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continued on the back inside cover

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ARTICLE

Regional, ecological and biodiversity context of the Kashmir Valley, northwestern Himalaya, India

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Abstract: The Kashmir Valley (Kashmir region) part of the western Himalaya of India is an intermontane basin with an area of around 16,000 km². The valley forms a biogeographic transition between the Palearctic and Oriental realms of the world. The elevation of the valley ranges from 1,100 m to >5,000 m, and the lowest area of the valley is Uri sector, from where the water drains. Due to the strong elevational and climatic gradients, the valley forms a mosaic of temperate forests, subalpine scrub, alpine meadows, glaciers, and a network of internationally important wetlands, including Hokera/Hokersar and Wular. Despite the 19 terrestrial protected areas including national parks and multiple wildlife sanctuaries and conservation reserves, large portions of the species' habitats occur outside formal protection. They are highly exposed to land-use change, unregulated grazing, infrastructure expansion, human-wildlife conflict, and poaching. This study compiled data from published literature, government records, and field-based ecological insights from field studies. This study provides a concise, regional profile of the Kashmir Valley for biodiversity and threatened species study and conservation. The valley's physiography, climate and hydrology, major habitat types and land-use zones, wetlands are summarized. This study also focuses on, the protected-area network, and key conservation priorities for threatened species such as the Hangul (Kashmir Stag) *Cervus hanglu hanglu*, Kashmir Musk Deer *Moschus cupreus*, and Kashmir Markhor *Capra falconeri*. This study aims to support standardized reporting of Kashmir as regional area context and to inform landscape-scale conservation planning that extends beyond protected areas in the Kashmir Himalaya.

Keywords: Biogeographic transition zone, climate refugia, habitat connectivity, human wildlife interactions, landscape conservation, land-use change, Palearctic Oriental transition, protected-area network, Ramsar wetlands, threatened ungulates, transhumant pastoralism.

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Geographic and ecological overview of Kashmir Valley

The Kashmir Valley in India, often called the Vale of Kashmir, is an intermontane basin located in the northwestern Himalaya between 33°20′ - 34°54′ N and 73°55′ - 75°35′ E . The landscape is bounded by the Pir Panjal Range on the south-west, by the Shopian Gulmarg area and the Greater Himalayan Zanskar Range to the north-east, and by the Kishtwar Valley on the south. The valley stretches approximately 235 km in length from southern Kashmir to northern Kashmir, spanning an area of about 16,000 km². The area shows variation in altitude, landscape, and habitat pattern over a very short distance, with a mosaic of habitats occurring within as little as 1 km². Elevations of the landscape ranges from 1,100 m in Uri at the western most point of northern Kashmir. The city and surrounding area have elevation of around 1,500 m which forms the Jhelum River floodplains near Srinagar and Baramulla. The highest elevation regions are towards the Zanskar range to over 5,000 m at the mountain passes in Gurez and Sonmarg. The Jhelum River which serves as the major waterbody originating from a spring at Verinag in southern Kashmir traverses the whole valley and exits at the Uri sector in the northwestern side of Kashmir. The area is the valley's only drainage outlet towards the Indus system (Khajuria et al. 1999; Romshoo et al. 2020). Along its course, the Jhelum River feeds multiple lakes and wetlands, including Wular, Dal, Anchar, Hokersar, and Shallabugh, several of which are designated Ramsar Sites due to their international ecological importance (Jamal et al. 2022). These wetlands of Kashmir are ecologically important and serve as crucial stopover habitats for migratory waterfowl. They form a part of the Central Asian Flyway, hosting hundreds of thousands of migratory birds during winter (Javid & Ahmad 2023; Rahmani & Javid 2023). The climate is temperate, with warm summers and cool to cold winters. There is strong spatial variation in climate, the surrounding mountains experience heavy snowfall often >2–3 m in winter at higher elevations and remains for months to years. The valley floor city and low altitude areas of Srinagar, Bandipora and Baramulla have milder winters with less snowfall and most of the precipitation is in spring and summer. In human dominated landscapes, snow remains on the ground for a week with an average accumulation of less than 0.5 m. This variability, in landscape, is coupled mainly with steep elevational gradients, creating a mosaic of habitats in a relatively compact area.

Biogeographically, the Kashmir Valley lies at southern most end of the palearctic region and northern most end of oriental region (Image 1). The valley is climatically temperate and lies at the crossroads of the western Himalaya and the trans-Himalayan/Central Asian regions. It is part of the Himalayan biodiversity hotspot (Myers et al. 2000) and harbors ecologically important and endemic biodiversity. Due to differences in the climate, the Valley harbors different species than the rest of the country. The valley's floor, low altitude landscape and lower slopes 1,500–1,800 m were historically covered by temperate broadleaf forests and wetlands. Most of the area of this altitude has been modified into habitation, horticulture, farm plantation and agriculture over the centuries (Raza 2011). Middle elevations 1,800–3,000 m are dominated by coniferous forests, e.g., *Cedrus deodara*, *Pinus wallichiana*, *Abies pindrow*, *Picea smithiana* mixed at some places with broadleaf species *Aesculus indica* and *Juglans regia*. *Quercus* spp., is restricted to few patches in Dachigam National Park. At higher elevations around 3,200–3,500 m, the mix conifer forests give way to subalpine scrub and alpine meadows, stands of birch *Betula utilis* with rhododendron understory mark the tree line zone. Beyond the tree line, grasslands, and summer pastures are the open landscapes and harbor hundreds of seasonal herder families with their livestock in summer season. The pastures end up with the rougher and rocky landscape and seasonal and permeant snow-clad peaks. Floristically, the region is rich with an estimated 3,000+ herbaceous plant species, which have been recorded in Jammu & Kashmir (Dar & Khuroo 2020). The herbaceous strata, include medicinal and endemic plants (Kaul 1997). Some of these form as livelihood for locals by collecting and selling the medicinal plants some of which cost around $100 to 500 /kg.

Traditional land-use practices like transhumant grazing and terrace farming towards the Gurez and Lolab Valley have shaped the landscape in a way that still supports significant wildlife outside dense forests. Expanding human population tourism expansion and agricultural development have led to deforestation and important wetland loss like Shallabugh, Mirgund in parts of the valley. The valley floor around the capital of Jammu & Kashmir, Srinagar City, and the southern districts mostly Pulwama and Shopian, large tracts of forest buffer and wetland buffers have been converted to orchards or settlements over the past few decades; and wetlands like Hokersar have shrunk due to siltation and land reclamation (Mir et al. 2014; Ahmad et al. 2015). Studies indicate that built-up area around protected forests is rapidly increasing, around Dachigam National Park, urban expansion of ~325% was observed over 55 years, contributing to high habitat fragmentation

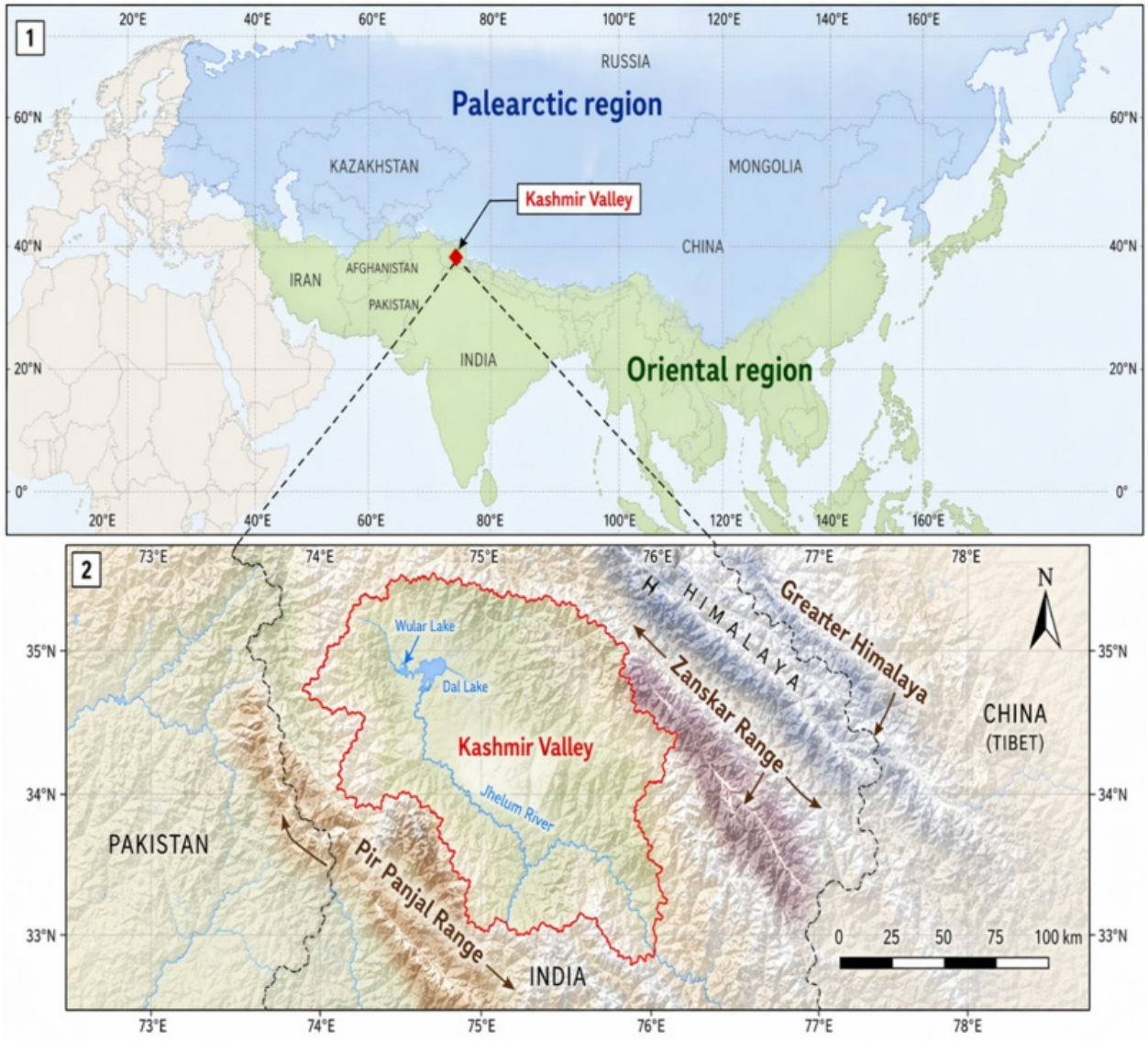

Image 1. Biogeographic position of the Kashmir Valley at the interface of the Palearctic and Oriental regions.

(Aneaus et al. 2023).

Despite these increasing pressures, and land-use conversion about half of the Kashmir Valley remains under natural vegetation cover. Based on the India State of Forest Report (FSI 2021), the Kashmir region has around 50% forest cover, one of the highest proportions in India (Kashmir Life 2024). The forests and other natural habitats of the region support a high diversity of fragile fauna, making the valley a critical refuge for Himalayan wildlife. Some of the species are close to the bottle neck extinction if proper steps are not being taken on time.

Faunal diversity and key species

The Kashmir Valley's diverse and rich habitats support ecologically important assemblage of wildlife, including endemic, charismatic and threatened species. The region is the last stronghold of the Kashmir Stag or Hangul *Cervus hanglu hanglu*, a Critically Endangered only southern Asian red deer species found in and around Dachigam National Park (Ahmad et al. 2016). Hangul migrate seasonally and shows the altitudinal migration between low-elevation riverine forests and highland meadows. Their population has dwindled to few hundreds due to poaching and habitat loss. Dachigam and connected landscapes like Wangat conservation reserve and Tral Wildlife Sanctuary are important landscapes for their long-term survival. Another flagship species is the Kashmir Markhor *Capra falconeri cashmiriensis*, a wild goat with spectacular curved horns. In India, Markhor are now confined to the region

only and in Kashmir, further restricted to north-western Kashmir Valley around the Kazinag range along the Line of Control. Kazinag National Park was established to protect the Markhor's last habitat in the valley, and this area also holds other mountain ungulates like Kashmir Musk Deer *Moschus cupreus* and Himalayan Grey Goral *Naemorhedus goral*. Goral is restricted to Lachipora Wildlife Sanctuary and parts of Kazinag National Park.

The Kashmir Musk Deer *Moschus cupreus* is an endangered ungulate endemic to the Western Himalaya (Timmins & Duckworth 2015; Singh et al. 2020). The species is a shy, crepuscular animal known for the male's musk gland. It inhabits high-altitude temperate and subalpine forests, generally between the altitudes of 2,500-4,000 m. Musk Deer are habitat specialists; they prefer dense understory, often in birch-rhododendron, scrub near tree line and steep rugged terrain where they can escape predators. The species occurs patchily throughout the Kashmir Valley and was recorded throughout the valley in upper Dachigam, Sindh Valley thajwas, in the Pir Panjal Range of southern Kashmir, and in Gurez Valley. Reliable data on its distribution and status have historically been scarce due to the inaccessibility of its habitats and decades of sociopolitical conflict in some areas. Camera trapping effort provided new insights, confirming musk deer presence in all major landscapes of Kashmir, including the areas outside formal reserves. Gurez valley was the high abundance zone of the species and lies outside the formal protection. Poaching for musk pods and habitat fragmentation from logging and fuelwood collection are thought to be primary threats to musk deer (Rashid et al. 2015; Jain et al. 2025). Emerging threats from climate change, shifting the tree line and vegetation structure of its habitat will also impact the species over the time (Singh et al. 2020).

Himalayan Ibex *Capra sibirica* is distributed towards the Zanskar Range, including the upper parts of the Sindh Valley and the whole of the Gurez Valley. They prefer the sharp cliffs, and the whole of the population lies outside the protected area network. The abundance of the species gets concentrated in the lower parts of the valley during winter and migrates over the alpine meadows in summer. Our camera traps have documented the species in overlap with musk deer in Gurez Valley and with hangul in the Mammar area of Sindh Valley outside the boundary of Wangath Conservation Reserve. The Himalayan Serow *Capricornis thar* is a rare and secretive goat-antelope inhabiting the forests of Kashmir. Classified as 'Near Threatened', this unusual mammal shows a striking blend of goat-, donkey-, and pig-like features. It prefers steep, rugged slopes in places such as Dachigam National Park and Overa-Aru, and is rarely seen because of its timid behavior and the dense woodland habitat it occupies. The ungulate in Dachigam was sited only during the field survey in April 2023 and a single capture in a camera trap from the Brain Nishat Conservation Reserve.

The Indian Muntjac or Barking Deer *Muntiacus muntjak* is a rare and highly elusive ungulate inhabiting the forested areas of Jammu & Kashmir. Its recent rescue in the Uri sector of northern Kashmir, Baramulla, by the Wildlife Department of Kashmir confirms its presence in the region, although it remains very rarely documented. During the field surveys, this species was not encountered directly, and it was also not recorded in the camera-trap data. This indicates that the Indian Muntjac is either extremely uncommon in the study area or occurs in habitats where the probability of detection is very low. Besides ungulates the Kashmir Valley harbors diversity of other threatened mammals. Asiatic Black Bear *Ursus thibetanus* and Himalayan Brown Bear *Ursus arctos* are both present, at different locations and come in contact in some seasons in landscape of Gurez and upper Sindh valleys. The black bear is common in forest foothills and often raid orchards and villages, whereas the brown bear is found in alpine meadows of upper Sindh and Gurez valleys. The black bear migrates with the herders in late spring and comes back in autumn along with the herd. It escapes the valley heat during summer and the harsh winter in high altitudes. The migration also impacts the brown bear as it migrates further high during summer. Common Leopards *Panthera pardus* and Himalayan Wolf *Canis lupus chanco* are the top predator of the region and have a widespread distribution. Both the predators are distributed throughout the valley but the Himalayan Wolf prohibits to come in direct interaction with humans and avoids the human habitation areas. The negative interactions with the leopard exists throughout the valley and drastic increase in child lifting have happened over the past few years towards the forest fringe villages (Javid et al. 2024a). Occasional reports of the Snow Leopard *Panthera uncia* come from the high mountain passes of Kolahoi, Harmukh, especially in winter when they may descend closer to human habitations, but our camera survey did not capture any Snow Leopard in the valley during 2023–2025. Other carnivores include the Leopard Cat *Prionailurus bengalensis*, Jungle Cat *Felis chaus*, Red Fox *Vulpes vulpes*, Golden Jackal *Canis aureus indicus*, and Yellow-throated Marten *Martes flavigula*. They are distributed throughout the valley and are enemies of the poultry rearing in Kashmir, usually the local farmers who raise in homes. The Eurasian Otter

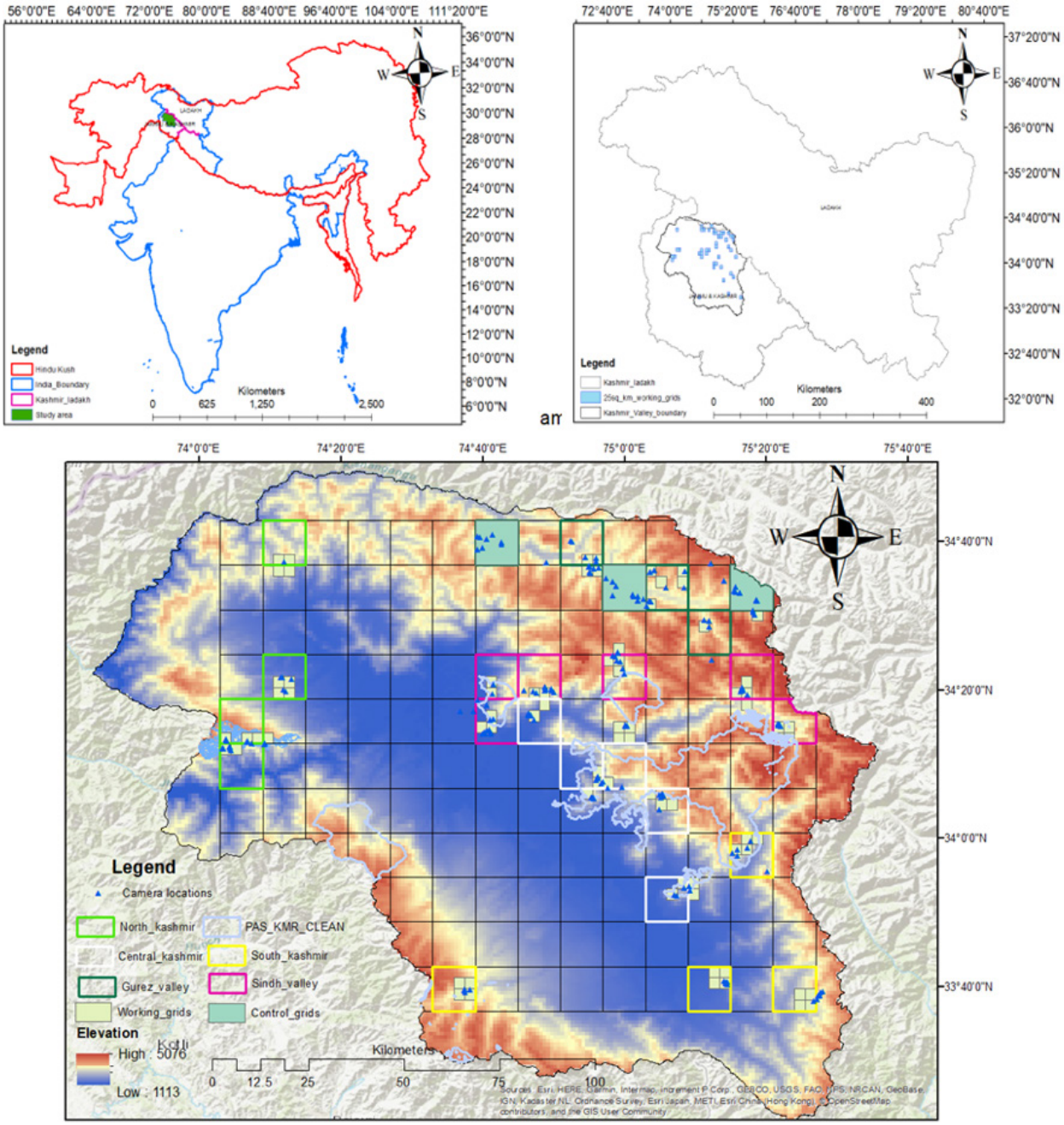

Image 2. Map of the Indian Kashmir Valley showing the five landscape strata, camera trap locations, and major protected areas.

Lutra lutra indicates a healthy trophic web in many areas. It is distributed throughout the valley streams, the highest population is observed in Wular Lake. The diversity of small mammals like pikas, marmots, rodents, bats, and herpetofauna in the valley is less documented but likely high, given the habitat range, the Himalayan Marmot is common in alpine meadows of Sonamarg and Gurez. Other than mammals, eight bat species have been recorded from the Kashmir valley by Malik & Gupta (2020). The checklist of Jammu & Kashmir, including Ladakh, on mammals has reported 112 species of mammals: including 34 globally threatened, with one Critically Endangered, six Endangered, 12 Vulnerable, and eight Near Threatened species (Ahmad et al. 2020). The checklist of Jammu & Kashmir UT has documents 111 species across eight orders and 28 families, with 94 species verified by specimens and 70 by photographic records (Kichloo et al. 2025).

Avifauna of the valley equally important and the valley is home to over 300 bird species (Dar & Khuroo 2020).

The valley harbors species ranging from high-altitude specialists like the Himalayan Snowcock and Golden Eagle, to forest birds like the Himalayan Monal, Western Tragopan, Koklass Pheasant, and the Kashmir Flycatcher an endemic breeder, and migratory and residential wetland birds in the valley's lakes. A comprehensive updated checklist that covers both Jammu & Kashmir Union Territory has documented 599 bird species (Kichloo et al. 2024). Earlier including Ladakh (before reorganization) the checklist has reported 555 birds in 76 families (Suhail et al 2020). The wetlands of Kashmir Wular, Hokersar, Haigam, Shallabugh, and Mirgund are of international importance; they support millions of migratory ducks, geese, swans, and shorebirds in winter and are breeding grounds for species such Mallard, Coot, and Moorhen. The Shallabugh wetland at the mouth of Sindh River, hosts tens of thousands of waterfowl each autumn and spring, making it a vital link in the migratory network (Rahmani & Javid 2023; Javid et al. 2024a). Upland game birds like Chakor Partridge and Himalayan Snow Partridge occur on open slopes.

The Kashmir Valley's fauna reflects its position as a biogeographic transition zone and a Himalayan biodiversity rich region. Many species of the migratory birds Mallard, Northern Showler, Bar-headed Goose use the valley as a corridor and transit between the Himalaya and the plains or between different Himalayan sub-regions. This underscores the importance of maintaining habitat connectivity across the landscape (MOEFCC, 2018; Mukharjee et al. 2021).

Landscapes and land use zones in the valley

For the purposes of ecological sampling and landscape level representation, we stratified the Kashmir Valley into five broad landscapes, based on physiography, land use, and administrative blocks to ensure coverage of the valley's environmental heterogeneity (Image 2). These landscapes are: (i) central Kashmir, (ii) northern Kashmir, (iii) southern Kashmir, (iv) Sindh Valley, and (v) Gurez Valley. They also reflect management units for the presence/absence of species, protected areas distribution and biogeographic differences within the landscape.

Central Kashmir (Central Valley floor) landscape comprises the central part of the valley around the capital city Srinagar, extending southward to the foothills of the Pir Panjal and northward up to the Sindh Valley's mouth. The landscape comprises of the Zabarwan Hills, Dull Lake and other important landscapes. It includes human-dominated areas towns, agricultural land and important protected areas on the fringes. Key area includes Dachigam National Park and its surrounding reserves Bren-Nishat Conservation Reserve, Dara and Khrew areas, which protect the Dachigam landscape and support Hangul, Musk Deer, Himalayan Black Bear, and other fauna. The nearby Tral Wildlife Sanctuary was also included that is situated on the southeastern fringe in the Pulwama District under central Kashmir as that is connected through the upper Dachigam and is similar to the area in context of ecology and habitat. The landscape is characterized by moderate elevation forests (1,600–3,000 m), dominated with orchards, rice fields on the valley floor. The area also comprised the urban and rural areas around Srinagar. The area covering an elevational range from about 1,500 m in city and goes up to 4,500 m. in the nigberan area of upper Dachigam towards Narstan, Zuastan area of Tral tehsil of Pulwama District. Despite being relatively developed in the culture and infrastructure; this central landscape still retains pockets of wilderness. The data shows ~24% of central Kashmir grid samples were alpine meadows or grasslands and ~13% shrubland, often on the higher slopes of Dachigam and Tral. Forest cover (broadleaf and conifer combined) accounted for roughly 26% of this landscape by area, while agriculture and orchards covered ~9% based on our LULC map of the region.

Northern Kashmir (Jhelum Valley & northwestern highlands), the landscape covers northwestern part of the Kashmir Valley along the Jhelum River downstream of Baramulla, extending to the Line of Control (LoC) with Pakistan. It includes the Uri area, Lachipora, Limber area and Kazinag National Park. The area includes the famous Bangus Lolab, Keran Valley in Kupwara District. The Shamsbari range divides the Karnah and Kupwara region. Northern Kashmir is mountainous terrain, excluding the area around the Wular Lake, furcated by the Jhelum and its tributaries. Kazinag National Park (89 km²) lies on the northern bank of the Jhelum River, protecting dense conifer forests and alpine cliffs that are the last viable habitat of the Kashmir markhor in India. Adjacent to Kazinag are the Limber and Lachipora wildlife sanctuaries, also serving as a buffer to the Kazinag National Park and the Naganari Conservation Reserve. Limber and Lachipora hold an abundance of Markhor and Goral, and can act as the best place in Kashmir to start up with nature tourism. In Lachipora, from the terrace of houses, the Markhor and Goral are seen easily and best accessible place to photograph the Markhor. To the west, near the LoC, towards the Tangdar side of Kupwara, is the Bangus valley, a high-altitude grassland basin ringed by forests, known for its meadows. This study explored the area for the first time

Table 1. Ramsar sites and important bird areas of Kashmir, with area, region, habitat significance, and representative avian species of conservation importance.

Site	Region	Area	Bird-importance note	Representative avian species and status
Wular Lake	Kashmir Valley floodplain, northwestern side of Srinagar / Sopore side	18,900 ha	Ramsar since 1990; current BirdLife/ KBA factsheet describes it as an important wintering and stopover wetland that regularly holds >20,000 waterfowl.	Pallas's Fish-Eagle *Haliaeetus leucoryphus* - EN; also supports large numbers of ducks and geese, plus Koklass Pheasant and Himalayan Monal in surrounding habitats.
Hokera Wetland (often written Hokersar/ Hokarsar in bird-area sources)	Western side of Srinagar	1,375 ha	Ramsar since 2005; major resident and migratory waterfowl site, with KBA notes recording up to 25,000 wintering ducks at one time and very large winter counts in some surveys.	Pallas's Fish-Eagle - EN; Ferruginous Duck *Aythya nyroca* - NT; also, Common Teal, Northern Pintail, Mallard, Pheasant-tailed Jacana.
Hygam Wetland Conservation Reserve	Northern side of Kashmir / Baramulla-Sopore side	802 ha	Ramsar since 2022; BirdLife lists Haigam Rakh (marshes) under IBA criteria A1, A4iii. Studies describe it as a major reedbed-waterfowl wetland.	Recent/regularly reported birds include Common Teal, Northern Pintail, Eurasian Wigeon, Mallard; earlier site reports also note Ferruginous Duck (NT) and Pallas's Fish-Eagle (EN) among species recorded from the wetland.
Shallbugh Wetland Conservation Reserve	Central Kashmir / Srinagar-Ganderbal fringe	1,675 ha	Ramsar since 2022; KBA factsheet describes it as an important staging and wintering marsh, with >150,000 ducks and geese recorded at one time.	Ferruginous Duck - NT; also, Northern Pintail, Eurasian Wigeon, Mallard, Garganey, Northern Shoveller, Red-crested Pochard.

for wildlife through camera traps and has documented western tragopan, along with the other important wildlife species. The area has no official protected status yet, and is also home for endangered Kashmir Musk Deer, also a buffer to the Kazinag Markhor Landscape. People revealed that they have sighted Markhor in the area in earlier times. Northern Kashmir experiences harsh winters with snow up to 2 m at higher elevations and pleasant summers. The area covering elevation ranges 1,100–4,500 m. The lowest altitude point of the valley also falls in this landscape, from where the whole water of the Jhelum catchment drains to Pakistan. Land cover is a mix of coniferous forests and alpine meadows, with relatively less agriculture than the central or southern landscapes. Most farming is confined to narrow river valleys like Uri and Teetwal. The environmental analysis indicates the human footprint is moderate here mean human footprint index of ~11,800, intermediate among landscapes. Most of the population lives in rural villages and a high army presence along the LoC, but large tracts of forest and pasture still remain roadless. Wildlife in northern Kashmir from our cameras confirmed species like Common Leopard, Black Bear, Red Fox, Markhor, Coral, Musk Deer in this region.

Southern Kashmir (Pir Panjal Range) towards the Anantnag, Shopian, and Kulgam. The landscape covers the southern end of the valley and the Pir Panjal Mountain ranges that separate Kashmir from the Jammu region. The landscape gives two entry passes to the Kashmir from rest of the India, through Banihal towards the Ramban side and Mughal Road towards Rajori side. The area connects Kashmir with the Kishtwar Valley through Simthan top, the part of the Rajparian Wildlife sanctuary. It is a region of steep valleys and include Lidder, Bringhi, Veshu draining into the Jhelum, and hosts some important protected areas. Overa-Aru Wildlife Sanctuary (near Pahalgam in Anantnag District), Rajparian Wildlife Sanctuary (Daksum in the Bringhi Valley), and Hirpora Wildlife Sanctuary (a high-altitude reserve in Shopian District along the Mughal Road). These protected areas range from temperate forests to alpine meadows and collectively form a crucial habitat for Hangul in Overa-Aru, which is connected with Dachigam and a secondary Hangul site. This is considered the old corridor of Hangul connecting the Kishtwar landscape. The landscape serves as the habitat for Kashmir Musk Deer, Kashmir Markhor in the Hirpora towards Mughal road and Tatakuti, brown bear in the upper range of the Pehalgam area. Southern Kashmir also has heavily populated areas and significant human pressures, for example, the Achabal Conservation Reserve (CR) and Khiram CR cover foothill forests surrounded by a mosaic of orchards, pasture, and military establishments in Achabal. The area ranges in altitude from 1,600 m at Anantnag urban area to 4,800 m towards the Pir Panjal Mountain range. The area spans over the farmlands to alpine pastures in mosaic habitat conditions. This region showed a relatively high wilderness index (mean ~0.75) despite human presence. The high wilderness value is because of the presence of the inaccessible Sanctuary areas like upper Hirpora and Overa Aru, and the Simthan region that is closed for part of the year and that has limited road access to most of the regions. Still, lower elevations of southern Kashmir are quite impacted,

e.g. the Anantnag has extensive apple orchards and villages. The land cover analysis for our South Kashmir grids showed ~33% alpine meadows/shrub, ~10% dense conifer forest, and over 15% agriculture/horticulture, especially in the lower Lidder and Shopian areas. The South Kashmir's Pir Panjal meadows are the entry point for the seasonal herders in the valley and receive the herders from late spring when herders enter the valley to late autumn when herders leave the valley. The area is seasonally used by large numbers of nomadic herders (Gujjars and Bakarwals) who bring flocks of sheep and goats in summer for grazing and escape the harsh summer of the Jammu region of Jammu & Kashmir. This seasonal grazing is a prominent land-use in the Pir Panjal range and has implications for wildlife like musk deer, markhor, leopard, wolf, and bears.

Sindh Valley (Sind River Basin), throughout the Ganderbal District. The area is a distinct sub-valley branching north-east from central Kashmir, following the Sindh River. The valley starts from the Jhelum at Shadipora up to the Zojila Pass towards Ladakh. It is often considered the ecological backbone of central Kashmir due to its connectivity and habitat diversity. Elevations in Sindh range from ~1,600 m at the mouth near Shallabugh area to ~3,600–4,500 m at Sonamarg and Baltal, where it gives pass to Ladakh with surrounding peaks over 5,000 m. The valley is flanked by the Zanskar Range to the northern side and a corridor through the Thajwas Glacier to the Pir Panjal in the south. The Sindh Valley contains a mix of coniferous forests mix deodar and Wallichiana forests in the lower reaches, alpine meadows like Sonamarg's famous grasslands and the connecting Gurez landscape, which forms a long stretch of grass meadows. The area harbors high altitude lakes like Gangabal and Vishansar. The human settlement is concentrated along the Sindh River, forming a stretch of habitation over a 70 km length. It is a crucial corridor for trade and wildlife. Historically the Zojila Pass at its head was part of ancient trade routes connecting Kashmir with Tibet and Central Asia. Key protected areas in the Sindh region include Thajwas Baltal Wildlife Sanctuary near Sonamarg, and Wangath Conservation Reserve in a side valley, Naranag Pandaw Temple. The Sindh Valley also adjoins the Overa-Aru and pehalgam landscape through the Baltal area via mountain passes, making it a potential wildlife corridor. Land cover in Sindh sampling was quite varied: dense forests in some lower segments, but a high proportion of alpine pastures (~36%) and shrublands (~11%) at middle-high elevations, plus rocky areas at the high-altitude landscape. Increased human footprints are present towards the tourist area villages like Kullan, Gund, Sonamarg tourist hub, and a highway to Ladakh, but large areas remain wilderness (mean wilderness index ~0.71). The Sindh Valley is rich in wildlife the cameras recorded Musk Deer, Hangul, Leopard, Black Bear, Brown Bear, Martin, Marmot, Himalayan Ibex and Red Fox frequently. The area favors movement of Hangul Deer between Dachigam and Wangat Sindh area through connecting ridges. The valley's high-altitude lakes, Gangbal, Gadsar, Vishansar, Krishansar, and Satsar lakes and alpine meadows, Mohan Marg, Lal Marg, Mengandob, Gangbal, Salnai around Harmukh Range are used by herders in summer. The meadows are culturally important, but raises concern of competition with wild herbivores and disturbance. The dogs with the herd are of main concern for wildlife conservation and pose a significant threat.

Gurez Valley, the extension to the Nelam Valley of Pakistan, (high northwestern frontier) forms the northernmost extension of Kashmir. The valley is an isolated high-elevation landscape running parallel to the main Sindh Valley but separated by the vast Harmukh Range. The Razdan Pass is the highest pass that connects the valley with other parts of Kashmir region through Bandipora. The valley remains detached from other parts of Kashmir during winter and the army operated helicopters are the only source of transportation. Gurez is drained by the Kishanganga River and in Pakistan its Neelum River. The river flows westward from the Kabul Gali the valley west most point into Pakistan. Elevations in inhabited villages of Gurez range from ~2,300 m at Dawar (the main town) to ~3,500 m at the highest village Checkwali towards the west most point. The valley is surrounded by mountains exceeding 5,000 m. This valley is particularly remote and wild it lies along the Line of Control and until 2019 it was mostly off-limits to tourism. There is not a single notified wildlife protected area in Gurez, yet while as it harbors some of the highest quality habitats and threatened flora and fauna in the region. Extensive birch forests, present in rills of the small narrow valley alpine shrublands, and undisturbed meadows characterize Gurez valley. The human population density in the area is very low, villages are small and scattered and the locals migrate to other parts of Kashmir during winter. From our survey about 65% of the families migrate in winter to district Ganderbal and Bandipora. Livelihoods traditionally revolve around subsistence agriculture (potatoes, pulses) and pastoralism (Sultan et al. 2019). Most of the youth is working with army as porters and daily labors, this study found that people are interested in ecotourism through homestay and nature guides. Gurez had the highest wilderness index of all

Table 2. Protected areas and wetlands of the Kashmir region with their area.

	Protected area / wetland	Category	District	Area (km²)
1	Dachigam National Park	National Park	Srinagar / Pulwama	141
2	Kazinag National Park	National Park	Baramulla	90
3	Overa-Aru Wildlife Sanctuary	Wildlife Sanctuary	Anantnag	425
4	Rajparian (Daksum) Wildlife Sanctuary	Wildlife Sanctuary	Anantnag	20
5	Gulmarg Wildlife Sanctuary	Wildlife Sanctuary	Baramulla	180
6	Limber Wildlife Sanctuary	Wildlife Sanctuary	Baramulla	21
7	Lachipora Wildlife Sanctuary	Wildlife Sanctuary	Baramulla	37
8	Hirpora Wildlife Sanctuary	Wildlife Sanctuary	Shopian	341
9	Thajwas (Baltal) Wildlife Sanctuary	Wildlife Sanctuary	Ganderbal	203
10	Tral Wildlife Sanctuary	Wildlife Sanctuary	Pulwama	154
11	Achhabal Conservation Reserve	Conservation Reserve	Anantnag	20
12	Khrew Conservation Reserve	Conservation Reserve	Pulwama	50
13	Khonmoh Conservation Reserve	Conservation Reserve	Pulwama	67
14	Brain-Nishat Conservation Reserve	Conservation Reserve	Srinagar	16
15	Khimber-Dara-Sharazbal Conservation Reserve	Conservation Reserve	Srinagar	34
16	Wangat Conservation Reserve	Conservation Reserve	Ganderbal	12
17	Ajas Conservation Reserve	Conservation Reserve	Bandipora	48
18	Naganari Conservation Reserve	Conservation Reserve	Baramulla	22
19	Salim Ali City Forest National Park	National Park	Srinagar	8.69
20	Hokera / Hokersar Wetland Reserve	Ramsar wetland	Srinagar / Budgam	14
21	Hygam Wetland Reserve	Ramsar wetland	Baramulla	8
22	Shallabugh Wetland Reserve	Ramsar wetland	Ganderbal	17
23	Mirgund Wetland Reserve	Wetland Reserve	Baramulla	4
24	Malgam Wetland Reserve	Wetland Reserve	Bandipora	3
25	Chatlam Wetland Reserve	Wetland Reserve	Pulwama	0.426
26	Manibugh Wetland Reserve	Wetland Reserve	Pulwama	0.053
27	Kranchoo Wetland Reserve	Wetland Reserve	Pulwama	0.064
28	Freshkori Wetland Reserve	Wetland Reserve	Pulwama	0.1525
29	Wular Lake	Ramsar wetland	Bandipora / Baramulla	189

landscapes mean index of ~0.82, with most of the areas virgin and essentially pristine. Over one-third of the Gurez landscape is open meadows, and another ~25% is alpine scrub or bare rock; forest cover is patchy (~13% combined conifer and mixed forest) and largely confined to lower slope birch/conifer groves. Despite the lack of formal protection, Gurez serves as a vital refuge for wildlife. These surveys and other recent studies show Kashmir Musk Deer thrives in Gurez's birch forests and subalpine zones, which likely represent some of the best remaining musk deer habitat. Other species documented in camera are Himalayan Brown Bear, Himalayan Ibex, Eurasian Otter, Yellow-throated Martin. There are some local evidences of Snow Leopard but our camera traps did not record. The Snow Leopard is well reported and more frequently recorded just across the LoC in Pakistan's Neelum Valley. The absence of large-scale development has kept Gurez ecologically intact. Apart from a hydroelectric project on the Kishanganga and its associated infrastructure development residential and administrative, is increasing the fragmentation in the landscape. Being outside the protected area network, it does not remain distant from conservation programs but also implementation of the wildlife laws. The high wilderness value of Gurez underscores the importance of integrating such unprotected valuable landscapes into regional conservation planning.

Protected areas and land management

From the early maharaja time the Kashmir Valley

have, many bird and animal protected areas where were conserved for royal hunting only. After recognizing the Kashmir Valley's ecological significance, a network of protected areas (PAs) has been established throughout the valley over the past century. These areas include national parks, wildlife sanctuaries, conservation reserves, and wetland reserves. As of 2025, the valley contains three national parks and eight wildlife sanctuaries, along with 13 conservation reserves and several Ramsar wetlands and IBA sites (Farooq et al. 2021). The total area under this wildlife protection network in region is about 2,171 km², which forms approximately 13.57% of the geographical area of the Kashmir Valley. This is slightly below the current Kunming–Montreal GBF Target 3 (30% by 2030) for terrestrial protection, but comparable to the average for mountainous regions in India. The PAs in Kashmir are not contiguous, they are distributed throughout the landscapes in pockets mentioned above, often separated by valleys with human settlements.

Major protected areas Dachigam National Park (141 km², established in 1981), situated on Srinagar's outskirts, is the flagship park of Kashmir, famous for Hangul Deer. Dachigam ranges 1,700–4,200 m, encompassing habitats from riverine forest to alpine meadow (Ahmad et al. 2016). It is IUCN Category II and has a well-defined core zone closed to grazing, surrounded by buffer conservation reserves. The Dachigam's upper catchment extends into Thajwas CR, Tral wildlife sanctuary and Sindh Valley. Despite legal protection, Dachigam faces pressures from encroachment and resource extraction on its fringes mostly in Upper Dachigam area.

Kazinag National Park (90 km², est. 2007) in Baramulla district along the LoC, was created by merging some part of the Lachipora and Limber Sanctuaries and adjacent forests. Kazinag harbors the only viable Indian population of Markhor. It's terrain (1,800–4,300 m) includes steep cliffs and river gorges. Due to security restrictions, access is limited, which has inadvertently kept human disturbance low. But in the Lachipora B area and Harbaji Bahak, the area is invaded by the seasonal herders. Kazinag is part of a larger transboundary conservation landscape contiguous with protected areas in the Hattian Bala District of Pakistan-occupied Kashmir, with the Qazinag Game Reserve.

Overa-Aru WS (425 km²) in Pahalgam area of Anantnag District, which, despite its name, covers a large area of the Lidder basin including forests and alpine zones of Aru and Olvera. The sanctuary is an Important Bird Area also. Hirpora WS (341 km²) in Shopian, covering the high-altitude Pir Panjal meadows and known as a corridor for markhor moving between Kashmir and Jammu regions Tatakuti WS. The efforts have not captured Markhor in camera trap over a survey period of two months March–April 2025. Tral WS (154 km²) in south-central Kashmir, protecting forest hills in Pulwama. The sanctuary is the second top refuge for Hangul and conservation breeding programme for Hangul have been started there in shikargah area of the Sanctuary. Gulmarg WS (180 km²) in the Pir Panjal northwestern side of Srinagar, is known for its alpine pasture and fauna like Kashmir Musk Deer and pheasants. The sanctuary is highly fragmented by the tourism and the Gandola (cable car) service, snow seeking and ATV operation make it un available for most of the wildlife. Thajwas Baltal WS (203 km²) at the western most point of Sindh Valley around Sonamarg tourist spot, which protects glaciers and meadows on the way to Zojila. The sanctuary is important corridor for the wildlife and harbors the highest abundance of the Musk Deer in sarbal area. Rajparian WS (20 km² official, though an expansion has been proposed) in the southeastern valley, important for musk deer connectivity. The sanctuary is highly disturbed by the presence of sheep form the sheep husbandry department. The sheep farm lures the Himalayan Wolf and can serve the best spot to work the Himalayan Wolf. In addition, there are wetland reserves, Hokersar, Shallabugh, Haigam, and Mirgund, each just a few to a few dozen square kilometers, designated to protect waterfowl habitats. But the fluctuation in the seasonal waters and encroachment have disturbed them to the maximum of its possible extent.

The Wildlife (Protection) Act 1972 provides for community co-managed areas called Conservation Reserves (CR). In Kashmir, these include forest patches and earlier maharaja time game reserves like Bren Nishat CR (16 km²) and Khimber-Dara CR on Srinagar's periphery (buffering Dachigam), Ajas CR (48 km²) in Bandipora, Naganari CR (22 km²) in Baramulla (buffer to Kazinag), Achabal CR (20 km²) in Anantnag and others. These CRs often serve as buffer corridors for NP and WS and corridors to connect larger PAs or protect smaller habitat fragments. Although legally protected, the level of protection is low compared to national parks/ sanctuaries, traditional activities and even development can occur, subject to proper permission from authorities.

Overall, the protected area network in Kashmir is ecologically representative of the region's biodiversity to an extent. But requires policies on herder movement and their carrying capacity. Protected areas cover alpine zones, temperate forests, and wetlands. They harbor threatened and endemic species (Hangul, Markhor,

Musk Deer, Himalayan Brown Bear, Western Tragopan, pheasant) find refuge in these PAs. The network also has gaps and need to be addressed in future for long term conservation. Entire landscapes like Gurez valley remain unprotected, and some PAs are small isolated (e.g., the wetland reserves, Naranag, Ajas, Achabal CR and Gulmarg, Rajparian WS). Furthermore, most PAs in Kashmir were delineated several decades ago, and there is evidence that environmental conditions have since changed. Some protected areas are facing the highest rate of exploitation from the tourism; these areas should be delaminated from the wildlife protected areas and a new area nearby should be delaminated in exchange. Forest cover and tree line have shifted upward in some areas due to climate change (Pandit et al. 2014), and intense development has occurred around PA boundaries (leading to edge effects). Some wildlife populations have moved outside original PAs in response to these changes or due to population recovery in surrounding areas. Hangul Deer once thought confined to Dachigam (Ahmad et al. 2023), this study has recorded Hangul in adjoining landscapes™ like Tral WS and even outside PAs in Wangath and Kangan areas of Sindh Valley, likely dispersing in search of suitable habitat for future sustenance. Similarly, our camera-trap data show Kashmir Musk Deer more presence in unprotected forests of Gurez and Tulail, highlighting that viable habitats exist beyond the current PA network (Table 2).

In context of landscape level assessment the study treats the entire Kashmir Valley as a single, integrated landscape for conservation analysis. While protected areas are crucial cornerstones but differences between sites inside vs outside PAs were not evaluated, focusing solely on PAs would overlook large portions of wildlife habitat in the valley and may ignore the species presence outside the PAs. Animal do not know the boundaries they search for the quality habitats. High-quality habitats and wildlife occurrences even fall in multiple-use zones or community lands. In fact, quantitative analysis of a wilderness index was made from remoteness and human footprint. The index which reveals that Gurez Valley, with no formal protection, has the highest wilderness score then all other landscapes (mean index ~0.82), exceedingly even the well-protected Dachigam landscape scored (~0.66). This indicates that some unprotected areas in Kashmir are as undisturbed or even less disturbed than the protected areas. Focusing conservation only within PAs boundaries is not sufficient for long-term biodiversity conservation in the region.

Another factor is climate change, which is expected to alter species distributions in the Himalayas. A recent modeling study by Singh et al. (2020) projected that by 2050s–2070s, suitable climate habitats for Kashmir Musk Deer will shift, and only about 4% of the species future climatic refugia lie within the current protected area network. This stark finding implies that ~96% of musk deer's potential refugia under climate change are outside present PAs network. This underscores the need for connectivity and protection beyond existing PA boundaries. As temperatures rise, many species in Kashmir may move to higher elevations or more northerly which are less disturbed areas in the valley. Species ensure that they can safely move through corridors like the Sindh Valley or the Pir Panjal range, and that destination habitats like Gurez are safeguarded, is critical.

Over the past decade, intensive land- use change happened due to human greed, the conversion of the fallow and fodder cultivation land to horticulture. This decreased the buffer between the habitation and forests, which provided the pseudo-habitat for the wildlife species. Protected areas also adopted changes in land use and habitat quality since PAs were established due to climate change in precipitation. Logging is prohibited inside PAs, but often continues in adjacent forests, which changes the microclimate inside the protected areas. The change sometimes makes the habitat inside PAs actually less favorable. Unmanaged vegetation is more susceptible for the natural fire which can act as deterrent for wild animals like bears compared to surrounding lightly used forests where a mosaic of vegetation exists. Some protected stands have aged without much undergrowth, reducing forage for deer, whereas community-managed forests may still maintain varied structure due to controlled grazing and extraction (Javid et al. 2024b). Managed and controlled grazing can be favorable for the vegetation in context of dispersal of palatable plant seeds (Sultan et al. 2019). In certain cases, wildlife especially wide-ranging herbivores and carnivores now spends significant time outside PAs in these surrounding landscapes which may offer ample forage or lower intra-specific competition. The Gurez and Tulail valleys, for example, have become safe zones for species like Musk Deer and Brown Bear simply because human presence is low. They lack legal protection, leaving them vulnerable to future development or poaching if not proactively managed.

Environmental covariates for the study were derived for each site from remote-sensing data using Sentinel-2 satellite imagery from October 2024 to quantitatively represent habitat differences (European

Space Agency 2015). Land use/land cover (LULC) for Kashmir was generated using supervised classification of the satellite imagery supported by ground-truthing (Maxwell et al., 2018). Topographic variables such as elevation and slope were derived from the ASTER global digital elevation model (ASTER GDEM) (Abrams et al. 2022). Anthropogenic variables, including distance to the nearest road and distance to settlements, were measured as Euclidean distances from road and village layers, while the human footprint index was extracted from a global human footprint dataset for 2020 across the landscape (Venter et al. 2016; Gassert et al. 2023). A wilderness index was computed for different landscapes, scaled from 0–1, by combining factors such as remoteness from roads and the lack of human modification, following established wilderness-mapping approaches (Radford et al. 2019). As noted, this index varied significantly among landscapes, with Gurez and parts of Sindh scoring very high, whereas central and north Kashmir scored lower in the analysis.

Major threats and conservation priorities

Key pressures on biodiversity in the Kashmir Valley include habitat fragmentation from road construction and human settlement growth. The seasonal herder grazing adds the fine scale competition between the livestock and wildlife. Livestock forms a major component of the rural and pastoral economy of Kashmir. According to the latest released official livestock data for Jammu & Kashmir from the 20th Livestock Census (2019), the Union Territory had cattle 2,539,240; buffalo 690,829; sheep 3,247,503; goats 1,730,218 (Department of Animal Husbandry and Dairying, 2021; PIB, 2023). Seasonal pastoralism is equally prominent practice in the Kashmir Himalaya, where transhumant Gujjar and Bakarwal herders move with their livestock from the Jammu region to the Kashmir Valley and high-altitude pastures in spring, and descend again in autumn with the onset of snowfall (Choudhary 2022; Daily Excelsior 2023). Government reporting on the autumn migration revealed that, in 2023, transport support was provided to 12,497 tribal families and 1,56,215 livestock moving from Kashmir Valley back to Jammu, highlighting the continuing scale and significance of this biannual herding system (HT Correspondent 2023; Daily Excelsior 2023). A proper root should be delineated for the herders to enter Kashmir all the landscapes should not be opened to the threat as the livestock carry diseases and pests. Madhaya pradesh grazing rules 1986 have proper delineated routes for the herders Published vide Notification No. F-7-1-84-10-3, dated 30 June1986, published in M.P. Rajpatra (Asadharan), dated 30 June 1986 at page 1057. The already framed policy should be revised for the Kashmir in context of the conservation of the threatened species.

The human wildlife negative interactions involving carnivore lifting child or livestock and crop-raiding is increasing over the time in the Kashmir Valley. This becomes a big challenge for wildlife department over the years. Human-wildlife negative interactions from Asiatic Black Bears and Common Leopards in the Kashmir region is a major conservation and livelihood issue (Choudhury et al. 2008; Moten et al. 2017). A decade-long study in the Kashmir Valley indicated a rise in interaction-related injuries, with bear attacks being the most prevalent, succeeded by leopard attacks (Moten et al. 2017). Autumn from August to October as the harvesting season is high risk season for people working outdoors in orchards (Javid et al. 2024b). A comprehensive assessment of the Kashmir Valley, involving over 200 victim interviews and more than 100 site visits, revealed that approximately 47.26% of bear incidents occurred in agricultural fields and orchards, while around 52% of leopard attacks transpired near human habitations. This study also identified bear-conflict hotspots in the Tral-Khrew and Kulgam regions, and leopard-conflict hotspots in Kupwara, Handwara, Bandipora, and Shangus (Choudhury et al. 2008). A household-level survey conducted around Dachigam National Park indicated that 44.82% of respondents experienced crop damage and loss of domestic animals, 26.25% reported a direct threat to humans, and livestock predation reached its highest point in summer at 58.4% (Dar et al. 2022). An 11-year study in and around Hirpora Wildlife Sanctuary found 634 cases of injury (Bhat et al. 2022). Black bears caused 56% of the injuries and leopards caused 44%. The study also found that injuries decreased as people moved away from forests (Tariq et al. 2022). Recent official numbers from Kashmir media show that human-wildlife negative interactions killed 264 people and hurt 3,164 people between 2006 and March 2024. A different report said that since March 2023, nine people have died and 51 have been hurt in Kashmir alone, showing that the problem is still very serious (The Tribune 2023; Kashmir Life 2024).

In 2022, under a National Mission on Himalayan Studies (NMHS)-funded waterfowl migration project, the Division of Wildlife Sciences, SKUAST-Kashmir, deployed satellite Platform Transmitter Terminals (PTTs) on selected migratory waterbirds. One transmitter was fitted to a Northern Shoveler *Spatula clypeata* and another to a Greylag Goose *Anser anser*. The transmitter

attached to the Northern Shoveler remained operational for approximately four months; tracking data and subsequent field information indicated that the bird was killed in the Hajin area of Wular Lake. The Greylag Goose was also reportedly killed within one week of transmitter deployment, resulting in the premature termination of its tracking record due to poaching pressure. PTTs were installed on three Ibisbills *Ibidorhyncha struthersii* in 2023 and are functional from more than two years. The species is generally not targeted for poaching or human consumption.

Poaching is also a big threat; the winter migrant birds are on high threat in all the wetlands of Kashmir. Division of wildlife Sciences SKUAST-Kashmir installed PTT on waterfowl to study the migratory route of the species but unfortunately, they were killed by poachers in a month or two. Our camera traps revealed 16 photographs of active poachers from the field most of them were target poachers with proper professionalism. The poachers particularly threaten musk deer, pheasants and other high-value species. Wetlands face additional pressures from encroachment. The Jammu & Kashmir government has revealed that an area of 19,501.87 ha of forest land in J&K Union Territory has been encroached. Of the total forest land under encroachment, 5,891.49 ha of forest land is in Kashmir while the rest in Jammu region (Down to Earth 2026). Water and soil pollution, hydrological alteration, and invasive vegetation like Alternanthera *philoxeroides* (alligator weed), *Myriophyllum aquaticum*, and *Nymphoides mexicana* (Javid et al. 2024c). Ramsar-designated wetlands require sustained catchment-scale management to maintain their ecological character (MoEFCC 2025).

Climate change is expected to amplify risk to the wildlife and its habitat by shifting tree lines, altering snow regimes, and changing seasonal availability of forage and water. These changes may increase spatial overlap between wildlife and livestock and intensify conflict in forest mosaics and along forest edges. The distribution of seasonal herders and wildlife both depends in summer on water. Herders prefer the area where their livestock can drink freely and they make temporary shelters at the close water places. These shelters become deterrent for the wildlife and forces them to go beyond the area. Over the time water flow is decreasing in Kashmir and some of the permanent streams are becoming seasonal due to the change in show regime and early melting.

Priority actions for the region include: (i) identifying and safeguarding movement corridors for movement of wildlife without resistance from livestock between protected areas and high-value unprotected habitats; (ii) strengthening community-based governance for conservation reserves and wetland reserves; (iii) improving livestock management through seasonal zoning, grazing regulation, and disease-risk mitigation, and there migration routes; (iv) maintaining wetland ecological character through catchment-scale water and pollution management; and (v) standardizing landscape-scale biodiversity monitoring using repeatable designs and open reporting of sampling effort and context.

CONCLUSION

The Kashmir region is a globally significant Himalayan landscape that combines strong environmental gradients with high human dependence on natural resources. Its biodiversity values extend beyond the protected-area network and include wetlands of international importance and extensive unprotected forest and alpine habitats.

A standardized regional profile can improve comparability among studies and strengthen management relevance for threatened-species research in the Kashmir Himalaya. Long-term persistence of threatened species in the Kashmir region will depend on integrating protected-area management with connectivity conservation, wetland stewardship, and collaborative governance beyond protected areas.

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