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Research Article

Understanding high altitude mountain steppe: A review of current literature on rangelands in Changthang, Ladakh, India

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ABSTRACT

Rangeland systems are dynamic and large-scale changes in their social and ecological characteristics can lead to degradation and remains a cause of worry worldwide, including the rangelands of Changthang in the Trans Himalayan region of Ladakh. Rigorous research on different aspects of rangeland systems are required to develop a sustainable conservation-based management strategy. In this article, we review the existing literature on the rangelands of Changthang to identify various trends and patterns of research knowledge related to this landscape to identify significant knowledge gaps. In our review, we found that wildlife studies dominate the research knowledge generated from the area. We found some important patterns in this literature with a very prominent discourse on 'overgrazing by livestock', which it identifies as the primary reason for rangeland degradation and wildlife population decline in Changthang. We argue that this discourse is a reflection of deep-rooted knowledge structures that conceptualise nature and society as dichotomous concepts. It thus provides limited insights into interactions between human, wildlife and livestock on the rangelands of Changthang. We identify this as an important knowledge gap along with the need for habitat assessment to identify other possible threats to rangelands such as land-use changes, developmental changes, invasive plant species and climate change. Addressing these knowledge gaps will provide crucial inputs for developing robust strategies and policies for sustainable rangeland management and conservation strategies to support resource-dependent human and wildlife communities.

Keywords: Community based rangeland management, Pastureland, Rangeland degradation, Rangeland management, Trans Himalayas, Ungulate-livestock interaction

INTRODUCTION

Rangelands are an ecosystem dominated by natural vegetation (such as grasses and shrubs) that is either grazed or have potential to be grazed by wild and domestic animals. Rangelands produce a wide variety of goods and services including wildlife habitat, livestock grazing, fresh-water, recreation spaces, medicinal plants, and fodder. Rangeland watersheds are important regulators of the quality and quantity of lakes, streams, and aquifers. Rangelands include grasslands, savannahs, and treeless areas in a forest ecosystem, wetlands and steppe (Heady and Child, 1994; Grebner et al. 2013). Rangelands, grasslands and pasturelands are often used interchangeably in different parts of the world while referring to the same set of environmental conditions. However, conceptually rangelands differ from pasturelands in that the rangelands are home to native vegetation whilst the pasturelands are managed grasslands. Rangelands are dynamic and complex systems. Changes in their ecological and social characteristics in different timescales impose variable challenges and threats to their management and conservation. The causes of these changes include climatic and anthropogenic activities such as over-grazing, competition between wildlife and livestock, socio-economic changes and fragmentation due to land-use change and intensification (Greiner et al., 2021; Dolker, 2021). If the magnitude of these changes is high, these rangelands may be altered permanently leading to rangeland degradation. Rangeland degradation can cause desertification, salinization, and moisture fluctuation in the ecosystem affecting flora and fauna variably (Wang et al., 2003; Zeng and Yang, 2008). Increasing degradation can decline soil fertility, nutrient depletion, reduce rangeland productivity, limiting the availability of forage and water resources for livestock and wild animals (Bolo et al., 2019). These changes in an ecosystem cumulatively affect the pastoralists who rely on healthy rangelands, resulting in shrinking economic returns from livestock and other livelihood sources such as wildlife tourism and in consequence amplifying poverty and food insecurity (Bedunah and Angerer, 2012).

Authors like Bekele and Kebede (2014) claim that 50% of the world's rangelands have already been degraded while others argue that the actual figure is over 70% (Seymour et al., 2010, Dong et al., 2012), making rangeland degradation a major global environment challenge. This is especially true for high altitude rangelands that are very sensitive to environmental and anthropogenic changes while also providing important habitat to a large variety of distinctive flora and fauna and supporting pastoral communities and their livestock. The Tibetan plateau is a high-altitude rangeland ecosystem in Asia, which is often called 'the water tower of Asia' (Qu et al., 2019) due to its vast glacial and

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permafrost resources that feed several major river systems. Thus, the rangelands of the Tibetan plateau are of great importance to humans while also supporting a wide assemblage of species including Tibetan gazelle, Tibetan argali, Tibetan antelope, and snow leopard. However, more than 90% of rangelands on the Tibetan plateau are said to be degraded as reported by Han et al. (2008). Similar processes are assumed to be underway in Ladakh, India, which marks the western extremity of the Tibetan plateau. Most rangelands in Ladakh are in the high altitude and ecologically fragile region in eastern Ladakh called Changthang (which is distinctly different from the much larger Changthang plateau in Tibet).

The average height of Ladakh's Changthang is 4,500m above mean sea level, which is around the upper limit for agriculture at this latitude. Changthang is surrounded by Tibet in the east and north-east, Himachal Pradesh in south and Nubra valley in the west and north (Figure l). The maximum temperature in the short summer months (June to August) is 30^{o}C while winter temperatures can drop to minus 40^{o}C or lower. The region experiences higher precipitation than other parts of Ladakh. Changthang region has many scattered high-altitude lakes, which include freshwater lakes, salty marshes and flooded meadows. These ecosystems sustain a high-altitude rangeland system that supports a diversity of mammalian and avian fauna along with livestock. These areas also serve as breeding and staging grounds for migratory species that use the Central Asian Flyway to travel between their wintering grounds and their breeding grounds in northern Asia (Ghosal and Ahmed, 2017; Mahar et al., 2022) These rangelands are also used by livestock herders called Changpas whose livelihoods are primarily dependent on their herds (Hagalia 2004; Bhasin 2012). It is thus critical to manage and conserve these rangelands for the ecological goods and services they provide in supporting biodiversity as well as human communities and their livestock herds (Heady and Child, 1994), especially when there is intensification of land use change in the area (Bhasin et al., 2022) and the negative impact of other extrinsic factors such as climate change are profound on rangelands worldwide (McCollum et al., 2017) In this context, rangeland management is required in the region to counter the impact of uncertain future development and climate change on such crucial rangeland system where resources are shared by number of wild ungulates with some of it are endemic to Tibetan plateau like Tibetan gazelle, birds like black-necked crane, humans and livestock. Rangeland management approaches should provide tools to identify degradation, along with contributing factors and assist in developing suitable management strategies (Sandhage-Hofmann, 2016). Any effort to develop a conservation-based management strategy for rangelands requires data and information on livestock grazing, wildlife ecology, quality and quantity of vegetation, use of rangelands and its resources for recreational activities and its impact. This will highlight the status and critical gaps in knowledge where research is required to enhance the understanding of rangelands ecosystem locally and also increase the overall knowledge on rangelands and contribute in global biodiversity and sustainable goals.

In this paper, we review current literature to understand patterns of research knowledge related to the rangelands in Changthang, eastern Ladakh. We identified peer-reviewed scientific papers from different sources based on the assumption that this represents current knowledge related to this region. We analysed these papers to identify patterns and knowledge gaps. Addressing these knowledge gaps can help to develop sustainable range management strategies to facilitate co -existence of wildlife, livestock and humans. Reviews such as this is essential to protect the diversity in nature because every region has different factors posing challenges and affecting the knowledge implementation (Nguyen et al., 2021). This will help to enhance the research in the area and will also facilitate the decision making and capacity building for rangeland management and conservation.

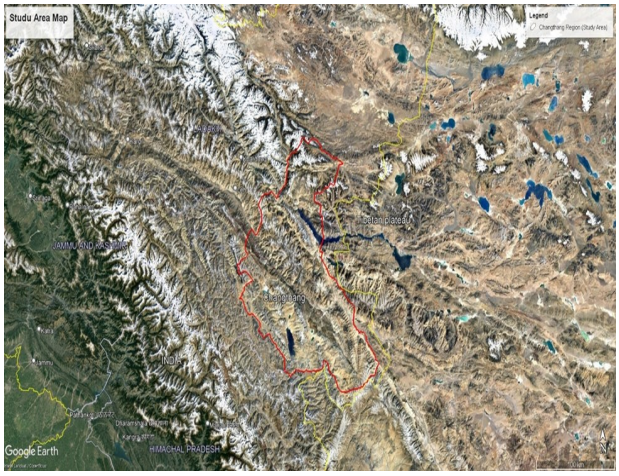

Figure 1. Study area map (red outline: Changthang region, yellow outline: International Boundary, Background Satellite Image is a Google Earth image).

METHODOLOGY

We identified peer-reviewed scientific papers relating to rangelands in Changthang by searching online databases using Google Scholar (http://www.scholar.google.com). We used keywords in English such as 'rangeland', 'rangeland management', 'pastureland', 'rangeland degradation', 'livestock production', 'wildlife conservation' and filtered the results with words such as 'Changthang, Ladakh' and 'Trans Himalayas'. We also cross-checked the reference sections of papers to identify relevant papers related to the region. We then analysed these papers to identify their conceptual approaches and findings while also listing their funding agencies.

RESULTS

Through these methods, we identified 133 relevant papers (Table 1). This may not constitute all the published scientific literature on the rangelands of Changthang because we included only peer-reviewed papers and excluded reports, books and websites in this review. We are confident that these papers are representative of the current knowledge and pattern related to this reionSome of the significant patterns we found in the literature are listed and discussed below.

Research focus

Wildlife-related research dominates current knowledge about rangelands in Changthang and accounts for 41%

of all the papers we reviewed followed by 21% of the literature that focused on socio-economic changes in pastoralism and livestock production system with study of plants being third at 20% (Figure. 2). The wildlife research includes papers (35%) focussing on status and distribution of wildlife while 21% of them focus on wildlife conservation and management issues (Figure. 3 and Table 2). In botany, 35% of the papers discuss the use of medicinal plants, their distribution and the need for their conservation.

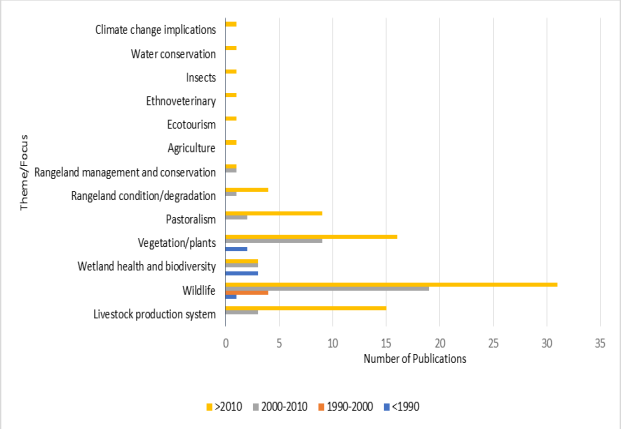

Figure 2. Distribution of publications according to their focus area in different time frames

Temporal trends and research discourse

There is a steady increase in the number of papers published after 2000 with a significant growth in the number of papers relating to wildlife and their interaction with livestock, and conservation (Figure. 2 and 3). We found only five scientific papers on wildlife conservation prior to 2000, which increased to 24 by 2010 and 55 by 2021 (Table 1). Wildlife conservation research after 2000 shows a definitive shift towards quantifying the consequences of socio-economic changes in traditional pastoralism and livestock production system on wildlife though it does not explore other contributing factors such as the impact of land use change, climate change and increase in unplanned tourism on wildlife. There is also an increase in the number of papers after 2000 on pastoralism and livestock production system that try to understand changes taking place in local nomadic pastoralism and production of pashmina in Changthang. These studies highlight the importance of making pashmina a productive industry with special focus on fodder production and nutrient supplements. In addition, we also found an increase in the number of papers focussing on medicinal plants and ethno-botany in Changthang after 2005

In total, we found only five papers on interactions between livestock and wild ungulates, which is an important topic for the management of wildlife-livestock interface on rangelands. Interestingly, all of these studies have concluded that the interaction is competitive in nature due to a perceived increase in the number of livestock. However, these papers provide limited insight into these interactions from a small area in Changthang and exclude inputs from local communities. These papers discuss the condition of rangelands and degradation due to social and environmental changes and identify overgrazing by livestock as the main cause for these changes. However, these papers provide inconclusive and insufficient evidence of degradation such as changes in vegetation species composition in the area that can be linked to grazing pressure, biomass loss and loss of biodiversity.

Funding agencies and institutional affiliation

We identified 73 funding agencies and 90% of the research projects were funded by multiple funding agencies (details presented in online resources 1 and 2). This is important as organisations providing funds influence research orientation and prioritisation (Halpern et al., 2006; Bakker et al., 2010).

Table 1. Focus of the review paper in different time

Theme	<1990	1990 - 2000	2000 - 2010	>2010	Total
Livestock production system	0	0	3	15	18
Wildlife	**1**	**4**	**19**	**31**	**55**
Wetland health and biodiversity	3	0	3	3	9
Vegetation/ plants	2	0	9	16	27
Pastoralism	0	0	2	9	11
Rangeland condition/ degradation	0	0	1	4	5
Rangeland management and conservation	0	0	1	1	2
Agriculture	0	0	0	1	1
Ecotourism	0	0	0	1	1
Ethnoveterinary	0	0	0	1	1
Insects	0	0	0	1	1
Water conservation	0	0	0	1	1
Climate change	0	0	0	1	1
Total					**133**

Table 2. Thematic focus of publications in wildlife discipline for different time frames

Theme	Before 1990	1990-2000	2000-2010	After 2010
Behavior	0	0	1	2
Community based conservation	0	0	0	2
Ecology	0	0	2	9
Genetics	0	0	0	1
Ethnozoology	0	0	0	1
Conservation and management	1	2	6	3
Status and distribution	0	2	6	11

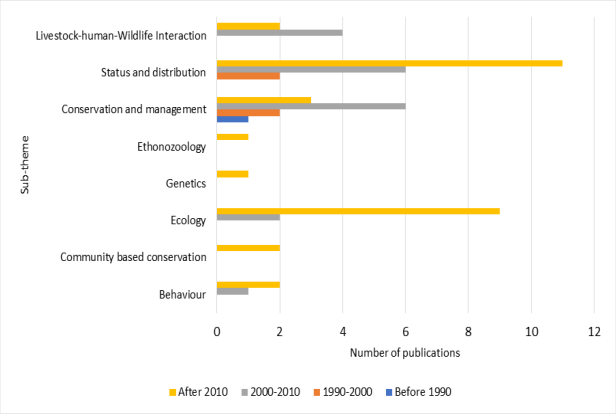

Figure 3. Distribution of publications according to their thematic focus in different time periods

DISCUSSION

The surge in number of publications on medicinal plant and ethno-botany from Changthang reflects a similar global trend. According to Salmerón-Manzano et al (2020) between 1960 and 2016, more than 110,000 studies related to ethno-botany have been published around the world with most papers emerging from India and China, probably reflecting the wealth of their traditional knowledge systems. There is growing demand for plant-based medicines, health products, cosmetics, and food supplements in the national and international market for which India is a major raw material producing nation in south Asia (Salmerón-Manzano et al. 2020). In this regard, Ladakh is an important region as it is home to a large number of species used in traditional medicine systems. The traditional healthcare system in Ladakh is called Sowa Rigpa (as well as Amchi) and it has a large body of ecological knowledge of herbs and medicinal plants. There has been a growing emphasis on documenting this traditional knowledge system and studying the status of medicinal plants for their sustainable use and conservation, which probably explains the increase in the number of papers on medicinal plants

There is an overall increase in the number of papers on wildlife conservation that focus on changes in the socio-economy of pastoralism and its implication for wildlife and rangelands in Changthang. This seems to be a reflection of the hegemonic view in global wildlife conservation discourse that directly correlates rangeland degradation with changes in pastoral practices.

Livestock production and grazing remain the main land-use pattern in Changthang where agriculture is unproductive as it is above the altitudinal limit for agriculture at this latitude (Bhatnagar et al., 2006; Bhasin 2012; Tewari et al., 2016). The socio-economy of pastoralism in Changthang has changed with time and it has also been influenced by the influx of security forces and Tibetan refugees after the Sino-Indian war in 1962. Local pastoral communities have lost access to their pasturelands in western Tibet due to geo-political changes after the 1962 war and the end of different forms of trade including salt and borax (Dollfus, 2012). Around the same time, Ladakh was opened for tourism—though parts of Changthang were opened for tourism only in 1994—which resulted in increased movement of people in the region. Roads and other infrastructure development increased with military presence and tourism in the area. The 1962 war also cut the supply of raw pashm from Tibet and the erstwhile state government of Jammu and Kashmir initiated the development of raw *pashm* in Changthang. This resulted in an increase in the number of Pashmina goat and changed the composition of livestock among Changpa communities in terms of ratio in the number of goat and sheep (Ghosal and Ahmed, 2017).

In addition, the government facilitated the creation of medical centres, improved access to education services and public distribution system (for subsidised wheat and kerosene), and incentives for goat kidding shelter to encourage locals to increase pashmina production (Bhatnagar and Singh, 2011). Changes in herd composition with fewer multi-use animals such as yak and more economically valuable pashmina goat is the result of political and historic changes taking place on the rangelands of Changthang (Angmo et al., 2016). The influx of Tibetan refugees with their herds and the loss of access to pasturelands have increased pressure on available rangeland resources in Changthang. The rearing of pashmina goats may also have a negative impact on rangelands as goats are often said to consume everything that is edible (Peacock and Sherman, 2010) and compete with other livestock species for forage resources (Rosa García et al., 2012).

In this context, it is important to understand the implications of these changes on wildlife, its conservation and rangelands. It is plausible that these socio-economic, cultural and political changes may have triggered the trend of investigating the impacts of these changes on wildlife and the ecosystem. However, the literature frames all interactions between pastoralists, their livestock and wildlife as competition over resource use. Although, there is urgent need for conservation of rangelands across globe (Toit, Kock & Deutsch, 2010), it is equally important to develop effective strategies to reconcile wildlife conservation with livestock production for better rangeland management, which the current body of literature seems to lack.

The push to recognise the value of biodiversity and its conservation in recent years is a global trend and has played an important role in generating funds for wildlife research (Adams, 2005; Gubbi, 2010; Ghosal et al., 2013). Our review reveals that organisations such as Rufford Grants, Whitney Fund for Nature and Wildlife Conservation Society are among the prominent funding agencies that have supported research in Ladakh. All these organisations have established their presence in India between the 1990s and early 2000s and started providing funds for wildlife conservation in India (Lewis, 2004). In the context of Changthang, these organisations have provided funds to research the impact of socio-economic changes in pastoralism on wildlife.

The organisations funding conservation research in India have an overt interest in promoting protected areas (PAs) as priority conservation area for wildlife (Neumann 1998). In the case of Changthang, research seems to have emerged as a priority among wildlife conservationists and funding agencies after the first notification of Changthang as a wildlife sanctuary in 1987. The research related to wildlife and its conservation continued to increase subsequently.

The wildlife conservation discourse in Changthang started questioning the sustainability of pastoralism in the context of socio-economics changes in traditional livestock production systems along with government schemes to promote *pashm* production that facilitated changes in livestock herd composition (Dollfus, 2012). The arguments that emerged from this research include claims that the increase in the number of goats and overall livestock population has led to increased competition with wild ungulates for forage,

degradation of rangeland ecosystems and the need for innovative grazing schemes (Namgail et al., 2010). This has also led to other research to identify threats to livestock production system and safeguarding *pashm* production including efforts to re-generate pastures and developing a fodder production system to overcome scarcity of fodder (Yatoo 2016; Tewari et al., 2016) to reduce competition with wild ungulates. Our review suggests that the wildlife conservation discourse focusses primarily on these socio-economic changes as the primary cause of wildlife loss and rangeland degradation in Changthang though it provides limited evidence to support these claims. Furthermore, it ignores other factors that may have contributed to changes in rangeland ecology and wildlife population in the region.

Poorly understood interaction between livestock and wild ungulates

Managing livestock-wildlife interactions in Changthang is an important aspect of rangeland management that includes reduction of competition over forage, disease transfer from livestock to wild ungulates and depredation (Toit et al., 2010). There is evidence in the literature of direct i.e. space and food (Hussain, Qureshi & Rawat, 2010; Namgail et al., 2010) and indirect competition between wild ungulates and livestock on the rangelands of Changthang. Reportedly, kiang and argali tend to change their habitat use in the presence of livestock. The competition between kiang and livestock is of serious concern in Changthang as pastoralists also complain that the kiang competes with their livestock and destroys their reserve/winter pastures (Bhatnagar et al., 2006). Kiang has abundant forage requirement to fulfil their nutrient demands (Kannan et al., 2016) and the perceived increase in kiang numbers intensifies intolerance of locals towards kiang as reported by Bhatnagar et al. (2006) However, there is little or no scientific insights into the interactions between livestock and kiang.

Concern of interspecific competition between livestock and Tibetan gazelle has also been raised by Bhatnagar et al. (2007). They argue that overgrazing by livestock has intensified pressure on the population of gazelle and recommend curtailment of livestock activity in gazelle habitat. Overgrazing is known to cause habitat degradation thus reducing the quality of forage for other species, which is regarded as interference competition (Latham, 1999). Overgrazing causes deterioration of vegetation community and changes in species composition. However, overgrazing is not the only indicator of interference competition between livestock and ungulates, and the studies conducted by Bhatnagar et al. (2007) and Namgail et al. (2007b) lack information about habitat condition, its quality or quantity and any practical evidence of competition between livestock and ungulates for resources and space.

Sympatric species are known to employ avoidance behaviour such as using different spaces or the same space at different times to avoid potential encounters with each other, which have been documented with environmental changes (Zanni et al., 2020). Thus, a detailed study on estimation of spatial and temporal overlap between livestock and wild ungulates is needed to understand the interaction between livestock and wild ungulate species (see Triguero-Ocaña et al., 2019; Zanni et al., 2020) and cross species disease transmission risk (Barasona et al., 2014). In addition, research insights are required on correlation of various abiotic and biotic factors with wild ungulate distribution and population density (see Lewis et al., 2017) to identify the diversity of factors that may have contributed to changes in wildlife populations (see Barnes et al., 2012; Katzner et al., 2020). Also, intensity of interactions may vary with factors such as body size, feeding habits, season (Odadi et al., 2011) and land-use types where domestic and wild ungulates overlap (Georgiadis et al., 2007). Thus, more rigorous studies are required to identify and understand the diversity of factors including land-use patterns and seasonal variations in spatial interactions between livestock and wild ungulates (see Kinga et al., 2018). Similarly, seasonal elements might provide insights into the complexity of spatial and temporal competition and coexistence of livestock and wild ungulates (Odadi et al., 2011).

The expansion and intensification of anthropogenic land-use change in recent decades has had a significant impact on biodiversity around the world (Hansen et al., 2004). It is thus important to study the complex relationship between land-use and biodiversity to gain better insight into the interaction between animals and their environment (Haines-Young, 2009). In the absence of such studies, our understanding of interspecies interactions remains limited and obscure.

This pattern is probably also a reflection of the discourses of funding agencies as 60% of the wildlife research we identified in Changthang were funded by American and European donors (Table provided as supplementary material online). In donor-driven processes, there are inherent biases towards research that adhere to specific theoretical standpoints to address management challenges (Kaul 2003) such as removal of human activities from conservation areas (Lele and Norgaard 1996; Guha 2003).

Reasons for rangeland degradation: Notional obscures the actual

Rangelands are dynamic ecosystems in which ecological changes are inevitable and these changes can be driven by climatic factors as well as human-induced factors. Though there is no clear evidence of consistent degradation of rangelands across the Changthang landscape, we are assuming there are some changes in the ecosystem that needs to be examined critically. Degradation of rangelands in terms of biodiversity loss (quality and quantity) or soil and both have been reported from Changthang by different researchers. The change in herd composition has been highlighted in many papers as the main reason for rangeland degradation and wildlife population decline (Dollfus, 2012; Fox, Nubra & Chundawat, 1991; Namgail et al., 2010; Angmo et al., 2016; Yatoo, 2016). The increase in goat numbers is assumed to increase stress on rangelands due to their feeding habits (Dollfus, 2012). There are others who claim that goats have a positive impact as they spend 90% of their time on browsing unlike sheep and other cattle that graze close to the ground, which loosens the soil and makes it more susceptible to erosion (Dollfus, 2012).

There are other aspects of Changthang's rangelands that are mentioned in the literature but remain under-explored. For instance, the presence of invasive plant species is a major threat to biodiversity of rangelands worldwide (Clout and Williams, 2009). It is known to increase competition between wildlife and livestock by decreasing plant diversity and a cause of ecological degradation. In Changthang, weedy invasion from *Cirsium arvense* is one such threat that has been

mentioned and need to be studied in detail as this species is unpalatable to livestock and most wildlife species (Raghuvanshi et al., 2020) Periodic surveys of the rangeland landscape should be conducted to monitor the spread of invasive species. Another possible reason for rangeland degradation is unplanned and unregulated tourism in Changthang, which is associated with multiple stressors such as trail use, dumping of waste, camping and off-road driving. This not only destroys vegetation but also impacts the health of soil and water and disturbs wildlife (Geneletti and Dawa, 2009). Unchecked motor traffic on rangelands in Changthang causes damage to the ecosystem, which takes years to recover, which is evident around Tso Kar wetlands (Dollfus, 2012). Although these areas are localised, they are important habitats for wildlife and livestock. Construction of roads and other infrastructure to support army and tourists in the area have an adverse impact on rangelands and biodiversity (Fox et al., 1994). Therefore, land-use changes in these areas need to be mapped and monitored regularly.

The presence of security forces in Changthang has also contributed to habitat degradation. While security forces have had a positive influence on the economy of the area, their ecological impact has not been studied or understood though it is regarded as being largely (Dollfus, 2012). For instance, there are many records of hunting of wild animals by security personnel in the area. Although, such incidents have reduced after the ban on hunting in 1970s, the impact has now shifted to habitat degradation, which have an indirect impact on wildlife (Sabharwal, 2016). There are other threats to rangeland resources and biodiversity in Changthang such as free-ranging feral dogs that prey on wildlife, which have been linked to army camps and tourism as feral dogs feed on leftover food from such facilities (Ahmad et al., 2017). All these factors require further study along with policy and management recommendations.

Such significant gaps in knowledge lead to the development of management strategies that are not effective in detecting and addressing rangeland degradation. In Changthang, this knowledge gap includes the direct and indirect impacts of tourism, climate change, and presence of invasive species on rangelands.

The literature identifies livestock as the single-most important factor for rangeland degradation and wildlife decline in Changthang (Bhatnagar et al., 2007; Namgail, Fox & Bhatnagar, 2007b; Namgail et al., 2007a; Namgail et al., 2010; Naoroji et al., 2011; Singh et al., 2013). However, our review reveals this research has excluded other possible threats to rangeland systems that have been identified in similar ecosystems around the worldwide including land use change, land tenure (Kyriazopoulos et al., 2013), invasive plants, developmental changes, and climate change (Barnes et al., 2012).

Furthermore, the geopolitical importance of the Changthang region may have also contributed to the nature of discourses on rangeland management in the area. For instance, the field of conservation in India is dominated by biologists (Guha 2003) and their research is conducted through a specific lens whereas issues such as habitat erosion or degradation, species diversity and their complex relationship with humans are not bound to theories of biology alone (Ludwig 2001). They require inter-disciplinary frameworks for a more holistic understanding of these issues (Saberwal and Rangarajan, 2003).

Though statistical information remains sketchy, livestock numbers are said to have increased in Changthang over the last few decades due to a variety factors and intensified grazing pressure over several years can result in ecological degradation (Teague et al., 2011). However, evidence to this effect is currently missing from the literature on rangelands in Changthang. Furthermore, grazing pressure cannot be analysed without contextualising it with factors such as climate change, land-use change, erosion, invasive plant species and human-induced stressors (Wilcox and Thurow 2006). Also, the impact of rangeland changes on water and other services such as carbon sequestration have not been documented in the current literature related to Changthang's rangelands. In this regard, habitat assessment of rangelands needs to be conducted periodically to monitor changes in plant species composition and soil condition along with factors correlated with changes. This will help provide insights to changes in rangeland ecosystems and help stakeholders, managers, and policymakers frame relevant management strategies.

Wildlife conservation discourse- competition or compatibility?

The discourse of competition between livestock and wildlife has been documented from different parts of the globe (Mace 1998; Reid 2012; Reid, Fernández-Giménez & Galvin, 2014). As a result, it is now regarded as a 'fact' that wildlife and livestock always compete for resources, which leads policymakers to conclude that pastoralism and wildlife conservation are separate and incompatible processes (Niamir-Fuller et al., 2012). The current literature on Changthang also presents this one-dimensional view with arguments that draw causal links between livestock management rangeland degradation and challenges to biodiversity conservation (Fox et al., 1994; Bhatnagar et al., 2007; Namgail et al., 2010; Singh et al., 2013). Though some research on pastoralism and how it is changing has emerged since 2000s (Bhasin, 2012; Dollfus, 2012; Hagalia, 2004; Sabharwal, 2016), these remain somewhat limited so far. There is need to critically evaluate the implications of the current scientific discourse on rangeland management in Changthang and focus on more holistic and inter-disciplinary research to understand the diversity of factors that influence change in this landscape.

There is a strong correlation between conservation interventions and research and are national governance processes (Smith et al., 2012). Even when research is funded by private organisations, institutional mechanisms still govern and regulate research processes. Thus, multiple interest groups influence research processes including government agencies and power elites. Current literature on rangelands in Changthang is rooted in a discourse that frames wildlife conservation and pastoralism as incompatible processes. It thus imposes a view of rangelands as 'ecological systems' rather than 'socio-ecological systems' that cannot be separated from anthropogenic factors. The predominance of ecology in conservation research that provide little insights on human interactions with wildlife is evident across India (Ghosal et al., 2013). This pattern is also evident in Changthang and influences current knowledge related to the region. This pattern is a reflection of deep-rooted institutional structures that frame scientific knowledge around dichotomies such as nature - culture (Latour, 2004). This leads to over-simplification of complex realities of socio-ecological

systems through pure biological lenses in landscapes designated as protected areas. In India, the separation of human and nature as two separate entities and processes are enshrined in policies such as Wildlife (Protection) Act, 1972, which aim to achieve conservation by creating human-free protected areas as conservation priority areas for 'pure' nature (Sukumar 1994; Rangarajan 1997; Ghosal et al., 2013). This has resulted in two clear narratives around protected areas, where natural science research continues to dominate. One narrative promoted primarily by social scientists focus on people impacted by conservation activities including the creation of PAs. The other narrative is promoted primarily by biologists and managers who promote and implement the idea of human-free PAs. Neither narrative explores the possibility of a middle ground that allows for coexistence of nature and society. These ontological dichotomies are evident in the current literature on Changthang's rangelands (see Latour, 2004; Ghosal et al., 2013) leaving limited scope for coexistence of pastoralism and wildlife in the landscape. This has created an important knowledge gap on interactions between nature and society in the literature on rangelands in Changthang.

Pastoralism and wildlife can compete (Namgail et al., 2006) as well as coexist (Chandrasekhar et al., 2007). We argue that the discourse on explicit competition between pastoralism, livestock and wildlife in Changthang overstates and skews the understanding of these interactions and is a direct reflection of the ontological and epistemological standpoints adopted by the researchers. In addition, the bias may also reflect limited understanding of the complex relationship between livestock, humans and wild animals as discussed earlier (section 4). This poor understanding of interactions between livestock and wild ungulates means competition has emerged as the dominant discourse regarding wildlife-livestock interactions on the rangelands of Changthang.

Need to reconcile livestock production and wildlife conservation

Pastoralism in Changthang is said to date back several millennia (Miehe et al., 2014). Pastoralists have used these rangelands sustainably to support their livelihoods in a harsh environment. They have used an intricate system of collective distribution of rangelands used on a rotational basis to prevent over-grazing and manage the spatio-temporally heterogeneous distribution of resources (Namgail et al., 2010). In addition, they have developed a number of flexible strategies to deal with uncertainty, unpredictability and a diversity of challenges including disease, droughts and other environmental challenges (Vetter, 2005; Bhasin, 2012). It seems unreasonable to disregard the intricate body of knowledge and practice of the Changpa community, despite changes since the 1960s, to understand the complex rangeland ecosystem in Changthang. This knowledge system needs to be included in the rangeland management system to develop innovative strategies to conserve pastoralism, wildlife and natural resources on the rangelands of Changthang to cope with historically unprecedented political, cultural, social and economic changes.

Despite the current framing of incompatibility of livestock and wildlife, rangeland management interventions are required to reconcile livestock production systems and wildlife conservation in Changthang. Discouraging pastoralism or sudden reduction of livestock numbers may not address the issue of rangeland degradation in Changthang (Sabharwal, 2016). Furthermore, many local communities are dependent on rangelands. There is evidence from other parts of the world that removal of livestock grazing or restriction on livestock mobility may also lead to wildlife decline and habitat degradation (Huntsinger, Sayre & Wulfhorst, 2012). There are instances where pastoralists have been known to create micro-habitats that are beneficial to the larger ecosystem (Riginos et al., 2012). Thus, the development of management strategies that enable compatibility between wildlife conservation and livestock production are essential for rangeland management in Changthang, while also accounting for other factors and processes of change. Successful management of rangelands for both wildlife and livestock require knowledge of ecology and social interactions (Hruska et al., 2017), local and traditional knowledge (Dika, Gemada & Tadese, 2016), participation of locals (Foggin, 2011; Reid, Jablonski & Pickering , 2021), and enhanced management skills (Anderson and McCuistion, 2012). In this context, guidelines should be framed for scientific management of rangelands. Management policy for rangelands in Changthang should focus on sustaining the coexistence of livestock production and wildlife conservation. Identification and involvement of stakeholders is crucial to develop the strategies for managing the multi-use landscape and prioritising some areas for livestock production and some for wildlife conservation by making land-use policies to conserve biodiversity rich areas. In addition, baseline studies such as biodiversity monitoring, large scale assessment of rangeland health, livestock grazing and land-use changes should be conducted periodically. This will provide data for mapping and planning rangeland management with all stakeholders to improve rangeland governance.

Knowledge gap in inter-species interactions

The poorly understood interactions between livestock and wild animals have resulted in a superficial understanding of livestock production and wildlife conservation in Changthang. It is crucial to understand the interactions between humans, livestock and wild ungulates in Changthang. These interactions must be studied at different spatial and temporal scales to understand where, when and why competition occurs, its relative magnitude and importance. Such research will also provide insights into the correlation between distribution of species and factors that influence their distribution, which will help develop relevant rangeland management approaches. This needs to be analysed in the context of factors such as land-use change, climate change, and governance processes.

CONCLUSION

The current literature on rangelands of Changthang has been influenced by various factors and has some significant knowledge gaps. It is important that future rangeland management strategies include environmental and social processes such as land-use intensification, habitat fragmentation, climate change etc. It is also important to recognise and integrate pastoralists' traditional ecological knowledge systems in rangeland management and conservation. Future rangeland management strategies must take into account the uncertainty and unpredictability of such changes and include monitoring mechanisms that will generate data and provide flexibility to adapt to change (Lawler et al., 2009). In addition, research scholarship on Changthang must focus on

reconciling conservation with livestock production for better rangeland management. In addition, management agencies should focus on integrated landscape-level approach in which communities are empowered to benefit from livestock production and wildlife conservation, which will enhance the resilience of rangelands ecosystems in Changthang (Anderson and McCuistion, 2012; Niamir-Fuller et al., 2012).

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