decades[7,8]. Based on census operations carried out in 2019 by the Department of Wildlife Protection, Jammu and Kashmir (J&K), India, the hangul population has been put at 237 adults. The census also highlighted an alarmingly low male to female ratio, with only about 30 adult males surviving in the wild. A recent study suggests that suitable habitats for hangul far exceed the area occupied by them in the landscape, as they exist as isolated populations with limited exchange between them[9]. The Dachigam National Park (DNP) probably supports a breeding population along with a small population in Shikargah, Tral Wildlife Sanctuary and Overa Wildlife Sanctuary, J&K. Few other small populations of 34, 14 and 15 individuals occur in Wangat–Naranag, Chandaji–Diver–Lolab and Overa–Aru respectively[10,11].

Past, present and future concerns to the population

The Kashmir Himalaya which falls within the biogeographic unit of Northwestern Himalaya, supports 11 large ungulate and 1 primate herbivore species. Since prehistoric times, the region has witnessed trophy hunting of hangul, Tibetan antelope, Tibetan argali, ibex and markhor, as they were much-valued for their horns, flesh, antlers and scent pods[12]. Edmund Loder, a hunter, visited Kashmir in 1900s and hunted markhor, ibex, musk deer, brown bear, black bear and hangul[13]. Until 1947, Kashmir was a princely state and hangul was considered a 'royal game' species. In 1960s, poaching was one of the biggest threats for ungulates in the region, and it was forewarned that if not uncontrolled, it might lead to the extinction of hangul[7,14].

Like many other mountain ungulates, hangul migrate between their summer and winter habitats in response to seasonal variations in forage availability and environmental conditions. However, the high-altitude alpine pastures

Figure 1. Female hangul sighted in lower Dachigam in December 2019.

Tanushree Srivastava and Karthikeyan Vasudevan are in the Laboratory for the Conservation of Endangered Species, CSIR-Centre for Cellular and Molecular Biology, Hyderabad 500 048, India.
*For correspondence. (e-mail: tanushree.wildlife@gmail.com)

have a long history of use by nomadic livestock herders during summer (June to September), thus overlapping with hangul visitation of their summer habitats. This has possibly been exposing the population to continuous threats of interspecific competition for forage, transmission of diseases from livestock, and the newborns to predation risk by guard dogs[7,14,15]. Lower-altitude habitats, on the other hand, pose other forms of threat like disturbance due to close proximity of roads, traffic and human settlements. As autumn and winter probably correspond to the breeding season and gestation in hangul females, such disturbances would have a direct impact on recruitment of adults in the population. Recent studies suggest that the hangul population in DNP is already confined to the middle and lower altitudes during summer, and that it tends to avoid suitable habitats even if there is less disturbance[16]. Large herbivores like hangul are therefore highly vulnerable to the risks of extinction through competitive exclusion due to livestock grazing or other forms of anthropogenic pressure for extended periods[17].

Another concern about the hangul population is the degradation and fragmentation of available habitats within its distribution range in the Kashmir valley. Suitable habitats far exceed the extent of habitats occupied by hangul[9]. However, the lack of connectivity between these habitats has restricted the movement of this species. Hangul population in DNP could be highly inbred, elevating risks of local extinction due to inbreeding effects[18].

Figure 2. A group of male and female hangul sighted in lower Dachigam in February 2021.

Improved connectivity between protected areas (PAs) as well as the surrounding wilderness areas and crucial habitats, has been identified as the key to conserve biodiversity through continued gene flow between the populations of a species. In addition, connected habitats give the populations a much better chance to respond and adapt to the changing conditions due to climate change in comparison to fragmented habitats.

Efforts put into hangul conservation so far

The recent elevation of the species status of *C. hanglu* has brought back the focus on its conservation status[5,6]. With geographic ranges drastically reduced after separation from the parental species, it was evaluated as Critically Endangered[19] and received international attention for its conservation. In 2007, the scheme 'Integrated Development of Wildlife Habitats' was put in place by the Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India (GoI). The scheme had three components, including support of PAs, protection of wildlife outside the PAs and recovery programmes for saving critically endangered species. The recovery programme aimed at recovering 17 critically endangered species, including hangul and their habitats.

For a species like the hangul, establishing a safe population outside its habitat in captivity is essential. Recommendations for conservation breeding of hangul for the purpose of its survival and augmentation of the population in the wild are being made since 1960s (refs 7, 10, 11, 20). Global examples exist for Arabian oryx *Oryx leucoryx* (Saudi Arabia), Pere David's deer *Elaphurus davidianus* (China), Przewalski's horse *Equus przewalskii* (Mongolia and China), and Northern white rhinoceros *Ceratotherium simumcottoni* (Africa), where small wild populations have been successfully augmented from captive-bred populations or rescued using assisted reproduction technologies (ARTs)[21–24]. Based on these successes, the Central Zoo Authority (CZA) under MoEF&CC, GoI emphasized the need to establish a captive hangul population in 2005 and supported establishing a breeding centre in the Kashmir Himalaya in 2008. The breeding centre was set up in Shikargah in Tral region, Pulwama district, South Kashmir in 2011, but there are still no hangul in captivity. A collaboration among Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST, J&K), Department of Wildlife Protection, J&K, Wildlife Institute of India, Dehradun and Smithsonian Conservation Biology Institute, USA, to initiate conservation breeding of hangul is in place.

Paving the way ahead

When the population size is smaller than the available suitable habitats, a proactive strategy would be to: (a)

translocate animals–protect–monitor, (b) conservation breed–reintroduce–monitor and (c) both. Alternatively, a passive strategy would be to establish corridors–protect–monitor. This strategy has certainly paid-off for the conservation of the species as it would secure a population and highlight the conservation status of the species. Given the critical nature of the hangul population, the proactive measure might be required, while keeping the passive strategy going hand-in-hand. When the recruitment as adults in the population is expected to be low as revealed from low fawn to female ratio of 7 : 100, it becomes imperative to identify the drivers of poor reproductive success[25]. There are several unknowns, such as: what is the breeding potential of the population? What percentage of adults is reproductively active? What is the survival rate of the young ones? Conservation breeding is a long-drawn process and it would not result in outcomes for conservation of the species immediately. Among the prerequisites to establish a successful hangul breeding programme, a few important ones are – establishment of a genetically diverse founder population, assessment of reproductive status of adults in the wild as well as in captivity, and assessing nutritive requirements in captivity, meeting behavioural requirements of the species and implementation of a conservation breeding plan.

Reproductive potential and survivorship are the two essential parameters for arriving at the reproductive value (RV) of a species. In natural populations, the contribution of residual reproductive value is constrained due to reproductive trade-offs. The use of ARTs to monitor reproduction and biobanking of semen, oocytes and embryos from live and post-mortem animals can therefore add another level of protection to the breeding stock and in turn the species conservation programme[26]. With implementation of ARTs, the residual reproductive potential becomes several folds high, thereby enhancing the RV of a species. Assessment of body condition and age of red stag using the acoustic patterns of their rutting calls is also possible. It has been used in different subspecies of red deer[27], but not so far in hangul. An assessment of vital parameters of the population, such as growth rate, birth rate, death rate and sex ratio using accurate techniques is also essential. The use of such multifaceted approaches and technologies is expected to hold tremendous potential for rescuing endangered species globally.

Recent research

The National Mission for Himalayan Studies (NMHS) has supported a project to improve capacity in wildlife conservation in the Kashmir Himalaya using hangul as a flagship species. This project is being executed by CSIR-Centre for Cellular and Molecular Biology's (CCMB) Laboratory for the Conservation of Endangered Species in collaboration with the Department of Wildlife Protection, J&K since 2019 to further streamline the conservation breeding programme by addressing the following: (a) genetic diversity of hangul population *in situ*, (b) reproductive parameters, including hormone profiles related to reproduction and stress in adult males and females, and (c) the dietary plant diversity associated with seasons, reproductive stages and sexes. The project aims to generate this information from non-invasively collected faecal samples from the wild. In addition, livestock herders residing in and around PAs where hangul are currently distributed will be interviewed to assess the extent of overlap in livestock grazing pastures and the foraging grounds of hangul. These surveys would reveal the level of impact of livestock grazing on the hangul population through competition for forage, disturbance and transmission of diseases.

We have marked permanent sampling trails in DNP and Tral Wildlife Sanctuary (Figures 3 and 4). We have collected fresh faecal samples of hangul while we monitored these trails on a monthly basis (Figure 5). We started our field-data collection in September 2019, and are processing the samples to understand the current reproductive value of adults, identify the associated fitness traits and monitor their reproductive cycles. We will use faecal metabolite concentrations of estradiol, progesterone and testosterone to assess the seasonal patterns of the reproductive cycle of the wild hangul population. We will also measure the faecal glucocorticoid levels to

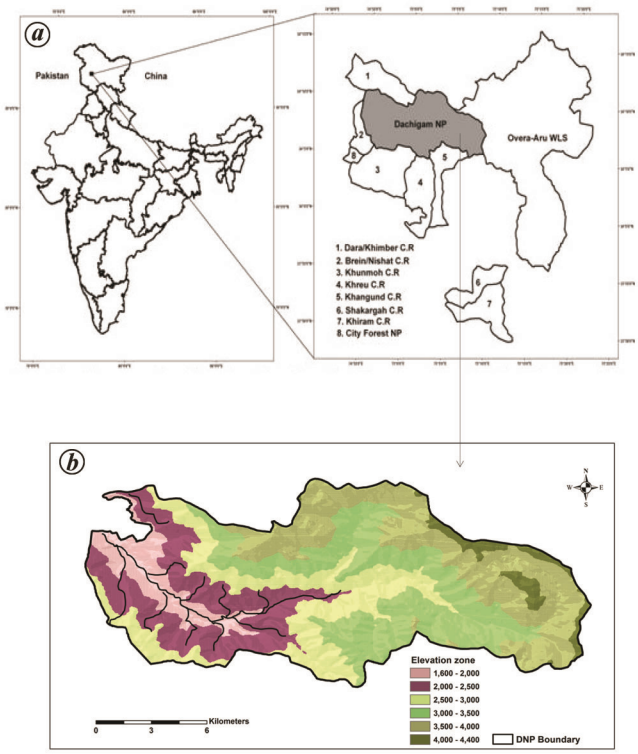

Figure 3. ***a***, Location of the Dachigam National Park (DNP) in India. ***b***, Location of permanent sampling trails in lower part of DNP.

assess the stress experienced by the population and to identify the factors associated with the same. When monitored at the population level it will provide a window to evaluate the patterns in reproduction in the species. This becomes an invaluable management tool as it would guide the decisions to manage the population. We are genotyping faecal samples to estimate the population size and sex ratio. We are also profiling the dietary forage plants using plant DNA barcodes generated from faecal samples. These efforts would fill some of the gaps in the current knowledge on the biology of hangul.

The scientists from CSIR-CCMB provided training for 30 officials at Department of Wildlife Protection, J&K, including forest guards, Range Officers and wildlife veterinarians and faculties and 65 Ph.D. students at the University of Kashmir and SKUAST, Srinagar, through workshops on wildlife forensics investigation, wildlife disease monitoring and diagnosis, advanced wildlife forensics, ARTs and biobanking, basics of R for ecology and basic open-source GIS. Outreach programmes were held for schools in Srinagar and a wildlife photography competition was also held.

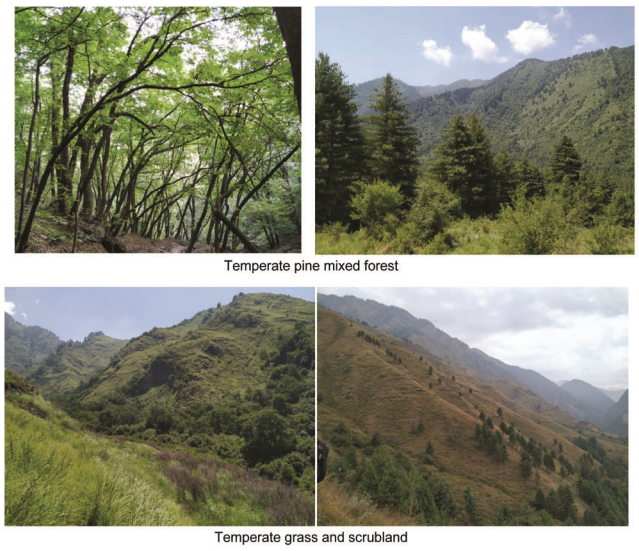

Figure 4. Habitat types exhibited by the permanent sampling trails.

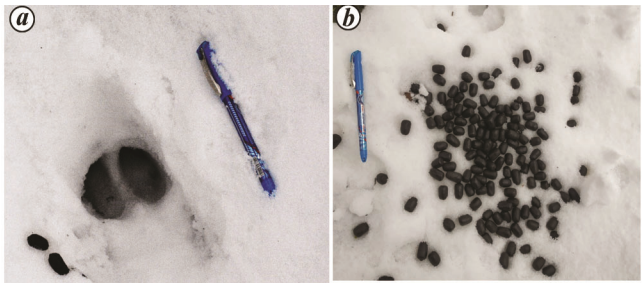

Figure 5. (***a***) Hangul hoof mark on snow and (***b***) fresh hangul pellets on snow in DNP in February 2021.

Aspirational goals of the work

By acquiring information on the project objectives as mentioned above, we expect to help in speeding up the process of protecting and managing the hangul population as well as its habitats in a more informed and efficient way.

For instance, the reproductive profiles of the population would enable us to identify the critical phases in its reproduction, viz. breeding and birthing. This could inform the management to afford greater protection to the population at a particular elevation and during a specified period of the year. The reproductive biology and dietary niche reconstruction for the *in situ* population would equip the Department of Wildlife Protection, J&K to manage the captive hangul population, once it is established. These hormone profiles would serve as a parameter that could be monitored in the future for evaluating different impacts, including climate change. More immediately, it would serve implementation of ARTs in the captive population. The capacity building programmes are meant to engage with the stakeholders of hangul conservation in a variety of ways. If the conservation of hangul has to be successful, the people of Kashmir valley have to step into different roles that the project has demonstrated. We hope that the mentees of the programme turn into mentors and create many more human resources to carry forward the work.

Globally, conservation of critically endangered species constitutes aspirational projects which involve several institutions. At a time when there is a spate of species extinctions, it brings hope, restores confidence in institutions and promotes scientific growth. They have the characteristics of any large science-driven programmes that showcase the strengths and resolve of the society. It is possible to restore the population of hangul to levels documented over a century ago. Since the historic area of occupancy of the species is known[11], and adequate suitable habitats still exist[9], it should be made as the goal of the species recovery programme to restore the population to this level. To achieve this in the future, efforts should be made to identify, connect and secure all available habitats and the corridors without any further delay. Establishing a captive population is one of the several important steps in achieving this aspirational goal. It would be one which builds foundational knowledge about the population, and reproductive biology and feeding ecology of the species so that hangul populations, both *in situ* and *ex situ*, seamlessly benefit from management decisions that enhance their numbers and improve their conservation status. It should use the best available scientific knowledge on the reproductive, trophic and population biology of hangul or any other related species. From global experiences, we now know that extinction of hangul can be averted. However, the initiatives rest with us.

1. Geptner, V. G., In *Mlekopitayushchie Sovetskogo Soyuza, Vol. 1: Parnokopytnye i neparnokopytnye (Mammals of the Soviet Union, Vol. 1: Artiodactyles and Perissodactyles)*, Vysshaya Shkola, Moscow, Russia, 1961, pp. 121–172.
2. Nikolsky, A. A., *Zvukovye signaly mlekopitayushchikh v evolyutsionnom protsesse (Auditory Signals of Mammals in the Evolutionary Process)*, Nauka, Moscow, Russia, 1984.
3. Sun, J., Zhang, L., Deng, C., Zhu, R., Evidence for enhanced aridity in the Tarim Basin of China since 5.3 Ma. *Quaternary Sci. Rev.*, 2008, **27**, 1012–1023; doi.org/10.1016/j.quascirev.2008.01.011.
4. Geist, V., *Deer of the World: Their Evolution, Behaviour, and Ecology*, Stackpole Books, Mechanicsburg, Pennsylvania, USA, 1998.
5. Lorenzini, R. and Garofalo, L., Insights into the evolutionary history of *Cervus* (Cervidae, tribe *Cervini*) based on Bayesian analysis of mitochondrial marker sequences, with first indications for a new species. *J. Zool. Syst. Evol. Res*., 2015, **53**, 340–349; doi.org/10.1111/jzs.12104.
6. Meiri, M., Kosintsev, P., Conroy, K., Meiri, S., Barnes, I. and Lister, A., Subspecies dynamics in space and time: a study of the red deer complex using ancient and modern DNA and morphology. *J. Biogeogr.*, 2017, 1–14; doi.org/10.1111/jbi.13124.
7. Gee, E. P., Report on the status of the Kashmir stag. *J. Bombay Nat. Hist. Soc.*, 1965, **62**, 379–393.
8. Kurt, F., Kashmir deer (*Cervus elaphus hanglu*) in Dachigam. In Working Meeting of the IUCN Deer Specialist Group, Longview, September 1977, p. 43.
9. Mukherjee, T. *et al.*, Landscape-level habitat management plan through geometric reserve design for critically endangered Hangul (*Cervus hanglu hanglu*). *Sci. Totl. Environ.*, 2021, **777**, 146031; doi:10.1016/j.scitotenv.2021.146031.
10. Qureshi, Q. *et al.*, Status and distribution of hangul *Cervus elaphus hanglu* Wagner in Kashmir, India. *J. Bombay Nat. Hist. Soc*., 2009, **106**, 63–71.
11. Kaul, R., Chatterjee, M., Bhattacharya, T., Bodhankar, S., Ahmad, R., Sofi, M. N. and Charoo, S. A., Conservation prospects of the Kashmir red deer (*Cervus hanglu hanglu*) beyond Dachigam National Park, in Jammu and Kashmir, India. *Curr. Sci*., 2018, **114**, 2123–2130.
12. Doughty, M., Afoot through the Kashmir Valleys, Sands, London, 1901, pp. 1–226.
13. Pease, A. E., *Edmond Loder – Naturalist, Horticulturist, Traveler and Sportsman. A Memoir*, J. Murray, London, 1923, pp. 142–203.
14. Schaller, G. B., Observations on the hangul or Kashmir stag (*Cervus elaphus hanglu*). *J. Bombay Nat. Hist. Soc*., 1969, **66**, 1–7.
15. Stockley, C. H., *Stalking in the Himalayas and Northern India*, Herbert Jenkins Ltd, London, UK, 1936, pp. 178–192.
16. Ahmad, K., Qureshi, Q., Agoramurthy, G. and Nigam, P., Habitat use patterns and food habits of the Kashmir red deer or hangul (*Cervus hanglu*) in Dachigam National Park, Kashmir, India. *Ethol. Ecol. Evol.*, 2015, **28**, 85–101; doi:10.1080/03949370.2015.1018955.
17. Mishra, C., Van Wieren, S., Heitkonig, I. M. A. and Prins, H. H. T., A theoretical analysis of competitive exclusion in a Trans-Himalayan large-herbivore assemblage. *Anim. Conserv.*, 2002, 5, 51–58; doi.org/10.1017/S1367943002002305.
18. Mukesh, Sharma, L. K., Kumar, V. P., Charoo, S. A., Mohan, N., Goyal, S. P. and Sathyakumar, S., Loss of genetic diversity and inbreeding in Kashmir red deer (*Cervus elaphus hanglu*) of Dachigam National Park, Jammu & Kashmir, India. *BMC Res. Notes*, 2013, **6**, 326.
19. IUCN, The IUCN Red List of Threatened Species, Version 2017-2; www.iucnredlist.org
20. Shah, G. M., Jan, U., Bhat, B. A. and Ahanger, F. A., Causes of decline of critically endangered hangul deer in Dachigam National Park, Kashmir (India): a review. *Int. J. Biodivers. Conserv*., 2011, **3**, 735–738.
21. Islam, M. Z., Ismail, K. and Boug, A., Restoration of the endangered Arabian Oryx *Oryx leucoryx*, Pallas 1766 in Saudi Arabia: lessons learnt from the twenty years of re-introduction in arid fenced and unfenced protected areas. *Zool. Middle East*, 2011, **3**, 125–140.
22. Jiang, Z., Yu, C., Feng, Z., Zhang, L., Xia, J., Ding, Y. and Lindsay, N., Reintroduction and recovery of Pere David's deer in China. *Wildl. Soc. Bull.*, 2000, **28**, 681–687; doi:10.2307/3783620.
23. Xia, C., Cao, J., Zhang, H., Gao, X., Yang, W. and Blank, D., Reintroduction of Przewalski's horse (*Equus ferus przewalskii*) in Xinjiang, China: the status and experience. *Biol. Conserv*., 2014, **177**, 142–147.
24. Tunstall, T. *et al.*, Evaluating recovery potential of the northern white rhinoceros from cryopreserved somatic cells. *Genome Res.*, 2018, **28**, 780–788; doi:10.1101/gr.227603.117.
25. Hangul population census report, Department of Wildlife Protection, Jammu and Kashmir, 2019.
26. Wisely, S. M., Ryder, O. A., Santymire, R. M., Engelhardt, J. F. and Novak, B. J., A road map for 21st century genetic restoration: gene pool enrichment of the black-footed ferret. *J. Hered.*, 2015, **106**, 581–592; doi:10.1093/jhered/esv041.
27. Volodin, I. A., Volodina, E. V. and Golosova, O. S., Automated monitoring of vocal rutting activity in red deer (*Cervus elaphus*). *Russ. J. Theriol*., 2016, **15**, 91–99; doi:10.15298/rusjtheriol.15.2.03.

ACKNOWLEDGEMENTS. We thank the National Mission on Himalayan Studies, Ministry of Environment, Forest and Climate Change, Government of India for funds and Department of Wildlife Protection, Jammu and Kashmir, for research permits. We also thank Nisar Ahmad for assistance in field-data collection.

Received 14 May 2021; accepted 18 July 2021

doi: 10.18520/cs/v121/i4/485-489