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Distribution Update

Jackals in the world's highest elevation: a new record of a golden jackal (*Canis aureus*) in the Trans-Himalayan region of Ladakh, India

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Abstract

Golden jackals (*Canis aureus*) have a wide distribution range, owing to their omnivorous diet and tolerance to diverse environmental gradients. Originally native to northern Africa, eastern Africa, and southern Eurasia, golden jackals are currently expanding their range and have colonized much of eastern, central, and northern Europe. Golden jackals have previously been observed at elevations of 3,800 m asl in Ethiopia's Bale Mountains, at 3,400 m asl in Tibet, and at 2,000 m asl in some of India's hill regions. Here we describe the first record of a golden jackal in the Drass sub-division of the Trans-Himalayan Region of Ladakh, India. One golden jackal individual was photographed in October 2020 at an elevation of 3,120 m asl in the Drass area of the Kargil district, Union Territory (UT) of Ladakh. The analysis of mtDNA markers from carnivore scats collected for diet studies confirmed the presence of golden jackal at five other locations in the northeastern region of the high-altitude Changthang Wildlife Sanctuary at elevations between 4,724 – 5,365 m asl. These records were collected outside the current known range of golden jackals and represent the highest elevation ever recorded for golden jackals worldwide. Our findings raise important questions about habitat connectivity, range expansion, and the interspecific interactions of golden jackals, while also presenting potential conservation challenges.

Introduction

The golden jackal (*Canis aureus*, Linnaeus, 1758) belongs to the family Canidae. Traditionally considered native to northern Africa and southern Eurasia, it currently ranges from Europe to Southeast Asia, including the Indian subcontinent (Jhala 2004, Hoffmann et al. 2018). Across Asia, the golden jackal is found in a variety of landscapes such as semi-deserts, grasslands, savannas, forests, and mangroves, as well as agricultural, rural, and semi-urban habitats (Prater 1980). Since the early 1980's the golden jackal has been expanding its range rapidly into eastern and central Europe (Arnold et al. 2012, Lanszki et al. 2018). The golden jackal is a social animal with a highly flexible social structure that changes depending on food availability and distribution (Macdonald 1979). The golden jackal has been observed in high-altitude Himalayan regions of Nepal (Katuwal and Dahal 2013) at an elevation of 3,300 m asl in the Manaslu Conservation Area, and in the alpine meadow of Tibet (Dong et al. 2019) at an altitude of 3,400 m asl. The IUCN Red List classifies the golden jackal as Least Concern (Hoffmann et al. 2018) and it is listed in Appendix III of the Convention on International Trade in Endangered Species (CITES 1973) in India. The golden jackal found in India is included in Schedule III of India's Wildlife (Protection) Act, 1972. Schedule III species are not endangered but hunting is prohibited.

Methods

Study area

An extensive study area was selected for a systematic carnivore survey in the Trans-Himalayan region of Ladakh (Figure 1). The Union Territory (UT) of Ladakh is the northernmost part of India. The UT of Ladakh comprises two districts; Kargil and Leh region, which together constitute an area of 59,136 km^2. Kargil lies in the western region of Ladakh, close to the Greater Himalaya, and Leh is situated in the eastern region, contiguous with the Tibetan Plateau resulting in unique biogeographic features. The protected areas found in Ladakh are Hemis National Park, Changthang Wildlife Sanctuary, and Karakoram Wildlife Sanctuary. All these protected areas are found in the Leh district UT of Ladakh.

Within the Trans-Himalayan region of Ladakh, eight species of wild ungulates are present (Khan et al. 2023b), and they provide the main source of wild prey for large predators. Blue sheep (*Pseudois nayaur*) and Asiatic ibex (*Capra sibirica sakeen*) are the most common wild ungulates; small populations of Ladakh urial (*Ovis orientalis vignei*), Tibetan argali (*Ovis ammon*

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hodgsoni), musk deer (*Moschus* spp.), Tibetan gazelle (*Procapra picticaudata*), Tibetan antelope (*Pantholops hodgsoni*), and wild yak (*Bos mutus*) are also present (Fox et al. 1991, Chundawat and Qureshi 1999, Khan et al. 2023a) in the landscape. Marmots (*Marmota* spp.), hares (*Lepus* spp.), snowcocks (*Tetraogallus* spp.) and chukars (*Alectoris* spp.) can also form wild prey for predators. Sympatric carnivores in the Ladakh region are snow leopards (*Panthera uncia*), Himalayan wolves (*Canis lupus chanco*), Eurasian lynx (*Lynx lynx isabellina*), Tibetan foxes (*Vulpes ferrilata*), red foxes (*V. vulpes*), and Himalayan brown bears (*Ursus arctos isabellinus*; Fox and Chundawat (1995)).

Figure 1: Photograph showing the typical landscape of the Union Territory of Ladakh, India.

The vegetation of the region is predominantly dry alpine steppe consisting of widely spaced shrubs or subshrubs, including pea-shrub (*Caragana* spp.), wormwood (*Artemisia* spp.), woundwort (*Stachys* spp.), ephedra (*Ephedra gerardiana*), Sea buckthorn (*Hippophae* spp.), willow (*Salix* spp.), wild rose (*Rosa* spp.), myricaria (*Myricaria elegans*), poplar (*Populus* spp.), and birch trees (*Betula* spp.). The meadows in the valley bottoms are dominated by sedges (*Carex* spp.) and *Kobresia* spp. plant cover was approximately 15% of the area (Jackson et al., 2006). The Drass sub-division of the Kargil district is located at an elevation of 3,300 m asl which lies in Trans-Himalaya biogeographic zone (Rodgers and Panwar 1988). The region is dominated by alpine meadows with bistort (*Bistota officinalis*), hogweed (*Heracleum pinnatum*), and Prangos (*Prangos pabularia*) as dominant plant species.

Morphological identification

During a routine visit to the Drass town garbage dump site on 10 October 2020, we observed and photographed a single animal resembling a Himalayan wolf but with physical features that were significantly different from those of a wolf. A morphological investigation of the photograph was used to identify the species. The golden jackal is easily distinguished from the other canids (the Himalayan wolf, red fox, and Tibetan fox) found in Ladakh (Menon 2014). The photographed individual was identified as a golden jackal based on its fur colouration, body posture, and typical features like shorter legs, a more elongated torso, and a shorter tail. To crosscheck golden jackal presence at the same site, the team visited the area again on 12 October 2020 and sighted the same single individual near the garbage site.

Genetic analysis

During a systematic survey of carnivore occupancy and diet between July 2019 and October 2020, we collected scat samples from the UT which includes Hemis National Park, Changthang Cold Desert Wildlife Sanctuary, Karakoram Wildlife Sanctuary, and Kargil District. To spatially disperse the search paths for detecting species signs across the study area, grids consisting of 5x5 km^2 cells were layered over the study area, excluding areas above 5,500 m asl and inaccessible sites. The scats were collected during trail transects from a randomly selected 5x5 km^2 grid. For each survey, each grid cell had a minimum of three random transects. Each transect had a minimum length of 1 km. During this survey, we recorded both direct and indirect signs of carnivores on various occasions during the trail transect covering an elevation range from 2,700 – 5,000 m asl. Common types of carnivore signs recorded in the survey include pug marks, tracks, scat, and scrapes. Upon collection, scat samples were preserved in zip lock bags filled in silica and later transported for DNA analysis at the Molecular Ecology and Conservation Genomics lab at the Wildlife Institute of India. We collected a total of 513 scat samples from different areas of Ladakh (Hemis National Park, Changthang Cold Desert Wildlife Sanctuary, Karakoram Wildlife Sanctuary, and Kargil District) which were processed for DNA analysis. DNA was extracted from 513 scats using a QIAamp DNA stool micro kit (Qiagen, Germany). Every batch of extraction had a negative control to identify any contamination, and extractions were carried out in a dedicated room. Out of the 513 scat samples, 203 scats were collected from Changthang Cold Desert Wildlife Sanctuary. Species identification was carried out by amplifying the 218 bp region of the mitochondrial cytochrome b gene (Perrine et al. 2007). The mitochondrial cytochrome-b universal primer sequence to identify the species is given below:
Forward-RFCYTBBF: 5'-CTGCCGAGACGTTAACTATGGCTG-3'
Reverse-RF15149: 5'-CTCAGAATGATATTTGTCCTC-3'

The polymerase chain reaction (PCR) was carried out in a volume of 10 µl reaction mixture containing 1.0 µl of 10x PCR Buffer, 0.3 µl of 25 mM dNTPs, 1.0 µl of 10 µg/µl BSA, 0.2 µl of 5 U/µl Taq Polymerase Enzyme (Ge-Nie Taq), 0.50 µl of each 10 µM primer, and 1.0 µl of the DNA extract. The thermocycling conditions include initial denaturation at 94 °C for 3 minutes followed by 45 cycles of denaturation at 94 °C for 30 seconds, annealing at 50 °C for 30 seconds, and extension at 72 °C for 45 seconds with a final extension at 72 °C for 10 minutes. The amplified PCR products were visualized under ultraviolet light on a 2% agarose gel and sequenced unidirectionally using ABI 3500 XL sequencer (Applied Biosystems, USA). Finally, the generated sequences were manually inspected and validated using the GenBank BLAST tool to confirm the species (http://blast.ncbi.nlm.nih.gov/).

Data analysis

The golden jackal sequences generated in this study had a primer length of 218 bp and, after cleaning and trimming, we obtained sequences of 124 bp for all five golden jackal samples. We aligned these sequences with other published golden jackal sequences (GenBank Accession numbers mentioned in Table 1) using the Clustal W algorithm implemented in the BioEdit program version 7.2.6 (Hall 1999). We constructed a Bayesian phylogenetic tree using generated golden jackal sequences and other published golden jackal sequences from Genbank. Akaike information criterion (Akaike 1974) implemented in the jModelTest programme (Posada 2008) was used for the estimation of the best-fit nucleotide substitution model for the data (Posada and Crandall 2001). The phylogenetic tree was constructed using MrBayes v. 3.2 (Ronquist et al. 2012) with Markov chain Monte Carlo (MCMC) simulations of 25 million runs with the first 4 million runs discarded as burn-in. Finally, to view and annotate the consensus tree we used FigTree v. 1.4 (http://tree.bio.ed.ac.uk/software/figtree/).

Figure 2. Golden jackal photographed at Drass of Kargil district of Union Territory of Ladakh, India (34°24'57.99''N 75°43'13.08''E).

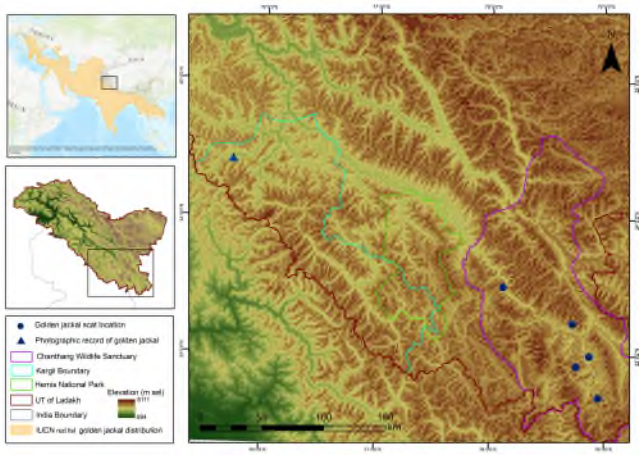

Figure 3. Upper left: IUCN red list golden jackal distribution. Middle left: Union Territory of Ladakh, India. Right: Location of golden jackal photographic and genetic records.

Results

We observed a single individual golden jackal near a garbage dump site in Drass (Ladakh) 34°24’57.99’’N 75°43’13.08’’E (Figure 2). Using the visual morphological analysis, we determined that it was a golden jackal and an additional visit confirmed the identification of the species. The photograph of the golden jackal was the first recorded at an elevation of 3,120 m in the Drass region of the UT, Ladakh. At the same dump site, other wild animals like Himalayan brown bears, free-ranging dogs (*C. familiaris*), and red foxes were also observed during the study.

From 513 scats amplified for species identification, we found five scat samples to be of golden jackal using the mtDNA cytochrome b region (124 bp). Generated sequences were identical to the reference sequences available in the Genbank. The NCBI BLAST results confirmed all five sequences were of golden jackal. All five samples were from the Changthang Wildlife Sanctuary of Ladakh (Table 1) which lies outside the known global range of golden jackals (Hoffmann et al. 2018). The phylogenetic tree constructed using mtDNA cytochrome b region (124 bp) indicates that the generated sequences, as well as Indian sequences from Genbank, are in one cluster (Figure 4). It is important to note that previous genetic studies on the large carnivores and mesocarnivores in Ladakh did not find any evidence of golden jackal (Ahmed et al. 2018, Shrotriya et al. 2022).

During the field survey, we also held a single focus group discussion with the local community (n = 6 participants) and they confirmed that they had never seen a golden jackal before in Drass. As the study area is close to Kashmir, many experts suggest that the golden jackal might have come from Jammu and Kashmir, where it has been reported to occur (Kait and Sahi 2011).

Table 1. Details of the scat collection and scat mtDNA collected from Ladak, India.

Scat No.	Date of scat collection	Field species identification	Scat mtDNA identification	Elevation (m asl)
1	17-07-2020	Snow leopard	*Canis aureus*	4,760
2	23-07-2020	Snow leopard	*Canis aureus*	4,346
3	24-08-2020	Unknown	*Canis aureus*	4,212
4	11-09-2019	Snow leopard	*Canis aureus*	4,793
5	23-08-2019	Unknown	*Canis aureus*	5,407

Discussion

In this study we report the first photographic and DNA evidence of golden jackals in different areas of the Trans-Himalayan region of Ladakh (3,120 – 5,365 m asl). To date, these are the highest known elevations recorded for golden jackals across their range. This species has previously only been reported up to the Greater Himalaya (2,000 m asl) of the Indian Himalayan Region (Hoffmann et al. 2018). It has previously been observed in Himalayan regions of Nepal (Katuwal and Dahal 2013) and recorded at an elevation of 3,300 m asl in Manaslu Conservation Area of Nepal, as well as in alpine meadows of Tibet at an altitude of 3,400 m asl (Dong et al. 2019) which may explain its expansion into the UT of Ladakh.

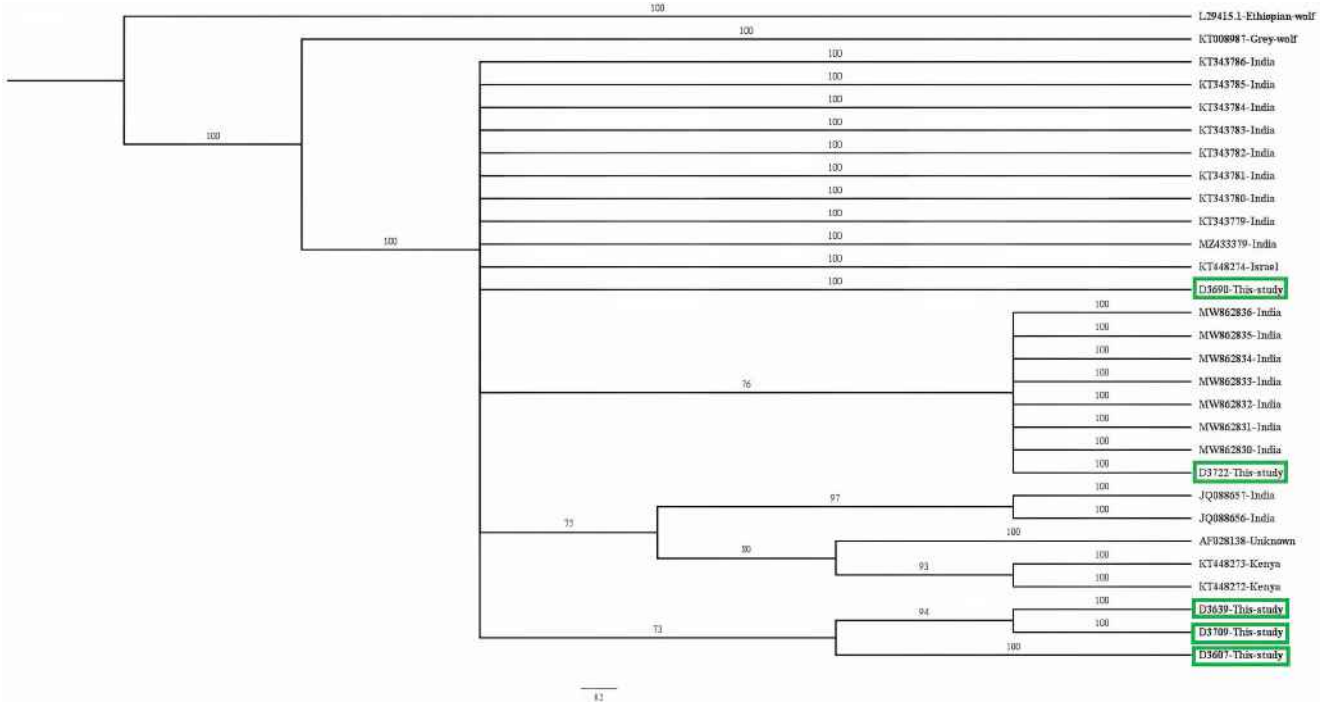

Figure 4. Phylogenetic tree of golden jackal using mitochondrial cytochrome b region (124bp), the five Ladakh samples clustered with GJ samples from India while GJ from India, Europe, and Africa formed a distinct cluster with high bootstrap support.

In high-altitude regions such as the Himalayas, climate change has been hypothesized as likely to favour the expansion of golden jackals by lowering dispersion barriers caused by more feasible climatic conditions (Walther et al. 2009, Cunze and Klimpel 2022).

Dispersal of jackals from their known historic geographic distribution into new areas makes the golden jackal now also a species of interest in Europe (Lanszki et al. 2018, Krofel et al. 2023). The major driving factors responsible for the expansion of golden jackals globally and locally over the past few decades (Arnold et al. 2012, Hoffmann et al. 2018) include its adaptability to varied habitats (Prater 1980) and various food sources (Macdonald 1979). The unsupervised garbage dump sites act as potential anthropogenic attractants and the presence of jackals in the newly colonized areas may increase the likelihood of competition with other carnivores including free-ranging dogs (Mahar et al. 2023).

The golden jackal may impact high-altitude ecosystems by altering predation pressure, especially on smaller mammal species, such as marmot, hare, and pika (*Ochotona royeli*), or by exerting competition pressure on other co-predators (Hobbs et al. 2006). However, these impacts do not seem of concern given the low density of the golden jackal in the relatively vast landscape. The presence of golden jackals at higher altitudes suggests a potential range expansion (or the species has simply not been detected earlier). Our findings raise many interesting questions about golden jackal dispersal, their ecology, and adaptation to high-altitude habitats, and may have important management implications. Ladakh is poised for development, this will inevitably result in more garbage dumps and concentrated food sources providing opportunities for jackals to expand in range and abundance

It is important to note that these new records of jackals from the Drass and Changthang regions of UT of Ladakh were only made possible through an extensive carnivore sign survey of the study area. A dedicated systematic survey of the species is needed to understand the distribution of this species in the high-altitude landscape.

To synthesize our findings, this study significantly expands the golden jackal's recorded geographical range in terms of altitude and highlights the species potential for habituation to anthropogenic food sources and its ecological adaptability.

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Biographical sketch

Niazul Hassan Khan studies large carnivore's ecology in greater and trans-Himalayan region of India. He is currently pursuing his doctoral study on Ecology of Himalayan brown bear in the Union Territory (UT) of Ladakh.

Vishnuvardhan has interest in population genetics of large carnivores and mega herbivores, including population genetics of snow leopard in Ladakh. He worked in All India Tiger Estimation (2022), Wildlife Institute of India.

Pankaj Raina is Wildlife Warden at Wildlife Protection Department of UT of Ladakh. His research interest in on the habitat and movement ecology of snow leopard in trans-Himalayan region of Ladakh.

Raza Ali Abidi is Wildlife Warden at Wildlife Protection Department of UT of Ladakh. He is interested in the management of human-wildlife conflict and assessment and management of wildlife in Kargil region.

Bivash Pandav has interest on large carnivores, mega herbivores and metapopulations. He is head of the department of PA Network, Wildlife Management and Conservation Education at Wildlife Institute of India.

Yadvendradev V Jhala interests include Asiatic lions, tigers and striped hyaenas. He has designed country-wide assessments assessing the status of tigers, large carnivores, prey and their habitat.

Appendix 1. Supplementary Table 1

Sample no.	Sample ID	Species	Location	Accession no.
1	KT008987_Canis lupus	wolf		KT008987.1
2	D3607 CYTB F F09 18	Golden Jackal	India	Present study
3	D3639 CYTB F H09 24	Golden Jackal	India	Present study
4	D3690 CYTB F E10 13	Golden Jackal	India	Present study
5	D3709 CYTB F G12 21	Golden Jackal	India	Present study
6	D3722 CYTB F F11 17	Golden Jackal	India	Present study
7	JQ088656_Canis aureus isolate CaurT1360	Golden Jackal	Senegal, Africa	JQ088656.1
8	JQ088657_Canis aureus isolate CaurT1362	Golden Jackal	Senegal, Africa	JQ088657.1
9	KT343779_Canis aureus haplotype CytbInd01	Golden Jackal	India	KT343779.1
10	KT343780_Canis aureus haplotype CytbInd02	Golden Jackal	India	KT343780.1
11	KT343781_Canis aureus haplotype CytbInd03	Golden Jackal	India	KT343781.1
12	KT343782_Canis aureus haplotype CytbInd04	Golden Jackal	India	KT343782.1
13	KT343783_Canis aureus haplotype CytbInd05	Golden Jackal	India	KT343783.1
14	KT343784_Canis aureus haplotype CytbInd06	Golden Jackal	India	KT343784.1
15	KT343785_Canis aureus haplotype CytbIsr01	Golden Jackal	India	KT343785.1
16	KT343786_Canis aureus haplotype CytbBlg01	Golden Jackal	India	KT343786.1
17	KT448272_Canis lupaster_CAU Kenya RKW1317	Golden Jackal	Kenya	KT448272.1
18	KT448273_Canis lupaster_CAU Kenya 2	Golden Jackal	Kenya	KT448273.1
19	KT448274_Canis aureus_CAU Israel RKW1332	Golden Jackal	Israel	KT448274.1
20	MW862830_Canis aureus isolate SS107	Golden Jackal	India	MW862830.1
21	MW862831_Canis aureus isolate SS125	Golden Jackal	India	MW862831.1
22	MW862832_Canis aureus isolate SS132	Golden Jackal	India	MW862832.1
23	MW862833_Canis aureus isolate SS186	Golden Jackal	India	MW862833.1
24	MW862834_Canis aureus isolate SS187	Golden Jackal	India	MW862834.1
25	MW862835_Canis aureus isolate SS299	Golden Jackal	India	MW862835.1
26	MW862836_Canis aureus isolate SS317	Golden Jackal	India	MW862836.1
27	MZ433379_Canis aureus_India	Golden Jackal	India	MZ433379.1
28	AF028138_Canis aureus	Golden Jackal	Old world	AF028138.1