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Ethnoveterinary Knowledge in Livestock Disease Management at Wildlife Livestock Interfaces Among Gujjar and Bakkarwal Pastoralists of Jammu, India

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ABSTRACT This study documents ethnoveterinary knowledge among nomadic Gujjar and Bakkarwal pastoralists in Jammu, focusing on livestock health management in areas of frequent wildlife-livestock interaction, within the context of seasonal movements intersecting protected areas. Data were obtained from ninety-one informants through semi-structured interviews, and the Relative Frequency of Citation and Informant Consensus Factor indexes were calculated. Foot-and-mouth disease was the most commonly reported condition, followed by healthy state, Peste des Petits Ruminants, and sheep and goat pox. Non-specific or no remedy was the predominant treatment approach, alongside topical applications. High consensus was observed for mastitis and bovine viral diarrhoea, with notable agreement for foot-and-mouth disease. These findings underscore the adaptive significance of ethnoveterinary practices and highlight their relevance for integration into participatory One Health frameworks in Himalayan pastoral systems.

INTRODUCTION

Ethnoveterinary knowledge (EVK) represents an indispensable component of traditional livestock management systems, particularly within marginal and high-altitude pastoral landscapes where modern veterinary infrastructure is limited (McCorkle 1986). Across South Asia, pastoral groups such as the Gujjar and Bakkarwal maintain intricate ethnomedical systems that integrate observation-based diagnostics, herbal pharmacopoeias, and ritual components to manage livestock health and productivity (Dutta et al. 2021; Haq et al. 2022; Hassan et al. 2023). These indigenous frameworks have evolved over centuries through experiential learning and oral transmission, often proving vital for disease mitigation under resource-scarce conditions (Rahman et al. 2023; Hankiso et al. 2024). The wildlife-livestock interfaces (WLI) represent ecological hotspots for disease transmission, where both direct contact and environmental contamination contribute to the spread of pathogens among species sharing water and grazing resources (Daszak et al. 2000; Kock 2005; Katoch et al. 2017; Khanyari et al. 2022; Singh et al. 2024; Virapin et al. 2025). In the Jammu region of the western Himalayas, Gujjar and Bakkarwal pastoralists routinely share forest-pasture mosaics with wild ungulates (Sambar Deer, Himalayan Goral, Himalayan Ibex, Wild Boar) and encounter large carnivores (Snow Leopard, Common Leopard, Himalayan Wolf, Red Fox, Brown Bears), particularly along migratory corridors and protected area fringes (Mishra et al. 2004; Bagchi et al. 2004; Bagchi and Mishra 2006; Chetri et al. 2019).

The Himalayas, characterised by ecological diversity, altitudinal gradients, and strong seasonal variation, host numerous transhumant and agro-pastoral communities whose livelihoods depend on livestock mobility and access to high-altitude pastures (Haq et al. 2021; Bhusal and Awasthi 2024). This mobility inherently increases the frequency of wildlife-livestock contact, particularly along forest fringes and alpine meadows that serve as eco-

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logical overlap zones (Khanyari et al. 2022; Virapin et al. 2025). Studies across Himachal Pradesh, Uttarakhand and Jammu and Kashmir have reported the use of more than 200 medicinal plant species for treating parasitic, respiratory, dermatological, and infectious livestock diseases (Bhat et al. 2021; Haq et al. 2021; Haq et al. 2022; Mir et al. 2022; Hassan et al. 2023). The persistence of diseases such as foot-and-mouth disease (FMD) and Peste des Petits Ruminants (PPR) within these pastoral zones underscores the epidemiological importance of wildlife-livestock contact (Khanyari et al. 2022; Virapin et al. 2025). Traditional ethnoveterinary practices, such as applying turmeric (*Curcuma longa*), mustard oil, and saltwater rinses to FMD lesions, represent adaptive, experience-based interventions developed by pastoralists after long-term observation of disease cycles influenced by environmental and wildlife factors (Jayakumar et al. 2018; Dutta et al. 2021; Gakuya et al. 2011).

In Jammu and Kashmir, the challenging terrain limits conventional animal health services, leading Gujjar and Bakkarwal pastoralists to rely on traditional symptom identification, strategic herd movements, and preventive herbal remedies to maintain animal productivity (Rashid et al. 2007; Dutta et al. 2021; Hassan et al. 2023). The indigenous expertise serves concurrently as an informal monitoring tool for health risks in shared ecological zones (Khanyari et al. 2022; Virapin et al. 2025). Recent studies across South and Central Asia emphasise the necessity of safeguarding this history of animal care expertise, which is declining due to urbanisation, changes in land management, and diminished intergenerational transmission (Haq et al. 2021). Integrating findings from domestic-wild animal interaction zones into conventional veterinary research can enhance integrated health frameworks by combining local observation networks with modern disease surveillance (Jori et al. 2021; Khanyari et al. 2022; Rahman et al. 2023; Virapin et al. 2025).

Recent studies have found high informant consensus on plant use for livestock ailments among Gujjar, Bakarwal and other ethnic groups, demonstrating EVK's resilience but vulnerability to erosion (Haq et al. 2022; Mir et al. 2022; Hassan et al. 2023). Furthermore, fluctuating herding tactics in high Himalayan pastoral systems increase parasite transmission risks at WLI, emphasising the necessity of EVK recording and integration for long-term management (Khanyari et al. 2022; Virapin et al. 2025). Though the existing studies focused on ethnoveterinary surveys, there is a dearth of studies that have focused on understanding association between WLIs as crucial transmission zones (Karmacharya et al. 2024). This present study aims to bridge crucial knowledge gaps in comprehending ethnoveterinary practices by pastoral groups of the region at the WLIs. By systematically documenting traditional knowledge and evaluating its reliability, the study aims to provide an empirical foundation for integrating such practices into sustainable livestock health management.

Objectives

The main objective of the study was to:

1. To document and analyse ethnoveterinary knowledge related to livestock diseases among Gujjar and Bakkarwal pastoral groups at WLI
2. To assess the variability, reliability, and consensus of the knowledge across ecological contexts, exploring the potential significance in sustainable livestock health management strategies.

The seasonal migration of Gujjar and Bakkarwal pastoralists throughout Jammu and Kashmir often coincides with protected areas, establishing WLI zones that could serve as hotspots for pathogen spillover and bidirectional disease transmission. Pastoralists use culturally entrenched adaptive approaches to alleviate animal health risks, and the study aims to detect important diseases associated with WLIs. Documenting and confirming these practices is crucial for safeguarding traditional knowledge and enhancing locally adapted, cost-effective disease management techniques within a One Health framework. With these findings, the researchers hope to lay the groundwork for a more sustainable approach to livestock health management that incorporates ethnoveterinary methodologies.

MATERIAL AND METHODS

Study Area

The study was conducted in pastoral regions of the Jammu division, located in the northwestern Indian Himalayas. The research specifically focused on migratory routes and grazing landscapes traditionally used by Gujjar and Bakkarwal pastoralists and the WLIs in Jammu and Kashmir. These transhumant groups undertake seasonal movements between the subtropical plains of Jammu during winter and the temperate alpine meadows of the Pir Panjal range during summer, managing multi-species herds of sheep, goats, cattle, and buffalo (Ahmed et al. 2025; Banka et al. 2025). The region exhibits substantial environmental heterogeneity, with sharp climatic transitions and rugged terrain that influence both disease ecology and the distribution of ethnomedicinal resources (Bhat et al. 2021). All sampling points were georeferenced using handheld GPS units and standardised using the WGS84 coordinate reference system (EPSG:4326), following recommended geospatial protocols (Pebesma 2018; Hijmans 2020; Ariza and Solymosi 2023).

Ethnographic Data Collection

Informant selection in the present study followed established ethnobiological approaches involving purposive and snowball sampling techniques (Huntington 2000; Tongco 2007), whereby 91 experienced pastoralists from Gujjar and Bakkarwal herding households were identified and interviewed from WLIs regions using semi-structured questionnaires during the fieldwork period spanning 2024 to 2025. Interviews explored local understandings of livestock diseases, symptom interpretation, indigenous disease terminology, and detailed descriptions of plant-based and non-plant-based remedies traditionally used in animal healthcare at WLIs regions. To enhance reliability, responses were cross-validated through focus group discussions, which facilitated comparison of knowledge both within and between households (Alexiades 1996; Reyes-García et al. 2013).

Ethical Considerations

Necessary permissions to carry out the research were obtained from the Department of Wildlife Protection, Government of Jammu and Kashmir ethical procedures as per the International Society of Ethnobiology (ISE) Code of Ethics (2006) were followed, and verbal informed consent was obtained from all participants. Official permission for research within the protected areas was granted by the Chief Wildlife Warden, Jammu and Kashmir (Permission No. 06 07 2025 dated 30/01/2025).

In the present study, quantitative ethnobiological indices were used to examine the societal importance, agreement among informants, and therapeutic consistency of traditional remedies (Heinrich et al. 1998; Tardío and Pardo-de-Santayana 2008). To ensure the robustness of ethnoveterinary information, cross-checking was performed by comparing responses provided by different informants reporting on the same disease categories. Methodological triangulation was incorporated through direct observation of animal health-care practices during field visits, supplemented by follow-up consensus-building discussions with knowledgeable pastoralists, an approach widely recommended in ethnobiological field methods (Alexiades 1996; Martin 2010). Data reliability was further strengthened through double-entry verification, complemented by random checks of translated transcripts to identify and correct inconsistencies. All statistical analyses and visual outputs were inspected for reproducibility and internal coherence using standardised R scripts, which were archived to enable transparent, repeatable analysis workflows (Sandve et al. 2013).

Quantitative Ethnobiological Analysis

To evaluate the cultural prominence and reliability of ethnoveterinary knowledge, three quantitative indices were employed, namely, Relative Frequency of Citation (RFC), Informant Consensus Factor (ICF), and Fidelity Level (FL).

Relative Frequency of Citation (RFC)

RFC was used to estimate the prominence of each disease and remedy within community knowledge. It was calculated as:

$$RFC = \frac{FC}{N}$$

Where, FC denotes the number of informants who mentioned a particular use, and N represents the total number of participants. Higher RFC values indicate greater cultural relevance, following established methodological recommendations (Vitalini et al. 2013).

Informant Consensus Factor (ICF)

ICF was applied to assess the degree of agreement among informants regarding remedies used for specific disease groups. It was computed as:

$$ICF = \frac{N_{ur} - N_t}{N_{ur} - 1}$$

Where, N_{ur} is the total number of uses reported for a given disease category, and N_t is the number of distinct remedies employed. Values approaching one suggest strong consensus, while values near zero reflect limited shared understanding (Heinrich et al. 1998; Gazzaneo et al. 2005).

Fidelity Level (FL)

FL was used to determine the specificity of individual remedies to particular diseases. It was calculated as:

$$FL = \left(\frac{N_p}{N}\right) \times 100$$

Where, *Np* is the number of informants citing a remedy for a specific disease, and *N* is the total number of informants citing that remedy for any disease. Higher FL values indicate stronger association of a remedy with a particular ailment (Friedman et al. 1986; Leonti 2011).

Collectively, these three indices (RCF, ICF and FL) established a comprehensive methodology for assessing the predominance, consensus, and specificity of ethnoveterinary knowledge among the Gujjar and Bakkarwal Pastoralists, facilitating its systematic assessment across ecological contexts in present study.

Data Processing and Visualisation

All data processing and cartographic visualisations were conducted in RStudio, leveraging a suite of geospatial and graphical packages to ensure analytical rigor and visual clarity. This integrated approach enabled the synthesis of spatial and statistical insights, supporting robust interpretation of ethnoveterinary knowledge across ecological contexts.

Geospatial Mapping

The spatial distribution of livestock diseases was delineated utilising field-collected latitude and longitude information. Administrative boundaries were obtained from publicly accessible Natural Earth shapefiles (South and South 2017) to ensure cartographic uniformity. Spatial objects were managed utilising the sf package (Pebesma 2018), whereas disease-specific layers were visualised with ggspatial, facilitating accurate annotations and scale-bar incorporation (Dunnington 2023).

RESULTS

The ethnoveterinary survey of 91 informants from Gujjar and Bakkarwal pastoral groups revealed that suspected FMD was the most frequently reported condition (Table 1), accounting for nearly one-third of all citations (FC = 27; RFC = 0.297). This was followed by healthy livestock status (FC = 17; RFC = 0.187), suspected PPR and sheep/goat pox (FC = 7 each; RFC = 0.077), and leptospirosis (FC = 6; RFC = 0.066). Moderate reports were made of anthrax, bovine viral diarrhoea, brucellosis, and mastitis (FC = 4 each; RFC = 0.044), while rare conditions such as bovine respiratory illness, tuberculosis, gastrointestinal parasites, and footrot were minimally cited (FC = 1 each; RFC = 0.011). Table 2 presents the distribution of reported livestock diseases, including their frequency of citation (FC) and Relative Frequency of Citation (RFC). The high RFC for suspected FMD highlights its status as the predominant viral threat in these migratory systems, imposing significant economic losses through reduced milk yield, lameness, and trade restrictions. The prominence of FMD highlights its role as the predominant viral threat in migratory pastoral systems, often linked to wildlife-livestock interfaces at communal water sources (Krish-

Table 1: Frequency distribution of reported livestock diseases among pastoral communities in the study area

Reported livestock disease	*Frequency*
Suspected FMD	27
Healthy	17
Suspected PPR	7
Suspected Sheep and Goat Pox	7
Suspected Leptospirosis	6
Suspected Anthrax	4
Suspected Bovine Viral Diarrhea	4
Suspected Brucellosis	4
Suspected Mastitis	4
Suspected Bovine Ephemeral Fever	3
Suspected Mites (Ectoparasite)	3
Suspected Bovine Respiratory Disease	1
Suspected Bovine Tuberculosis	1
Suspected GI Parasites	1
Suspected Ovine Footrot	1
NA	1

Table 2: Relative Frequency of Citation (RFC) and Frequency of Citation (FC) of livestock diseases reported by Gujjar and Bakkarwal pastoral communities in Jammu and Kashmir

Disease	*FC*	*RFC*
Suspected FMD	27	0.297
Healthy	17	0.187
Suspected PPR	7	0.077
Suspected Sheep and Goat Pox	7	0.077
Suspected Leptospirosis	6	0.066
Suspected Anthrax	4	0.044
Suspected Bovine Viral Diarrhoea	4	0.044
Suspected Brucellosis	4	0.044
Suspected Mastitis	4	0.044
Suspected Bovine Ephemeral Fever	3	0.033
Suspected Mites (Ectoparasite)	3	0.033
Suspected Bovine Respiratory Disease	1	0.011
Suspected Bovine Tuberculosis	1	0.011
Suspected GI Parasites	1	0.011
Suspected Ovine Footrot	1	0.011
NA	1	0.011

naswamy et al. 2021; Subramaniam et al. 2022). FMD epidemics were often linked to the descent from high-altitude woodland pastures, suggesting reverse spillover from wild ungulates like boars and cervids at communal water sources. These findings support the function of wild boars and deer in FMD virus cycles in Indian landscapes (Subramaniam et al. 2022; Dalal et al. 2025).

The pattern of distribution of ethnoveterinary medicines based on ways of administration at community-level analysis showed that Gujjar pastoralists contributed 57.1 percent (n = 52), while Bakkarwals accounted for 42.9 percent (n = 39). Gujjars reported higher instances of FMD and ectoparasitic infestations, whereas Bakkarwals more frequently cited sheep and goat pox and bovine ephemeral fever, reflecting ecological differences in grazing environments and migratory routes. A moderate positive correlation (r = 0.66) in reporting patterns suggests a shared ethnoveterinary knowledge base, though ecological differences in migratory routes shaped disease exposure.

Patterns of remedy administration revealed that the majority of treatments were unspecified (61.5%), followed by topical applications (29.7%), oral remedies (6.6%), and combined topical-oral approaches (2.2%). The predominance of topical remedies reflects adaptive strategies for mobile pastoralism, allowing rapid treatment of visible lesions such as FMD sores and mastitis swellings during migration (Table 3). This pattern illustrates the prevalence of straightforward and readily implementable treatment strategies in mobile pastoral systems (Table 3). The predominance of non-specific and topical methods reflects adaptive tactics for nomadic pastoralism, wherein topical applications allow for fast, on-site treatment of obvious lesions (for example, FMD or foot/mouth sores, mastitis or udder swellings), reducing preparation time during migrations. Similar patterns are observed in various Himalayan and African pastoral contexts where ecological accessibility promotes inexpensive, locally derived solutions (Feyera et al. 2017; Ndou et al. 2023; Rahman et al. 2023; Oda et al. 2024).

Table 3: Distribution of ethnoveterinary remedies based on routes of administration, expressed as counts and percentages

Route of administration	*Remedies*	*Percentage*
Topical	27	29.7
Oral	6	6.6
Topical and oral	2	2.2
NA	56	61.5

Consensus analysis demonstrated strong agreement among informants for certain diseases (Table 4). Perfect consensus (ICF = 1.000) was observed for bovine viral diarrhoea and mastitis, while substantial agreement was noted for FMD (ICF=0.692), anthrax (0.667), brucellosis (ICF=0.667), and PPR (ICF=0.600). Moderate consensus was noted for bovine ephemeral fever and ectoparasites (ICF=0.500), whereas leptospirosis showed diminished agreement (ICF=0.333). Sheep and goat pox exhibited no consensus (ICF = 0.000), indicating diversity in treatment methodologies (Table 4).

Table 4: **Informant Consensus Factor (ICF) values indicating the degree of agreement among informants for remedies used against different livestock diseases**

Probable disease	N_{ur}	N_t	*ICF*
Suspected Bovine viral diarrhoea	4	1	1.000
Suspected Mastitis	4	1	1.000
Suspected FMD	27	9	0.692
Suspected anthrax	4	2	0.667
Suspected Brucellosis	4	2	0.667
Suspected PPR	6	3	0.600
Suspected Bovine ephemeral fever	3	2	0.500
Suspected Mites (ectoparasite)	3	2	0.500
Suspected Leptospirosis	4	3	0.333
Suspected Sheep and goat pox	3	3	0.000

The distribution of diseases among the livestock and the responses by either pastoral communities are summarised in Table 5. Fidelity Level (FL) analysis identified fifteen remedies with complete specificity (FL = 100%), underscoring precise traditional knowledge. Bakkarwals reported leptospirosis, brucellosis, and anthrax more frequently, but ectoparasitic infestations (mites) were solely reported by Gujjars (Table 5). Notable examples included ash from burnt Bhojpatra bark mixed with salt for FMD lesions, garlic rubs, aloe vera combined with turmeric and lime paste for mastitis, and goatweed with ritual practices for PPR. These high-fidelity remedies demonstrate precise, targeted traditional knowledge honed through generations of observation (Hassan et al. 2023; Wendimu et al. 2024).

Table 5: Community-wise distribution of reported livestock diseases among Gujjar and Bakkarwal pastoralists

Disease	*Gujjar*	*Bakkarwal*	*Total*
FMD	18	9	27
Healthy	9	8	17
Sheep and Goat Pox	1	6	7
PPR	4	3	7
Leptospirosis	2	4	6
Mastitis	2	2	4
Brucellosis	1	3	4
Bovine Viral Diarrhoea	2	2	4
Anthrax	1	3	4
Bovine Ephemeral Fever	0	3	3
Mites (Ectoparasite)	3	0	3
Ovine Foot rot	0	1	1
GI Parasites	0	1	1
Bovine Tuberculosis	0	1	1
Bovine Respiratory Disease	0	1	1

Table 6 summarises predation patterns among communities. Wild boar (n = 15) and brown bear (n = 14) were the most commonly documented predators. Gujjar pastoralists documented a greater frequency of wild boar predation (n = 11), while Bakkarwals recorded more interactions with brown bears (n = 8). Additional predators comprised foxes and jackals (n = 9 each), wolves (n = 5), and leopards (n = 3), indicating variability in predator exposure throughout ecological zones (Table 6). These patterns match documented carnivore zonation and habitat shifts due to climate and fragmentation in the western Himalayas (Dawood et al. 2025).

Table 6: Frequency of livestock predation events by predator species across Gujjar and Bakkarwal communities

Predator	*Gujjar*	*Bakkarwal*	*Total*
Wild boar	11	4	15
Brown bear	6	8	14
Fox	5	4	9
Jackals	5	4	9
Wolf	4	1	5
Leopard	0	3	3
Wild cat	1	0	1
Feral dogs	1	0	1

The Fidelity Level (FL) investigation revealed some cures exhibiting high specificity (FL > 50%), notably those achieving 100 percent fidelity, as detailed in Table 7. The cures encompassed botanical, mineral, and ritualistic activities, with certain ones especially addressing illnesses like FMD lesions. The elevated FL values signify robust

Table 7: Ethnoveterinary remedies exhibiting high Fidelity Level (FL≥ 50%), indicating strong specificity of use for particular conditions

Remedy description (summarized)	*FL (%)*	*Targeted disease (if specific)*
Goatweed; avoided + purification rituals	100	–
Garlic rub	100	–
Fenugreek seed paste + jaggery, salt, ghee; soaked barley feeding	100	–
Decoction of Tulsi, turmeric, pepper; smoke from burnt dried herbs	100	–
Curd + roasted cumin + powdered Isabgol + dried Pomegranate peel tea	100	–
Curd + cumin	100	–
Cumin powder	100	–
Ash from cow dung + purification rituals	100	–
Ash from burnt *Bhujpatra* (*Bhojpatra*) bark + salt; rubbed on mouth	100	FMD lesions
Asafoetida dissolved in warm water + stomach massage	100	–
Aloe vera + turmeric + lime paste (topical)	100	–
Aconitum heterophyllum + *Brassica juncea* + *Hordeum distichon* paste	100	–

consensus regarding the application of specific medicines for designated diseases.

Overall, the findings demonstrate a structured and adaptive ethnoveterinary knowledge system that supports livestock health management under wildlife-livestock interface conditions. Informants recognised multiple diseases, reported an average of 2.1 remedies per condition, and relied predominantly on locally available resources such as herbs, minerals, and dairy products. Knowledge transmission remained oral and intergenerational, ensuring cultural continuity. Collectively, the RFC, ICF, and FL indices, alongside herder narratives, illustrate a resilient ethnoveterinary framework co-evolved with wildlife-livestock interfaces, serving as an effective frontline for disease detection, palliative care, and herd resilience in Himalayan pastoral environments. The findings, corroborated by Tables 1 to 7, reveal a systematic ethnoveterinary knowledge framework marked by differing illness prevalence, significant agreement on specific ailments, and dependence on locally available treatments for animal health maintenance.

Collectively, the RFC, ICF and FL indices, alongside qualitative herder narratives, illustrate a resilient ethnoveterinary system co-evolved with WLIs, serving as an effective frontline for disease detection, palliative care, and herd resilience in resource-scarce Himalayan pastoral environments.

The transmission of ethnoveterinary knowledge was mostly intergenerational and conveyed through oral traditions, underscoring the cultural continuity and social integration of indigenous veterinary procedures among Gujjar and Bakkarwal herders. The findings demonstrate that Himalayan ethnoveterinary systems have naturally co-evolved with wildlife-livestock interactions, establishing a basis for culturally informed One Health strategies.

DISCUSSION

The present study underscores the significance of ethnoveterinary knowledge in sustaining livestock health among Gujjar and Bakkarwal pastoralists at WLIs in the western Himalayas. The highest RFC = 0.297 and substantial ICF = 0.692 for FMD highlight infectious diseases as persistent challenges for transhumant production systems. Despite ongoing vaccination campaigns under India's National Animal Disease Control Programme (NADCP), FMD remains endemic in mountainous regions where seasonal migrations, communal grazing, and wildlife interactions exacerbate exposure risks (Khanyari et al. 2022; Karmacharya et al. 2024; Virapin et al. 2025). Recent molecular evidence confirms continued circulation of FMD virus strains in northern India despite control measures (Dalal et al. 2025). In this context, pastoral reliance on locally available remedies—garlic preparations, ash-based formulations, and neem-based treatments—reflects both pragmatic constraints of high-altitude livestock management and the adaptive resilience of traditional healthcare systems (Haq et al. 2022; Singh et al. 2019).

Unlike many ethnoveterinary studies that focus primarily on medicinal plants (Haq et al. 2022; Hassan et al. 2023), the present findings emphasize the ecological dimensions of WLIs in shaping illness management strategies. Indigenous veterinary knowledge emerges as a dynamic adaptive system responsive to environmental pressures, disease burdens, and shifting pastoral livelihoods, rather than a static repository of treatments (Jha 2026). High consensus for bovine viral diarrhea and mastitis (ICF = 1.000), alongside Fidelity Level values of 100 percent for several remedies, demonstrates strong cultural agreement in disease recognition and treatment. Comparable patterns have been reported among pastoral societies in Ethiopia (Oda et al. 2024; Wendimu et al. 2024), South Africa (Ndou et al. 2023), and Himalayan India (Jha 2026), where recurrent disease exposure reinforces intergenerational transmission of ethnoveterinary knowledge (Pawar et al. 2025).

Pastoralists function as effective "sentinels" for zoonotic infections (Kansiime et al. 2014). Their diagnostic accuracy, grounded in experiential validation and oral traditions, often aligns with clinical indicators of outbreaks. In this study, high consensus was observed for bovine viral diarrhea and mastitis (ICF = 1.000), and moderate consensus for anthrax and brucellosis (ICF = 0.667), while lower agreement for other diseases reflects diagnostic challenges inherent to nomadic contexts (Kelly et al. 2016; Mohamed 2020). These findings reinforce the value of pastoralist knowledge in participatory One Health surveillance systems.

Community-level differences between Gujjars and Bakkarwals highlight ecological distinctiveness in disease exposure and predation risks. Gujjars reported higher incidences of FMD and ectoparasitic infestations, whereas Bakkarwals reported greater prevalence of sheep/goat pox and bovine ephemeral fever, reflecting divergent migratory routes and settlement patterns (Jori and Etter 2016; Rashid et al. 2025). Predation assessments identified wild boars (RFC = 0.165) and brown bears (RFC = 0.154) as major threats, consistent with carnivore distributions in the Western Himalayas and Nepal (Chetri et al. 2019; Dawood et al. 2025). Knowledge transmission remains communal and egalitarian, with 67 percent of informants reporting at least three ailments and an average of 2.1 remedies per ailment (McCorkle and Mathias-Mundy 1992; Vilá and Arzamendia 2022). While this diffusion enhances resilience, it is increasingly eroded by livelihood diversification and declining youth participation in pastoralism (Sharifian et al. 2022).

The dominance of topical and easily administered remedies reflects adaptive responses to mobile pastoralism, where cost-effective, accessible, and practical treatments are prioritized. Similar preferences have been documented in pastoral systems across Asia and Africa, where healthcare choices are shaped as much by accessibility and autonomy as by perceived efficacy (Rahman et al. 2023; Ndou et al. 2023). Differences in disease reporting and predator encounters between Gujjars and Bakkarwals further underscore the ecological specificity of ethnoveterinary systems, shaped by herd structures, grazing practices, and wildlife interactions (Banka et al. 2025; Rashid et al. 2025). The prevalence of wild boar and brown bear predation aligns with broader patterns of human–wildlife conflict in Himalayan agro-pastoral contexts (Dawood et al. 2025; Nazir et al. 2025).

Overall, ethnoveterinary knowledge operates both as a treatment system and an informal disease monitoring mechanism, enabling pastoralists to diagnose livestock ailments and detect ecological changes. This dual role strengthens its relevance within participatory One Health frameworks (Jori et al. 2021; Karmacharya et al. 2024; Virapin et al. 2025). However, reliance on oral transmission remains a vulnerability. Climate change, livelihood transitions, and reduced youth engagement threaten the continuity of traditional ecological knowledge (Sharifian et al. 2022; Negi et al. 2025; Jha 2026). Taken together, these findings highlight the resilience and adaptability of Himalayan ethnoveterinary systems, while underscoring their vulnerability to socio-economic and ecological transitions. Integrating indigenous practices with laboratory diagnostics, pharmacological validation, and longitudinal monitoring is essential to strengthen livestock health management and achieve India's ambitious eradication targets for FMD and PPR by 2030 (Balamurugan et al. 2021; Govindaraj et al. 2023). Ethnoveterinary knowledge should thus be recognized as a dynamic, adaptive system that complements modern veterinary science and contributes meaningfully to sustainable pastoral livelihoods and national disease control goals (Jha 2026).

The ethnoveterinary knowledge of Gujjar and Bakkarwal pastoralists represents both a cultural heritage and a practical resource for livestock health management at wildlife–livestock interfaces. Its resilience lies in the adaptability of treatments to migratory contexts, ecological pressures, and systemic gaps in veterinary access, while its vulnerability stems from generational discontinuities and environmental change. Recognizing pastoralists as frontline actors in disease surveillance and ecological monitoring offers a pathway to strengthen participatory One Health frameworks. Future research should prioritize the pharmacological validation of traditional remedies, integration of community-based diagnostics with laboratory tools, and sustained documentation through collaborative platforms that respect intellectual property rights.

Such measures will not only safeguard pastoral livelihoods but also contribute to India's national goals of eradicating FMD and PPR by 2030, positioning indigenous veterinary knowledge as a vital complement to modern science offering sustainable pathways for disease control, pastoral resilience, and conservation in the Himalayas. The findings of this study highlight the critical significance of ethnoveterinary knowledge as both a cultural repository and a practical tool for sustaining livestock health in fragile Himalayan ecosystems. By documenting the adaptive strategies of Gujjar and Bakkarwal pastoralists, the research demonstrates how indigenous practices fill systemic gaps in veterinary service provision and contribute to resilience at wildlife–livestock interfaces. This underscores the broader importance of ethnoveterinary systems in supporting national disease control programs, biodiversity conservation, and pastoral livelihoods.

CONCLUSION

This study shows that ethnoveterinary practices among Gujjar and Bakkarwal pastoralists form a reliable, experience-based system that complements modern veterinary care. High agreement among informants, especially for major diseases like FMD and PPR, highlights the consistency of indigenous knowledge. Interactions with wildlife and seasonal movement further shape these practices, enabling early disease recognition and strengthening herd resilience. Integrating this knowledge within a One Health framework can enhance livestock health management and support sustainable conservation in Himalayan rangelands.

RECOMMENDATIONS

On the basis of the present study, it is recommended that ethnoveterinary practices be systematically integrated into regional veterinary services to strengthen disease control at WLIs. Establishing participatory One Health initiatives will be critical, ensuring that indigenous diagnostic methods are harmonised with contemporary surveillance systems to address transboundary diseases such as FMD and PPR. Targeted community-based training programs should be developed to promote intergenerational transmission and preservation of traditional knowledge, while safeguarding the intellectual property rights of pastoral communities. In parallel, supportive policies for sustainable transhumance and grazing access are needed to reduce risks of disease spillover and predation, thereby enhancing resilience of livestock-dependent livelihoods. Collaborative research partnerships must be fostered to scientifically validate traditional remedies and identify interface hotspots for focused interventions. Such efforts will advance equitable knowledge-sharing and innovation in livestock health management, ensuring that conservation, community welfare, and disease control objectives are jointly achieved.

LIMITATIONS

This study was based on verbal accounts from a geographically restricted sample of informants in selected areas of Jammu, which may limit the generalisability of findings to other Himalayan regions or seasonal contexts. The cross-sectional design precluded assessment of temporal dynamics in disease occurrence and remedy application. Reliance on self-reported data introduced potential recall bias, however, this was mitigated through triangulation with focus group discussions and field observations.

SCOPE FOR FUTURE WORK

Future investigations should adopt longitudinal designs to capture seasonal and inter-annual variations in disease occurrence and remedy application. Expanding the geographic scope to encompass diverse Himalayan regions would enhance representativeness and allow comparative analyses across ecological contexts. Integration of diagnostic validation techniques, including laboratory assays and molecular tools, would strengthen conclusions regarding remedy efficacy and disease causation. Moreover, linking ethnoveterinary knowledge with One Health frameworks could provide valuable insights into zoonotic disease management at WLIs. To conclude, participative approaches using larger and more diverse informant pools, combined with digital documentation platforms, would make it easier to create robust databases. Such efforts would not only preserve traditional knowledge but also allow for its methodical integration into long-term animal health management plans.

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