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Multiple Use of Trans-Himalayan Rangelands: Reconciling Human Livelihoods with Wildlife Conservation

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Introduction

The rain-shadow of the Himalayan Mountains in South and Central Asia constitutes the Trans-Himalayas, a vast rangelands system (2.6 million km^2; Figure 11.1) comprising the Tibetan plateau and its marginal mountains. This high-altitude arid landscape north of the main Himalayan range is contiguous with the Eurasian steppes and has a history of pastoralism dating back at least 3 millennia (Handa 1994; Schaller 1998). Historically, nomadic pastoralism in the region presumably involved low-intensity grazing, much like the Central Asian steppes (Blench & Sommer 1999). The Trans-Himalayas is amongst the least productive of graminoid-dominated ecosystems on earth in terms of above-ground graminoid biomass (Mishra 2001). Yet, the Trans-Himalayan rangelands harbour a surprisingly rich assemblage of wild mountain ungulate

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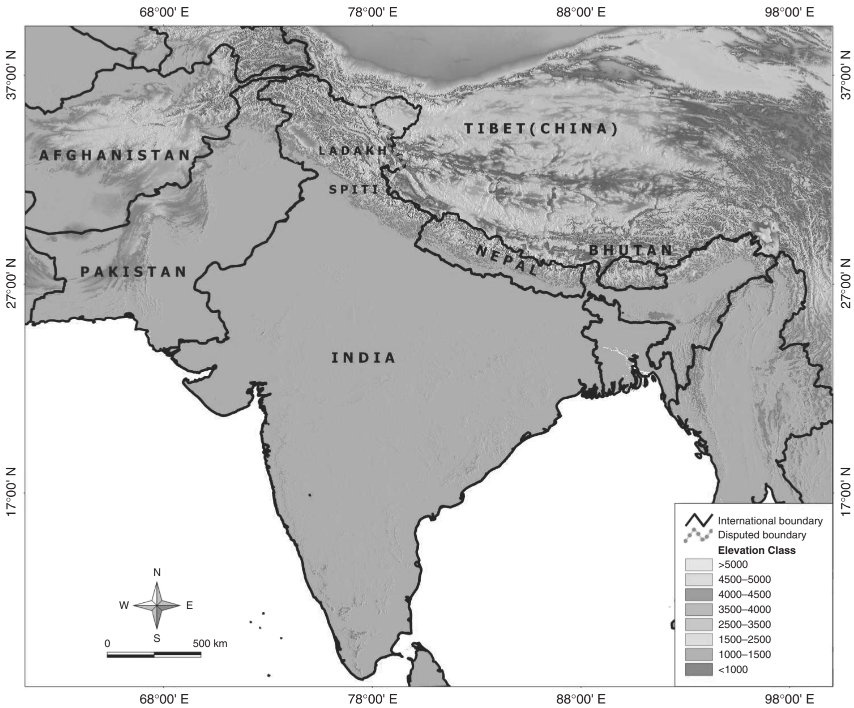

Figure 11.1 **The Trans-Himalayan landscape including the Tibetan plateau and its marginal mountains. The areas north of the Himalayan chain along India's northern boundary (above elevations of 3000 m), extending into Tibet, form the Trans-Himalayan rangelands.**

species and are home to endangered carnivores such as the snow leopard (*Uncia uncia*).

Within India, the Trans-Himalayas is spread over approximately 186,000 km^2 (Rodgers et al. 2000). In accordance with the country's preservationist policies (national and regional), wherein conservation is essentially viewed as a policing responsibility of the state (Mishra 2000), 8.2% of this region has been designated as wildlife protected areas (Rodgers et al. 2000). These protected areas are, however, by themselves inadequate in conserving Trans-Himalayan wildlife. Compared to the country's other terrestrial ecosystems, where most extant wildlife populations survive inside protected areas, the Himalayan and Trans-Himalayan landscapes are unique in that wildlife populations are not restricted to protected areas here, but occur across the landscape. At the same time, livestock grazing and associated use of rangelands is pervasive across the Trans-Himalayan landscape, including protected areas (Mishra 2001). Today, as local production systems become integrated with national and even global markets, the region is witnessing rapid changes in land use, grazing practices and herd composition (Mishra 2000; Mishra et al. 2003b; Namgail et al. 2007a). Because of these changes, the wildlife in the region faces a variety of threats, and given the unique topographic, climatic, ecological, political and cultural contexts of the Trans-Himalayas, current conservation approaches seem inadequate to address the region's important needs.

In this chapter, we first introduce the Trans-Himalayan rangelands in terms of their floristics and production, and provide an overview of their wildlife value. Then we briefly describe the livestock production systems and outline ongoing socio-economic changes and their consequences for conservation. We review the current understanding of rangeland dynamics and the response of rangeland vegetation to grazing, and outline the impacts of pastoralism on wildlife conservation. We assess the sustainability of the Trans-Himalayan rangelands and their wildlife in the context of the changing climate, socio-economy and land use. Finally, we highlight the need for an alternate approach to conserving wildlife in the Trans-Himalayas, and outline our recent efforts in this direction.

Rangeland vegetation

The Tibetan plateau attained its present average elevation (3500–5500 m) by the Miocene (8 million years ago) and through the Pleistocene and became progressively arid with open steppe vegetation (Harrison et al. 1992). Today, the two important vegetation formations in the region include open or desert steppe dominated by grasses and sedges (e.g. *Stipa, Leymus, Festuca, Carex*) at altitudes of up to 4600 m and dwarf shrub steppes between 4000 and 5000 m dominated by shrubs such as *Caragana*, *Artemisia, Lonicera* and *Eurotia*. Mesic sites such as river valleys and areas along springs and glaciers are often covered by sedge meadows (*Carex*, *Kobresia*). Vegetation occurs up to 5200 m, but becomes sparse above 4800 m and is limited to forbs such as *Saussurea* and cushionoid plants such as *Thylacospermum*. The important plant families include Gramineae, Cyperaceae, Brassicaceae, Fabaceae, Ranunculaceae and Leguminoceae.

Plant species richness and composition vary considerably over space and along gradients of altitude, soil moisture and soil texture (Klimes 2003; Rawat & Adhikari 2005). Kachroo et al. (1977) report 611 vascular plants from the Ladakh region (~90,000 km^2), from 190 genera and 51 families. Rawat and Adhikari (2005) report 232 vascular plants from a 300 km^2 basin in eastern Ladakh belonging to 101 genera and 38 families. Eighty one species including 13 Gramineae and 6 Cyperaceae are reported from a 35 km^2 area around a single village in Spiti region (Mishra 2001). In general, hemicryptophytes (perennial grasses and sedges) and chamaephytes (dwarf forbs and matted shrubs) are the dominant life forms in these rangelands (77% of all plants, Rawat & Adhikari 2005). The soils are generally alkaline (pH 7–9) and the texture varies from sandy to sandy-clay, with 4–6% organic carbon content and 0.1–0.5% total nitrogen (Rawat & Adhikari 2005).

Plant growth is restricted to a short season (May–August) because of low temperatures during the rest of the year and available soil moisture is an important limiting factor for plant growth during the growing season (Mishra 2001). Inter-annual variation in primary production is high (Bai et al. 2004) and seems dependent on precipitation. For instance, aboveground net primary production (ANPP) in Spiti's rangelands was c. 21 g/m^2 (±48% CV) in 2005, whereas it was 34 g/m^2 (±43% CV) during 2006 when there was higher precipitation (S. Bagchi, unpublished observations).

Wildlife of the Trans-Himalayan rangelands

The Trans-Himalayan rangelands support 20 species (7 families) of wild herbivores, 13 species (4 families) of wild carnivores (Table 11.1), and over 275 species (41 families) of birds (Pfister 2004). The region has many high-altitude wetlands, which serve as breeding habitats for migratory waterfowl such as Bar-headed Goose *Anser indicus*, Brown-headed Gull *Larus brunnicephalus*, and Black-necked Crane *Grus nigricollis*. Prominent resident birds include the Tibetan Snowcock *Tetraogallus thibetanus*, Tibetan Partridge *Perdix hodgsoniae*, Tibetan Sandgrouse *Syrrhaptes thibetanus*, Golden Eagle *Aquila chrysaetos*, and Lammergeier *Gypaetus barbatus*.

The Trans-Himalayas is one of the few places on earth that continues to support a relatively intact assemblage of Pleistocene large herbivores (Table 11.1) alongside a suite of domestic ungulates (Schaller 1977). Wild ungulates form the most significant group of wildlife in the region that shares

Table 11.1 **List of mammal species recorded in Trans-Himalayan rangelands and their IUCN Red List categories.**

Order/Family	Genus	Species	Common name	IUCN Status
Artiodactyla				
Bovidae				
Subfamily Caprinae	*Capra*	*C. ibex siberica*	Asiatic ibex	Low risk
	Ovis	*O. ammon hodgsoni*	Tibetan argali	Near threatened
		O. vignei vignei	Ladakh urial	Endangered
	Pseudois	*P. nayaur*	Bharal	Least concern
	Pantholops	*P. hodgsoni*	Tibetan antelope	Endangered
Subfamily: Antilopinae	*Procapra*	*P. picticaudata*	Tibetan gazelle	Least concern
Subfamily: Bovinae	*Bos*	*B. grunniens*	Wild yak	Vulnerable
Perissodactyla				
Equidae	*Equus*	*E. kiang*	Tibetan wild ass	Low risk
Rodentia				
Sciuridae	*Marmota*	*M. caudata caudata*	Long-tailed marmot	Low risk
		M. bobak himalayana	Himalayan marmot	Low risk
Muridae	*Alticola*	*A. roylei*	Royle's Mountain vole	Low risk
		A. argentatus	Silvery mountain vole	Low risk
		A. stoliczkanus	Stoliczka's mountain vole	Low risk
Lagomorpha				
Leporidae	*Lepus*	*L. oiostolus*	Woolly hare	Low risk
		L. capensis tibetanus	Cape hare	Low risk
Ochotonidae	*Ochotona*	*O. curzoniae*	Plateau pika	Low risk
		O. ladacensis	Ladakh pika	Low risk
		O. macrotis	Large-eared pika	Low risk
		O. nubrica	Nubra pika	Low risk
		O. roylei	Royle's pika	Low risk

(*Cont'd*)

Table 11.1 (*Continued*)

Order/Family	Genus	Species	Common name	IUCN Status
Carnivora				
Canidae	*Canis*	*C. lupus laniger*	Tibetan wolf	Least concern
	Cuon	*C. alpinus laniger*	Wild dog	Endangered
	Vulpes	*V. vulpes montana*	Red fox	Least concern
	Vulpes	*V. ferrilata*	Tibetan fox	Least concern
Felidae	*Uncia*	*U. Uncia*	Snow leopard	Endangered
	Lynx	*L. lynx isabellinus*	Eurasian lynx	Near threatened
	Otocolobus	*O. manul nigripectus*	Pallas's cat	Near threatened
Ursidae	*Ursus*	*U. arctos isabellinus*	Brown bear	Low risk
Mustelidae	*Lutra*	*L. lutra monticola*	Eurasian otter	Near threatened
	Martes	*M. foina intermedia*	Stone marten	Low risk
	Mustela	*M. altaica temon*	Mountain weasel	Low risk
		M. erminea whiteheadi	Stoat	Low risk
		M. siberica	Himalayan weasel	Low risk

forage resources with livestock and most of these species, including the wild yak *Bos grunniens*, represent an important genetic resource for potential livestock improvement. These mountain ungulates underwent adaptive radiation by evolving ecological and phenotypic diversity in the late Miocene, occupying the mountainous ecological niches created in the aftermath of the collision of the Eurasian and the Indian tectonic plates and the consequent rise of the Himalaya. Within the Indian Trans-Himalayas, there is a preponderance of large herbivores belonging to the tribe Caprini (Table 11.1), which appeared during the late Miocene (Ropiquet & Hassanin 2004).

Trans-Himalayan mountain ungulates are thought to have evolved in sympatry and diverged in their morphology and resource use patterns (Schaller 1977). For example, ibex *Capra ibex* have relatively muscular legs and stocky bodies that help them negotiate steep cliffs when escaping from predators, while the Tibetan argali *Ovis ammon* have longer legs that enable them to outrun predators. Mountain ungulates differ in the use of the terrain: ibex occupy very steep and broken areas, bharal *Pseudois nayaur* prefer rolling areas in the vicinity of cliffs and species such as the Tibetan argali, the Tibetan gazelle *Procapra picticaudata* and kiang *Equus kiang* occur on plateaus (Bhatnagar 1997; Bagchi et al. 2004; Namgail et al. 2004). Most species show limited local migration (up to 10 km) seasonally, often moving to relatively higher altitudes (by $\sim$500 to 1000 m) in summer and to relatively snow-free patches in winter. The chiru *Pantholops hodgsonii* is the only species where, in some populations, females show long-distance latitudinal migration (several hundred kilometres), moving North in summer and returning to lower latitudes in autumn (Schaller 1998). Several species of smaller herbivores such as pikas *Ochotona* spp. and voles *Alticola* spp. also occur in these rangelands (Table 11.1) and seem to play a role in maintaining vegetation diversity at local scales through soil disturbance (Bagchi et al. 2006).

Graminoids form a significant proportion of the diet of most Trans-Himalayan wild and domestic large herbivores (Schaller 1998; Mishra et al. 2002, 2004; Bagchi et al. 2004), though species are known to expand their diet breadth to include forbs and shrubs particularly during winter, which is a period of lean resource availability (Mishra et al. 2004). The only exception, presumably, is the small-sized Tibetan gazelle *P. picticaudata*, feeding predominantly on forbs (Schaller 1998). Given the region's relatively low graminoid biomass, interspecific competition, rather than facilitation, is expected to be the dominant form of interaction amongst Trans-Himalayan grazer species (Mishra 2001). Preliminary evidence on the possible role of competition in structuring this wild grazer assemblage is seen in a morphological pattern within this guild, where a proportional regularity in body masses is evident, with each Trans-Himalayan wild grazer species, on average, being about twice as large as the nearest smaller one (Mishra et al. 2002). Such morphological patterns within species guilds are thought to be brought about by competition through character displacement, which is a co-evolutionary mechanism, and species-sorting, which is an ecological outcome (Dayan & Simberloff 1998; Prins & Olff 1998).

Pastoralism in the Trans-Himalaya

For several millennia, the Trans-Himalayan rangelands have been used by Sino-Tibetan speaking pastoral and agro-pastoral communities of the Mongoloid stock. Within India, the present human population is largely Buddhist. Although the human population density is low ($\sim$1 person/km^2), populations are increasing with the breakdown of traditional systems of polyandry and primogeniture, as well as the influx of Tibetan refugees in some parts (Ahmed 1996; Mishra 2000; Mishra et al. 2003b; Namgail et al. 2007a). Production systems in the Trans-Himalayas include sedentary agro-pastoralism up to altitudes of c. 4500 m, and nomadic pastoralism up to 5200 m. Livestock are owned by individual families, while the herding systems are variable, ranging from individual to co-operative (between a few families) to communal herding managed by village councils. Most of the grazing land is communally owned, though individual families may have usufruct grazing rights. Rotational grazing between pastures is practised and some pastures may be maintained exclusively for winter grazing (Ahmed 1996; Mishra et al. 2003b).

Livestock in the region includes goat, sheep, yak, cattle, horse, donkey and hybrids of yak and cattle, which provide various goods and services including wool, milk, butter, meat, dung for manure, transport and draught. In parts of the Indian Trans-Himalayas, there has been a history of cashmere or *pashmina* production, obtained from the underwool of the local *changra* goat, a trade that is intensifying rapidly today (Jina 1995; Rizvi 1999; Bhatnagar et al. 2006b).

The diversity of livestock species and associated herding practices followed by the Trans-Himalayan pastoralists reduce climatic risks (e.g. avalanches) to livestock and allow a more efficient exploitation of the rangelands (Mishra et al. 2003b). The wide range of body masses of livestock (mean adult body mass ranging from 34 kg for goats to 298 kg for yaks) and the combination of fore-gut and hind-gut fermenters allows the use of a range of forage in terms of plant species and quality (Mishra et al. 2002, 2004).

The current trends in livestock population or biomass densities in the Trans-Himalayan rangelands are variable. At localized scales, livestock biomass densities have declined, remained stable or increased, while at regional scales, there largely appears to be an increase in biomass density over the last few decades (Mishra 2000; Bhatnagar et al. 2006a; Namgail et al. 2007a). A relatively large scale ($\sim$10,000 km^2) overstocking of Trans-Himalayan rangelands is reported (Mishra et al. 2001), though such overstocking may be relatively more common in agro-pastoral systems where forage grown in crop-fields allows livestock populations to be supplement-fed in winter and by off-setting winter starvation mortality, and be maintained above the levels that the rangelands can support (Mishra 2001). Pastoralists tend to maximize herd sizes for several reasons, including maximizing short-term livestock production as well as maintaining herd stability, particularly in areas where they lose livestock to wild carnivores (Mishra et al. 2001).

Even in traditionally purely pastoral Trans-Himalayan areas such as eastern Ladakh, biomass densities of livestock have increased as a consequence of the increase in the number of herding families, increased demands for cashmere, loss of access to traditional pastures that lie across the border in China and influx of Tibetan refugees with their livestock herds (Bhatnagar et al. 2006b; Namgail et al. 2007a). There is also increased access to imported concentrated supplemental feed, as well as the forage that is now being grown locally as a consequence of ongoing sedentarization (Namgail et al. 2007a). This is presumably facilitating a further increase in livestock biomass density in these rangelands.

Grazing impacts and conflicts between pastoralism and wildlife conservation

Available information from the Spiti region of the Trans-Himalayas suggests a consumption of 44–47% of ANPP by livestock and native herbivores during the growth season itself (S. Bagchi 2006, unpublished observations). This level of consumption is comparable with the global average for grass-dominated ecosystems, despite the ANPP in the Trans-Himalayas being two standard deviations below the global average (Milchunas & Lauenroth 1993). These results suggest a relatively high grazing intensity in Trans-Himalayan rangelands and are consistent with observations of widespread overstocking (Mishra et al. 2001) and vegetation degradation in the rangelands (Mishra 2001). Of the total forage removal, the majority is consumed by livestock, given that livestock densities are often up to 10 times greater than wild ungulate densities in these rangelands (Mishra 1997). For instance, the relative extent of forage removal by the kiang – a large-bodied hindgut fermenter (mean adult body mass 275 kg) whose population in eastern Ladakh is believed to be very high – is estimated to be only 3–4%, compared to 96–97% consumption by local livestock (Bhatnagar et al. 2006b).

There is considerable diet overlap between livestock and Trans-Himalayan wild herbivores (Bagchi et al. 2004; Mishra et al. 2004) and a growing body of literature establishes the competitive effects of high-intensity livestock grazing on wild ungulates. Studies have documented both exploitative and interference competition between these groups (Bagchi et al. 2004; Mishra et al. 2004; Namgail et al. 2007c), resulting in population declines of wild ungulates as the livestock density increases (Mishra et al. 2004). Competition with livestock, together with collateral effects such as hunting in a few places, has led to local extinctions and drastic range reductions of Trans-Himalayan wild herbivores (Mishra et al. 2002). For example, the range of the Tibetan gazelle in the Ladakh region, over the last 100 years, has diminished from approximately 20,000 km^2 to less than 100 km^2 today (Bhatnagar et al. 2006a). Table 11.2 illustrates the high variation in species richness seen in Trans-Himalayan catchments, presumably brought about by both intrinsic characteristics of the habitat as well as anthropogenic factors that have led to species' declines. Table 11.2 also suggests that the smallest and largest Trans-Himalayan wild herbivores have been more vulnerable to local extinctions compared to medium-sized ones, which is consistent with extinction patterns reported from other ecosystems (Newmark 1995, 1996).

The high livestock density and associated declines in wild herbivore density in the Trans-Himalayan rangelands presumably has a cascading effect of intensifying the conflict between humans and endangered large carnivores such as the snow leopard and the wolf *Canis lupus* over livestock depredation. Retaliatory persecution in response to livestock losses is one of the most important threats to these carnivores (Mishra et al. 2003a). Given the high relative abundance of livestock when compared to wild ungulates in Trans-Himalayan rangelands, expectedly high levels of livestock depredation are reported, amounting to up to 12% of the livestock holding annually (Mishra 1997; Bagchi & Mishra 2006; Namgail et al. 2007b). Snow leopards seem to have a high dependence on livestock for food – in two Trans-Himalayan wildlife reserves, 40–60% of the snow leopard's diet was comprised of livestock (Bagchi & Mishra 2006). Effectively managing such conflicts in the face of high livestock density is a major challenge, but they will need to be addressed for these endangered large carnivores to be conserved.

In parts of the Trans-Himalayas, a decline in hunting has enabled some mountain ungulates such as the Ladakh urial *Ovis vignei* and the Tibetan argali to recover locally, though the species continue to be threatened by increasing livestock populations in their habitats (Chundawat & Qureshi 1999;

Table 11.2 **Wild mountain ungulate species composition in 12 interspersed but isolated watershed catchments (each 200–400 km^2) in India's western Trans-Himalayas. Species are arranged along a gradient of body mass from left to right. Although species' presence–absence is governed by inherent habitat characteristics, 6 of the 12 catchments examined have only one extant species, presumably representing community collapse in some areas due to grazing and collateral anthropogenic factors.**

Catchment	**Species of wild large herbivore**							
	Tibetan gazelle (14 kg)	**Chiru (32 kg)**	**Bharal (55 kg)**	**Urial (70 kg)**	**Ibex (76 kg)**	**Tibetan Argali (80 kg)**	**Kiang (275 kg)**	**Wild yak (413 kg)**
Collapsed assemblages								
Hanle (lower)[a]			P				P	
Spiti (Pin Valley)					P			
Spiti (Tabo)			P					
Nubra (Kuber)					P			
Tso Mo Riri			P					
Kargil (Sangkoo)					P			
Diverse assemblages								
Hanle (Upper)	P		P				P	
Lower Indus (Sham)			P	P	P			
Upper Indus (Demchok)			P			P	P	
Hemis (Rumbak)			P	P	P	P		
Nubra (lower Shyok)				P	P			
Changchenmo		P	P				P	P

[a]P, presence of species.

Namgail et al. 2007c). A peculiar human–wildlife conflict has recently arisen in eastern Ladakh, where another such species, the kiang, is believed to be over-abundant, and is increasingly viewed as a forage competitor for local livestock (Bhatnagar et al. 2006b). A closer examination of this conflict has revealed that kiang densities here are not inflated and are comparable to those reported from Tibet (Schaller 1998). The misplaced perceptions of the over-abundance of kiang seem to have arisen, ironically, after its populations recovered over two decades following a drastic decline in the 1960s when a war was fought in the region between China and India (Bhatnagar et al. 2006b).

The future of Trans-Himalayan mountain ungulates remains uncertain. All species are potentially threatened by high-intensity livestock grazing, and of the eight extant species, only two have estimated populations of more than 10,000 within India, while four species number less than 500 individuals (Johnsingh et al. 2006). Most large mammal species are potentially threatened by livestock diseases. This is a little-understood but important conservation issue in the Trans-Himalayan rangelands, given that diseases such as *Peste des petits ruminants* and foot-and-mouth are increasingly being reported in the region's livestock (Bhatnagar et al. in press).

A well-documented consequence of overgrazing in water-limited ecosystems around the world is the catastrophic shifts in vegetation, rather than smooth successional changes, and the prevalence of stably degraded vegetation states (van de Koppel & Reitkerk 2000). The mechanism behind such threshold effects and discontinuous changes in vegetation is thought to be the interaction of grazing with a positive-feedback mechanism (habitat self-improvement by plants) that exists between vegetation and soils (van de Koppel et al. 1997). These feedback mechanisms lead to self-organized pattern formation in the vegetation (Klausmeier 1999; HilleRisLambers et al. 2001; Rietkerk et al. 2004); Trans-Himalayan rangelands commonly show such patterned vegetation (Mishra 2001). Vegetation in these rangelands can therefore be vulnerable to catastrophic shifts. Against this background, further research into vegetation dynamics in the Trans-Himalayas is critical, since the possibility of stably degraded vegetation states implies that even several years of protection following degradation due to overgrazing is unlikely to allow the vegetation to recover to original, more productive states. Such research would be critical to designing grazing policies that address the resilience of these rangelands, particularly during droughts.

A related aspect that also needs to be better understood is the response of these rangelands to climate change. Reports indicate that mean annual temperatures on the Tibetan plateau have been increasing at 0.16°C per decade since the 1950s and winter temperatures at 0.32°C per decade (Liu & Chen 2000), which can greatly influence local hydrological cycles. Average annual potential evapotranspiration (PET) has been declining since the 1960s (Shenbin et al. 2006), which may have a favourable impact on vegetation growth. At the same time, however, PET during the plant growth season seems to be increasing (Shenbin et al. 2006). The impact of the resultant shrinking glaciers and lakes on hydrological cycles remains unclear. Although simulations predict that climate change would increase this ecosystem's primary production, the expanse of shrub-steppe biome is likely to decline (Ni 2000). Coupled with such climate-induced changes are various socio-economic and herding-practice shifts (Mishra 2000; Mishra et al. 2003b; Namgail et al. 2007a) that collectively pose many challenges towards sustainable management of these rangelands for wildlife conservation as well as for pastoral livelihoods.

Towards better conservation management in Trans-Himalayan rangelands

Wildlife habitats and populations in most of India's terrestrial ecosystems today largely survive within wildlife protected areas that are often isolated and surrounded by rural and urban landscapes (Figure 11.2a). Wherever possible, these protected areas are further divided into core areas, where human presence and resource use are completely curtailed, and buffer areas, where, at least theoretically, some regulated human use is allowed. Following a similar approach, relatively large protected areas have also been declared on paper in the Trans-Himalayas, with an average size of 3035 km^2 compared to the national average of 267 km^2 (Rodgers et al. 2000). However, human use in the form of intensive livestock grazing and associated activities continues unabated in them and there are no truly inviolate core areas (Figure 11.2b), although they exist on paper in some cases. Furthermore, up to 30–40% of the land in some Trans-Himalayan parks is composed of areas that have hydrological and other kinds of importance but little biological value (such as permafrost areas and glaciers).

The Trans-Himalayas has traditionally been viewed as a low-productive ecosystem where wildlife inherently occurs in low densities and a region where Buddhist communities (again at very low densities) live in harmony with wildlife (see Mishra 2001 for a detailed discussion). Given that most

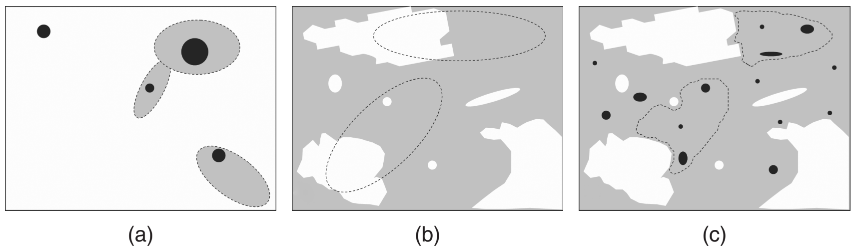

Figure 11.2 **A schematic representation of wildlife management in India. (a) The majority of India's terrestrial landscapes, where wildlife persists largely in insular protected areas, are further divided into core (no anthropogenic use; dark areas in the figure) and buffer zones (regulated anthropogenic use; grey in figure), surrounded by rural and urban landscapes (white). (b) In the Trans-Himalayas, where there is a near-complete absence of 'core' areas, but often-depleted wildlife populations persist across the entire landscape except permafrost areas (irregular white) and larger human settlements (white circles). (c) A more effective framework in the Trans-Himalayas would be to follow a landscape-level approach where each landscape unit is either a core or a buffer unit, with specific multiple-use objectives for each unit in the latter group. The protected area boundaries will need to be realigned to exclude white areas.**

of the landscape is grazed, ecological benchmarks that could show how the vegetation and wildlife would appear in the absence of livestock grazing are completely lacking (Mishra et al. 2002). Consequently, livestock grazing was not considered a serious conservation issue in this landscape until recent studies were undertaken, and this perhaps also explains the lack of serious efforts to establish core zones in Trans-Himalayan protected areas. Given people's traditional land use, lack of alternatives and a continued dependence on the landscape, establishing large core zones is also difficult. Thus, 'core' areas are missing in the Trans-Himalayas, while the 'buffer' areas, which form the bulk of the landscape today, have seen wildlife declines and species extinctions.

Nevertheless, the Trans-Himalayan (and higher Himalayan) landscape is unique when compared to most other terrestrial ecosystems in India, given that the bulk of the area comprises 'buffer' landscape units that continue to harbour wildlife populations, albeit in depleted states (Figure 11.2b). Keeping these realities in mind, we propose a slightly different conceptual framework for wildlife management and multiple use in the Trans-Himalayan landscape, which may have relevance for other rangeland and mountain systems as well.

Wildlife management in the Trans-Himalayas needs to look beyond protected areas and follow a larger landscape level approach, wherein, the first step would be to undertake biologically and socially meaningful landscape zonation (Bhatnagar et al. in press). This would involve identification of important landscapes (generally large spatial scales; $>1000\,\text{km}^2$) and setting the management objectives for each landscape unit within the larger landscape (smaller spatial scales; $\sim 10-100\,\text{km}^2$), based on its relative importance for wildlife conservation and human use. Each landscape unit may be demarcated based on a combination of geological, ecological and administrative characteristics. Such an exercise needs to be undertaken within as well as outside the existing parks, and on both government and community-owned lands.

Within this matrix of landscape units, based on zonation, a set of 'core' units needs to be established, interspersed among a series of 'buffer' landscape units, with each of the latter group having a variable set of multiple-use objectives. The guiding principles underlying the management objectives for wildlife populations for this mosaic of landscape units can be as follows:

1. In core landscape units, management objectives should aim to maintain wildlife populations ($\mathrm{N_c}$) at carrying capacity (K) over the long term, enable conditions where birth rates (b_c) exceed rates of mortality (m_c) and rates of emigration (e_c) are considerably higher than immigration rates (i_c) to enable spill-over effects, that is,

$$\mathrm{N_c} \approx \mathrm{K},\ b_\mathrm{c} > m_\mathrm{c}, \quad \text{and} \quad e_\mathrm{c} \gg i_\mathrm{c}$$

2. For each buffer landscape unit, it is at least conceptually important to estimate the desirable wildlife population size ($\mathrm{N_b}$) – which will be a function of the trade-off between conservation and rangeland use objectives – and ensure that populations are maintained around that level:

$$\mathrm{N_b} = \mathrm{K} - f(\mathrm{A}), \quad \text{and} \quad b_\mathrm{b} + i_\mathrm{b} \geq m_\mathrm{b} + e_\mathrm{b}$$

   where $f(\mathrm{A})$ is a function by which the wildlife population size is reduced below carrying capacity as a result of an acceptable level of human anthropogenic pressure for each landscape unit.

The size and number of core landscape units, wherever feasible, should be large and adequately interspersed within a matrix of buffer landscape units to enable the conservation of viable wildlife populations. At a minimum, the coupled landscape-level guiding principle for core and buffer units should be to aim for the total spill-over from core units to at least offset the net individuals lost from buffer units due to mortality and emigration, that is,

$$\sum \mathrm{N_c}(e_\mathrm{c} - i_\mathrm{c}) \geq \sum \mathrm{N_b}(b_\mathrm{b} - m_\mathrm{b} - e_\mathrm{b})$$

Illustratively, this means that as the livestock grazing intensity in a buffer or multiple-use landscape unit increases, one can expect a decline in the density of wild ungulates. A stated desirable wild ungulate density can help guide the management of livestock grazing and vice-versa within any given buffer unit. As the need for pastoral production in any landscape unit increases within sustainable limits, it will need to be counter-balanced by the need to establish a core unit in the proximity such that the inequality condition above continues to hold. This dynamic management approach will also facilitate grazing and wildlife management that is sensitive to inter-annual as well as long-term climatic variation. Our preliminary efforts at creating such core landscape units at experimental scales in the Trans-Himalayas have shown considerable wildlife recovery and spill-over effects within a span of 3–4 years in even small-sized (5–20 km^2) core areas (Mishra et al. 2003b, C. Mishra 1998–2007, unpublished observations). In a landscape where most of the area represents potential wildlife habitat and is simultaneously subjected to widespread anthropogenic resource use, this suggests that even small-sized core areas, which are more feasible, would be immensely valuable for long-term wildlife conservation as long as their numbers satisfy the inequality criterion specified above.

In such a management system, the need to have large-sized protected areas diminishes. At the same time, the legal implications of existing protected areas – in particular, for preventing land diversion to environmentally damaging large-scale developmental projects (such as big dams) that are a serious threat to biodiversity in the Himalayan landscape (e.g. Menon et al. 2003) – cannot be ignored. It may, therefore, be prudent to maintain the existing Trans-Himalayan protected areas but manage them within the larger landscape level, dynamic framework outlined here. The protected area boundaries, however, will nevertheless need to be realigned to exclude regions that have less biological value, but form considerable parts of existing Trans-Himalayan protected areas (Figure 11.2c).

In addition to adopting this broad framework for management of Trans-Himalayan rangelands, much needs to be done regarding human–wildlife conflicts. Flexible and community-based management of human–wildlife conflicts and providing incentives to local communities for conservation will be critical (e.g. Mishra et al. 2003b). There are other needs, such as putting in place adequate veterinary health care, scientifically well-informed regional, landscape-level and local grazing guidelines and policies, habitat restoration and species recovery programmes (e.g. Bhatnagar et al. 2007; Namgail et al. 2008).

The importance of constantly generating scientific knowledge on wildlife ecology and human society is particularly underscored in the Trans-Himalayas, where, until just a few years ago, it was believed that the region did not face any major conservation issues and that there was harmony between pastoral production and wildlife conservation (Mishra 2001). It is therefore critical that an adaptive framework for wildlife management be followed, which actively supports research and monitoring, and constantly incorporates ecological and social feedback into management planning at the landscape and landscape unit levels.

To address these issues, since 2004, we have been working with the concerned state and central governments to develop, along these lines, a new scheme and policy for the conservation of Himalayan and Trans-Himalayan rangelands and their wildlife, known as *Project Snow Leopard* (Anon. 2008). We are hopeful that Project Snow Leopard, whose broad objectives are outlined in Table 11.3, became operational in 2009. We would like to re-emphasize that most conservation efforts in landscapes used by people carry conservation costs to indigenous communities, and it is critical that future conservation initiatives be undertaken with their consent, support and participation. This is particularly important in the Trans-Himalayan landscape, where conventional large protected areas are difficult to establish and to manage effectively. Active participation of local communities is inherent to the framework for the management of Trans-Himalayan rangelands we have proposed here, which is essentially a combination of protectionist and sustainable use conservation paradigms (Mishra et al. 2003b). We believe that such a landscape-level, knowledge-based, adaptive, participatory, and dynamic conservation framework will be a major step in securing the conservation of wildlife and the sustainability of Trans-Himalayan rangelands.

Table 11.3 **Broad objectives of Project Snow Leopard, a new conservation policy for India's Himalayan and Trans-Himalayan landscapes being currently proposed.**

Objectives
1. Facilitate a landscape-level approach to wildlife conservation
2. Rationalize the existing protected area network and improve protected area management
3. Develop a framework for wildlife conservation outside protected areas and promote ecologically responsible development
4. Encourage focused conservation and recovery programmes for endangered species such as the snow leopard
5. Promote stronger measures for wildlife protection and law enforcement
6. Promote better understanding and management of human–wildlife conflicts
7. Restore degraded landscapes in the Himalayan and Trans-Himalayan biogeographic regions
8. Promote a knowledge-based approach to conservation and an adaptive framework for wildlife management
9. Reduce existing anthropogenic pressures on natural resources
10. Promote conservation education and awareness

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