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Ecology, Economics, and Equity of the Pastoral Systems in the Khangchendzonga National Park, Sikkim Himalaya, India

The Khangchendzonga National Park is a part of the eastern Himalaya global biodiversity hotspot and is located in the Sikkim state of India. Increasing livestock populations coupled with the government policy to ban grazing and its selective implementation resulted in conflict. Hence we undertook this multidisciplinary study involving consultations with traditional resource users, field surveys, and remote sensing. We found that in the greater Himalayan part, over the past 6 decades sheep have been increasingly replaced by yaks (and their crossbreeds), who descend only up to the multilayered temperate and subalpine forests during winter. These forests have been extensively manipulated by the yak herders to increase the fodder availability. In terms of economics and equity in benefit sharing, we found that a few yak herders earn high incomes by maintaining large herds while the sheep and pack animal herders earn subsistence level incomes from small herds. We propose a reduction in yak (and their female crossbreed) numbers with adequate alternative livelihood support for the herders.

INTRODUCTION

Sikkim, the second smallest (7096 km^2) and least populous (0.54 million) state of India, is located in the eastern Himalayan region (1). This region represents 1 of the 34 global biodiversity hotspots of the world (2, 3). The most significant locality set aside for the conservation of biodiversity in the state is the Khangchendzonga National Park (KNP; 1784 km^2), which was established in 1977 and covers nearly 25% of the total geographical area of the state. The park harbors both the greater Himalaya (86%) and the trans-Himalaya (14%). It has been carved out from existing reserve forests that were demarcated and freed from all previous rights in 1909. Khangchendzonga National Park also forms a part of the greater Khangchendzonga transboundary landscape providing biological connectivity with protected areas in Nepal (Kanchenjunga Conservation Area) and India (Barsey Sanctuary) (Fig. 1). It is well known for its high-altitude landscape, having 9 peaks that rise above 7000 m, including the third highest peak in the world: Mt. Khangchendzonga (8586 m). Ninety percent of the park lies above 3000 m; 70% lies above 4000 m; and 34% is under glaciers, ice sheets, or perpetual snow. The park also harbors more than 150 glaciers and 73 glacial lakes (4). The monsoon climate is characterized by an extended, wet summer followed by a long, dry winter.

According to the classification by Champion and Seth (5), there are 18 forest types in KNP. Maity and Maiti (6) found 1580 species of vascular plants composed of 106 pteridophytes, 11 gymnosperms, and 1463 species of angiosperms in the park and the surrounding forests. Eight herbivores, 10 carnivores, and 3 pheasants have been reported from here (7, 8). Four species of endangered mammals, namely snow leopard (*Uncia uncia*), red panda (*Ailurus fulgens*), wild dog (*Cuon alpinus*), and particolored flying squirrel (*Hylopetes alboniger*), are found here (9). Bombay Natural History Society Birdlife International has also declared the park an "Important Bird Area" (10).

This landscape is revered by the Hindus and Buddhists alike and is believed to have been blessed by Guru Padmasambhava, a revered sage of the 8th century AD But for a single village made up of 10 households, the remaining 9500 households with a total population of nearly 30 000 live in 29 villages adjacent to but outside KNP (1). A number of indigenous communities, viz. Lepcha, Limbu, Gurung, Mangar, Chettri, Bhutia, Sherpa, Lachenpa, and Tibetan Dokpa, have been residing in this landscape for at least the past several centuries. Large cardamom farming in the subtropical belt and livestock rearing in the temperate and alpine belt are the main livelihoods. Recently, tourism in select villages has brought about local prosperity. The stunning variation in altitude of 7466 m (1220–8586 m), the exceptionally high biodiversity, and the existence of nine major ethnic communities on its fringes make this park a global natural and cultural heritage site.

The cultural diversity of the local communities living adjacent to KNP has given rise to a variety of livelihoods. Traditionally, the Gurungs and Mangers were the shepherds, the Bhutias were the traders and yak herders, the Lepchas and the Limbus were the hunter-gatherers and shifting cultivators, the Chettris and Bahuns were the agro-pastoralists rearing cattle, and the Tibetan Dokpas were the nomadic yak herders in the trans-Himalaya. During the beginning of the 20th century, the forests of the state were demarcated, with the "protected forests" set aside to meet the firewood and fodder needs of the villagers and the "reserve forests" for long-term ecological security. The population of Sikkim increased almost 15-fold from an estimated 36 458 in 1891 to 540 891 in 2001, while the livestock (cattle, buffalo, yak, horse, sheep, and goat) population stood at almost 300 000 in 2003 (1, 11, 12). Because of serious degradation, the government of Sikkim banned the practice of open grazing in the reserve forests in 1999. Selective enforcement of this ban in the greater Himalayan part of KNP resulted in the eviction of about 300 agro-pastoralists owning about 6000 cows from the reserve forests adjacent to KNP by 2002. However, the yak population could not be reduced, because the yak herders were influential and accessed remote alpine pastures which had not been studied. This led to a 3-way conflict between the agro-pastoralists who had been evicted, the yak herders, and the forest department. The genesis of the present study lies in this conflict.

Pastoralism in the Himalaya and its coexistence with wildlife have been topics of intense research, hot debate, and limited "on-ground" action. Our goals in this paper are threefold. First, we document the changing composition and numbers of livestock grazed at high altitudes. Second, we document the impact of grazing on native flora by comparing heavily grazed areas with those that are less affected. Third, we show that some of the major recent effects in the temperate and subalpine

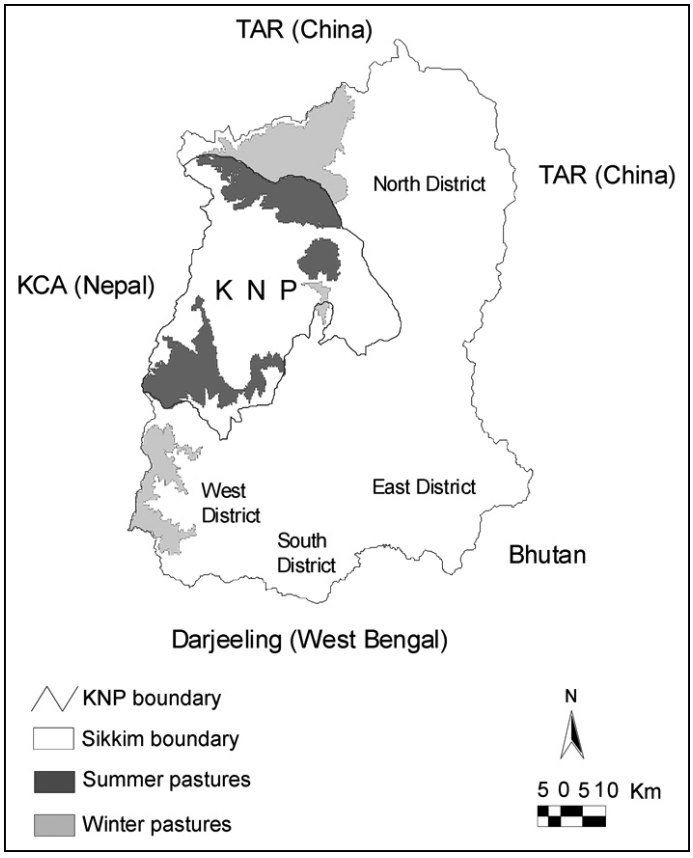

Figure 1. Location of summer and winter pastures of livestock in Khangchendzonga National Park and adjacent forests.

forests are due to the presence of yak herds, which are owned by relatively few individuals.

MATERIALS AND METHODS

Over the years, different approaches have been used to evaluate the sustainability of pastoralism in the alpine rangelands. A commonly used tool is the carrying capacity, which tries to balance forage production with consumption by livestock. These studies assume livestock production to be the sole objective of alpine landscape management. However, in the Himalaya, as elsewhere, the landscape is a multiple use area, serving as a habitat for endangered flora and fauna, an *in-situ* germplasm of valuable medicinal plants, a source of major perennial rivers, and more recently a destination for nature tourism (13). Hence, despite much information on the effects of pastoralism, only a few of them resulted in direct conservation action (14–17). Recent studies have attempted to correlate the health of livestock production systems with the health of the alpine rangelands, including impact on the wild ungulates and conflict with carnivores (18–20). Here we use a combination of techniques, including consultations with traditional resource users, extensive field surveys, and remote sensing, to assess recent effects of livestock grazing.

The study area was the alpine zone of KNP, which broadly includes the areas between 4000 m and 5000 m elevation. Physiognomically, it starts from where the krummholz thickets end and the alpine scrub begins and extends up to the subnival vegetation. About 22% of the park with an extent of 390 km^2 falls within this zone. The winter pastures of the yaks and their crossbreeds in the temperate and subalpine forests adjacent to KNP in the 2500 m to 3500 m elevation range were also surveyed. The data were collected from 2004 to 2006 with field surveys during summer and village consultations in winter.

Village Consultations

Information from herders, ex-herders, and other resource users was collected using participatory appraisal tools, such as historical timeline, participatory resource mapping, and pair-wise ranking. Consultations were conducted in 17 villages over 49 d, and 1 focal group herder interaction workshop was also organized. Each of these meetings had between 50 and 100 participants, including ex-herders. We recorded information on pastoral systems related to historical and current population trends, ownership pattern, migration routes, ecological impacts, and incomes using these participatory appraisal tools. Livestock composition and population data for the years 1950 and 1975 were collected in this manner village wise and were then consolidated. We cross-checked this information using field censuses. The number of households benefiting from a particular pastoral system was used as a measure of its equity. This interpretation tries to capture how broad based the livelihood and extent of society profiting or dependent on it are. The per capita income of the state was based on the economic survey (21).

Field Surveys

We surveyed the study area in summer season in 14 field visits spanning 125 d from 2004 to 2006. We conducted a census of the herders, and information relating to livestock holding, ownership pattern, migration, and fodder preference was recorded. The field study on the effects of pastoralism was carried out in the greater Himalayan part of the park, because this was the location of conflict and maximum impacts. Location of areas affected by herding and those relatively undisturbed was selected based on village consultations and herder interviews. The undisturbed areas were located far from the herder villages and also protected by steep passes. It was difficult to delineate the effects of various pastoral systems in the alpine meadows (summer pastures), because the grazing areas are the same and the vegetation has evolved over several years of sheep grazing and recently growing yak numbers. Thus, in the alpine meadows we studied the combined effects of the various pastoral systems on the native flora. We laid a total of 129 square quadrats of 1 m^2 area each in the alpine landscape between 4000 m and 5000 m elevation range, 88 in disturbed, and 41 in relatively undisturbed in 21 sampling sites with 5 replicates each. We recorded the plant species composition and abundance.

The winter pastures of the yaks and their crossbreeds are located largely outside KNP in the temperate and subalpine forests of Yambong and Barsey sanctuary. This is because these forests receive less snowfall and are accessible during winter, unlike the ones within KNP that are blocked by heavily snowed alpine passes, making it difficult for the herder to cross them to ascertain the wellbeing of his herd. Unlike the summer pastures, the winter pastures are used only by the yaks and their crossbreeds, because the sheep descend to the farmer's fields in winter. Here we laid 60 (10 m $\times$ 10 m) quadrates, 39 in disturbed and 21 in relatively undisturbed in 16 sampling sites, at least 4 km apart with 5 replicates each. We recorded density and girth at breast height of tree species for the top and middle layers and plant species and cover for the ground layer.

Most of the plants were identified closest to the genera and species in the field using the regional floras available, namely Flowers of Himalaya (22) and Flora of Bhutan (three volumes that include collections from Sikkim) (23). Voucher specimens of unidentified plants were collected and later verified from other monographs and herbaria at Gangtok and Dehra Dun. Native uses of plants were noted from the local field guides.

Table 1. Dynamics of livestock population and biomass in Khangchendzonga National Park from 1950 to 2004 (baseline year of the study) and to 2007 (after implementation of the study findings).

	Population				Biomass (in thousand kg)			
Livestock type	**1950**	**1975**	**2004**	**2007**	**1950**	**1975**	**2004**	**2007**
Greater Himalaya								
Sheep (Banpaala breed)	8800	5200	1141	912	264	156	34	27
Cow	100	600	150	145	30	180	45	44
Buffalo	0	200	5	0	0	60	2	0
Yak (Nepalese breed)	50	200	779	505	13	50	195	126
Female yak-cow crossbreed (urang or dzomo)	0	0	469	15	0	0	164	5
Pack animal (horse and dzo)	60	60	316	434	21	21	111	152
Trans Himalaya								
Sheep (Tibetan breed)	1000	1000	0	0	30	30	0	0
Yak (Tibetan breed)	1000	630	850	944	250	158	213	236
Total livestock	11 010	7890	3710	2955	608	655	764	590

Temporal Change in Vegetation

We compared a Normalized Density Vegetation Index (NDVI) of the 2 Landsat images acquired almost 24 y apart, on 23 January 1977 (24) and 26 December 2000 (25). ERDAS IMAGINE version 8.5 and ArcVIEW GIS 3.2 digital image processing software were used. The NDVI helps compensate for changing illumination conditions, surface slope, aspect, and other extraneous factors (26). Although seasonally the images are less than a month apart, the 1977 image showed higher shadow intensity and snow cover, leading to a positive bias in NDVI values. Presumably this could reflect annual differences as much as the 1-mo difference, and so we focused on only the negative changes. We highlighted the negative changes in the map with the change detection threshold set at more than 15% negative change in NDVI values.

Data Validation and Analysis

Herd owners when interviewed were inclined towards underreporting their livestock holding and underestimating their incomes. By contrast, the herd caretakers who were employed by the herd owners on wages and the ex-herders who had sold off their livestock recently were more forthcoming and reliable. Based on our independent field surveys, we found that the most reliable information on livestock was collected from these herd caretakers and the ex-herders, because they had a lesser conflict of interest. Deductive approaches were used to evaluate the economic traits of the pastoralism enterprise based on total livestock products sold and costs incurred. The exchange rate of 42 Indian Rupees is equivalent to USD 1 was used. The stocking levels of different types of livestock was combined into a common measure of livestock unit (LU) based on the grazing study of Singh (27). One LU is equivalent to 1.1 yak, 0.8 female yak-cow yak crossbreed, 0.8 horse, 0.8 dzo, and 3 sheep. The livestock impact unit (LIU) was calculated by multiplying the total LU with the total duration of stay of the livestock in the summer and winter pastures separately in days per unit hectare.

RESULTS

Evolution of Pastoral System

The livestock composition and population in KNP have been rapidly changing over the last 6 decades (Table 1). Current livestock composition includes sheep, cow, yak, yak-cow crossbreed, and horse. Historical records (11, 28, 29) indicate that whereas sheep and trans-Himalayan yaks (Tibetan breed) were traditionally grazed in the alpine landscape of KNP, cows, buffaloes, yaks (Nepalese breed), female yak-cow crossbreeds (urang or dzomo), and horses in the greater Himalaya have arrived only over the last 60 y. The total livestock population in KNP reduced significantly from about 11 010 in 1950 to 3710 in 2004, while the total livestock biomass increased from about 608 000 to 764 000 kg during this period, because sheep have been mostly replaced by larger sized livestock.

Impacts on the Alpine Meadows in Summer

The effects of pastoralism on the species richness and fodder cover in various vegetation types of the alpine landscape are shown in Figures 2 and 3. In the Juniper and *Rhododendron* scrub habitats, species richness increases substantially with disturbance. This vegetation in an undisturbed state is largely

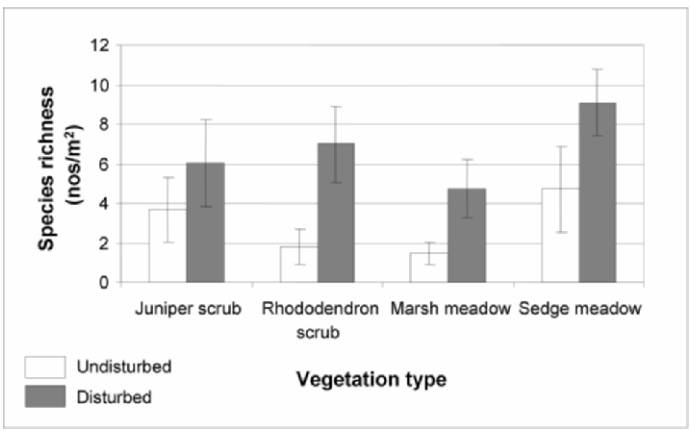

Figure 2. Mean (± SD as error bars) effects of pastoralism (burning and grazing) on plant species richness in the various vegetation types in the alpine landscape of Khangchendzonga National Park.

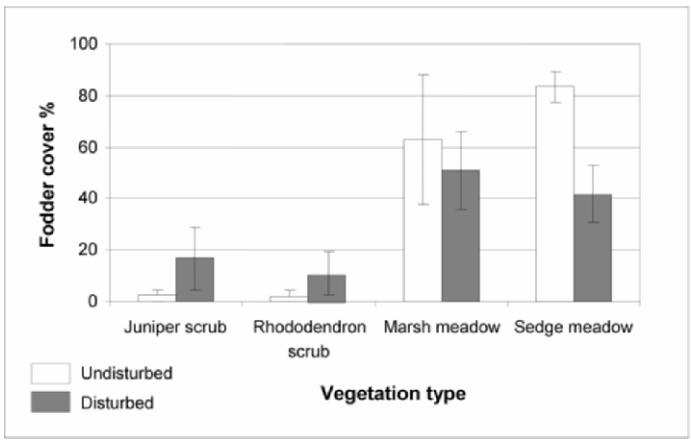

Figure 3. Mean (± SD as error bars) effects of pastoralism (burning and grazing) on fodder cover in the various vegetation types in the alpine landscape of Khangchendzonga National Park.

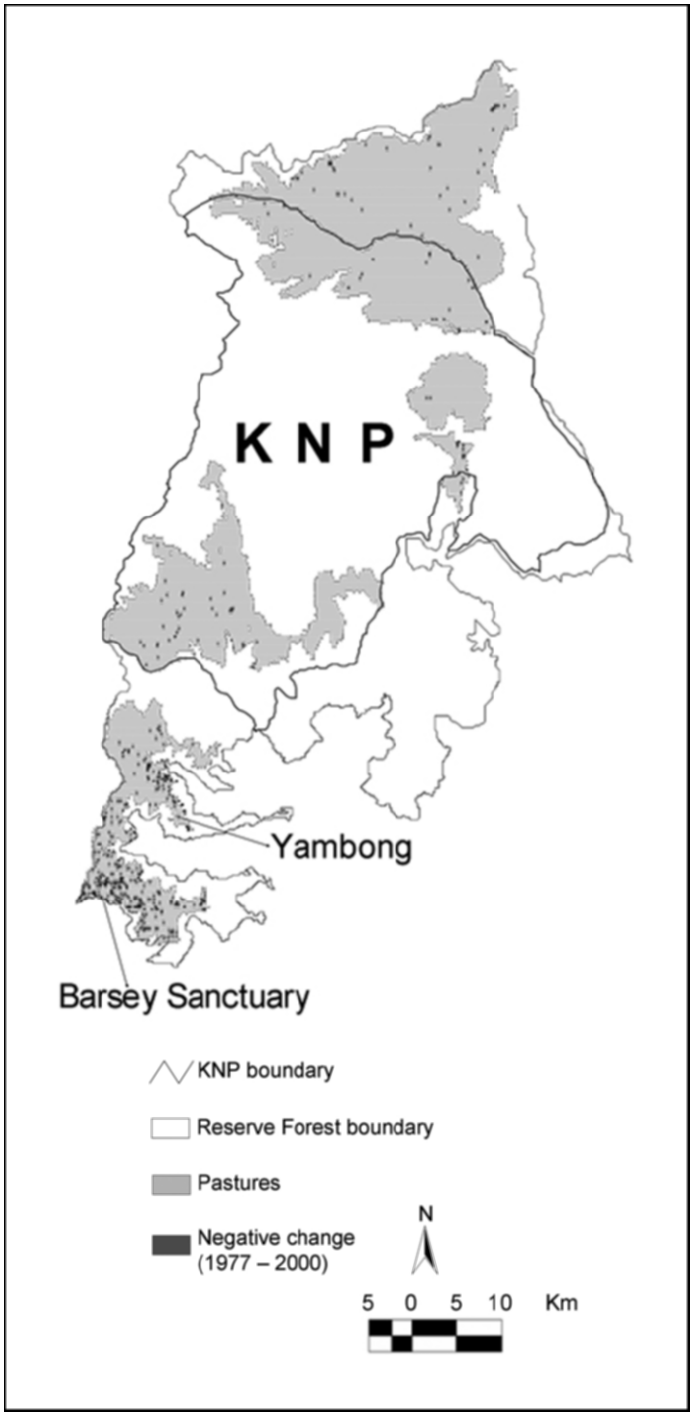

Figure 4. Map showing areas with a more than 15% decrease in the Normalized Density Vegetation Index between 1977 and 2000 in the pastures of Khangchendzonga National Park and adjacent reserve forests.

unpalatable, but with disturbance mostly in the form of burning and grazing, the fodder cover increases significantly due to the presence of palatable species, such as *K. nepalensis*, *Calamogrostis filiformis*, and *Festuca valesiaca* ($p = 0.02$, 95% CI). The yak herders clear this shrub habitat to increase the fodder availability. In the marsh and sedge meadows, the disturbed plots also show higher species richness. In terms of fodder availability, the sedge and marsh meadows are the only habitats with substantial forage in their natural state. The important fodder plants are *K. nepalensis* (sun buki), *F. valesiaca* (rani buki), *Kobresia duthiei* (bhalu buki), *Kobresia capillifolia* (kesari buki), *Kobresia* sp. (ghode buki), *Juncus* sp. (suire buki), *Allium prattii* (dandu), *Heracleum* sp. (ganer), *Selinum tenuifolium* (cheeru), *Rheum acuminatum* (khokim), *Carex nivalis* (dharkhare), *Carex nigra* (harkat), *Phleum alpinum* (doodhe jhar), *Kobresia pygmaea*, and *Elymus nutans*. However, during winter the alpine vegetation are not available to livestock due to heavy snowfall. In an undisturbed state, these meadows have a high fodder cover, but with grazing due to the spread of unpalatable plants, such as *Potentilla peduncularis, Ranunculus hirtellus, Anaphalis* sp., and *Geranium donianum*, the fodder availability reduces. Plants sensitive to grazing found in relatively undisturbed pastures are *Heracleum* sp. (ganer), *A. pratti* (dandu), *Pleurospermum* sp. (seto cheeru), *Rheum nobile* (kenjo), and *Saussurea uniflora* (thulo dudhe jhaar). Most of these plants are annual or biannual; tall; palatable; and, according to the herders, nutrient rich.

Effects on the Temperate and Subalpine Forests in Winter

The winter pastures of the yak and their crossbreeds (urang) are the multilayered evergreen oak and silver fir forests with a dense middle storey of dwarf bamboo and *Rhododendron* with a moss-dominated ground cover. *Yushania maling* (malingo) and *Thamnocalamus spathiflorus* (raat nigalo) are the main bamboo species that grow up to 7 m with a 7- to 10-cm girth and are densely packed with an average of 325 stems per 10-m-square plot. The herders open up kharkas or forest openings around their cattle sheds (goths) where the top canopy is lopped, and the middle storey is cleared to increase the ground fodder availability. South and east facing sunny aspects with moderate slope and perennial water availability are the preferred sites.

Between 1975 and 2004, the LIU of the yak and urang in the oak and fir forests (between 2500 and 3500 m) during winter increased from 2 to 17 LU d ha^{-1} (192–1531 LU). Change detection study in the 1977 to 2000 time series indicates that 25% of these forests, having an extent of 48 km^2, show more than 15% reduction in NDVI value (Fig. 4). Contemporary geospatial studies in the Barsey Sanctuary by Kushwaha et al. (30) showed that out of the total area of 120 km^2, 63 km^2 had been disturbed. Areas affected by cattle sheds (goth) have been converted to degraded forests and scrub showing relatively high disturbance.

Vegetation sampling showed that in these forest openings, the number of trees reduced from 3.7 ± 2.2 to 0.6 ± 1.6 in a 10-m square plot, while the basal area reduced from 103 ± 83 m^2 ha^{-1} to 21 ± 51 m^2 ha^{-1} compared with the undisturbed sites. Maximum difference was noticeable in the middle storey of bamboo (*Y. maling* and *Thamnocalamus spathiflorus*), whose stem density reduced from 324 ± 139 to 0.7 ± 2. In the openings heavily used by livestock, *A. microphyllus* (bonchu) is the dominant ground cover along with some *Carex* sp. (harkat) and moss. The herders also plant an exotic fodder grass, *Pennisetum clandestinum* (ghode dubo), in these openings. The ground fodder availability in these openings with *Arthraxon microphyllus* (bonchu) and supplemented with *P. clandestinum* increased substantially from 1.8 ± 1.4 % to 75.7 ± 20.8 %. With the opening of the forest canopy and clearing of the bamboo and *Rhododendron* middle storey, thickets of secondary, such unpalatable shrubs as *Viburnum erubescens, Berberis* sp., and *Rosa sericea* have increased substantially. The surveys also showed that fodder trees of the Moraceae, Lauraceae, and Araliaceae families are preferentially lopped in winter. *Ficus foveolata* (dudhe lahara), *Ficus neriifolia* (dudhilo), *Schefflera impressa* (bhalu chinde), *Symplocos racemosa* (badam), *Ilex* sp. (lisse), and *Machilus* sp. (rani kaula) are the preferred fodder trees.

Economics of Pastoral Enterprises

The incomes from pastoral systems depend on the herd size, livestock management system, and breeding strategy. The fixed costs include caretaker wages and living expenses, cattle shed

Table 2. Key economic traits of milch livestock in Khangchendzonga National Park in 2005.

Economic traits	Units	Yak	Urang	Sheep
Adult weight	kg livestock^{-1}	250	350	30
Age of first calving	y	3–4	3–4	2–3
Gestation period	mo	$9^{N}/10^{C}$	$9^{N}/10^{C}$	6
Daily milking yield	L d^{-1}	1	2.5	0.35
Lactation length	mo	8–10	6–8	6
Milking period	mo	3–4	6	3
Calving interval	mo	17–18	15–16	1
Hair/wool yield	kg y^{-1}	0.5	0	1
Life span	y	18–22	18–20	10–12
Total calving	No. of calves	8–10	14–16	7–8
Sale value of calf	USD calf^{-1}	33^{N} / 111^{C}	0	44
Sale value when adult	USD livestock^{-1}	144	167	44
Sale value when old	USD livestock^{-1}	89–100	56–78	44

N = normal calf; C = crossbreed calf.

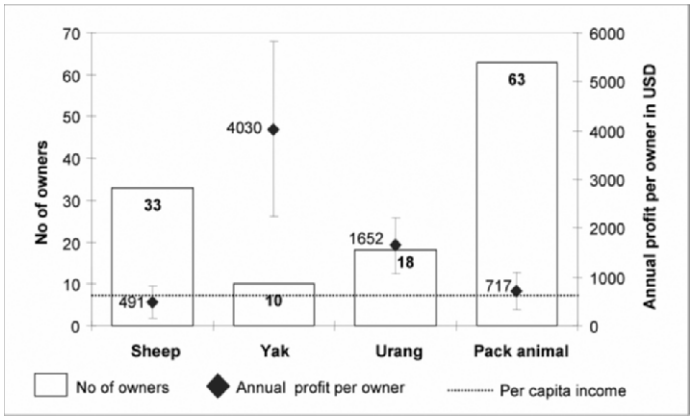

Figure 5. Mean annual profits (± SD as error bars) and benefit sharing from the pastoral systems in Khangchendzonga National Park relative to the per capita income of the state.

maintenance, and a stud bull, and the running costs (which vary with herd size) include the feed and salt requirements of the livestock. Although sheep and yak give incomes from sale of calves, wool, and milk products, the incomes from urang are only from the latter. Table 2 shows the key economic traits of these milch livestock. The dzos and horses are hired as pack animals in the trekking tourism sector. The major risks involved are early snowfall, falling off cliffs, feeding on poisonous plants, depredation by carnivores, and diseases.

Figure 5 shows that the annual profit earned is highest for the yak and then the urang owner, because the corresponding herd size owned by them is also much larger. The annual returns on investment, which was calculated as a ratio of the total annual profit of the herder to the total market value of his herd, is highest at 60% for the pack animal enterprise and varies between 30% and 37% for the other livestock production systems. Thus, whereas the total profits are the highest for the yak herder, the pack animals give highest annual returns on investment.

Equity and Benefit Sharing of Pastoral Systems

After studying the ecological and economic dimensions, the aspects relating to equity in benefit sharing were explored. In terms of livestock biomass ownership, 9 yak herders own 19 500 ± 8700 kg (71.7 LU) each, 18 urang herders own 9100 ± 3200 kg (31.3 LU) each, 63 pack animal herders own 1900 ± 1000 kg (6.0 LU) each, and 33 sheep herders own 1000 ± 700 kg (11.4 LU) each (Fig. 5). The per capita income of the state, which was USD 639 in 2005, was used as the baseline (21). Relative to this, the yak herder earns 6.3 times (USD 4030), the urang herder 2.6 times (USD 1652), the pack animal owner 1.1 times (USD 717), and the sheep herder 0.8 times (USD 491) the baseline. Thus, it was found that a few yak herders maintain large herds and earn high incomes. On the other hand, a substantial number of sheep and pack animal herders earn subsistence incomes from small herds. Urang rearing falls in between subsistence level sheep and pack animal rearing and commercial yak ranching.

DISCUSSION

Interviews with local villagers and historical records show that traditionally in the greater Himalayan part of KNP, Banpaala breed of sheep were the dominant livestock that used to graze in the alpine meadows during summer and then descend to the fallow farmer's fields in winter. The farmers provided the shepherds with shelter and rations, while the sheep manured his fields. This unique symbiosis between the seminomadic sheep herders and the sedentary farmer existed until the advent of large cardamom agro-forestry and intensive farming systems. With reduced access to winter pastures, the shepherds were forced to reduce the herd size and shift to a sedentary livelihood of mixed farming. From the mid 20th century, transborder Bhutia yak herders from eastern Nepal started migrating and settled in the border villages of West Sikkim adjacent to KNP. In 1975, with the merger of Sikkim with India, rapid development created new opportunities and markets. To meet the growing demand for dairy products, the herd size of the yak (Nepalese breed) and the female yak cow crossbreeds (urang) started increasing. In the summer, they accessed the moist alpine meadows until the winter snowfall forced them down to the temperate and subalpine forests.

The overall livestock composition and population trend shows that the number of smaller sized sheep has reduced drastically while the number of heavier animals, mostly yaks, their crossbreeds, and horses, is on the rise. The sheep traditionally migrate long distances between the alpine meadows (5000 m) in summer to the subtropical villages (1800 m) in winter. This long-distance migration of the sheep has been replaced by an altitudinal one of the yaks and their crossbreeds that do not descend to the permanent human habitations during winter. The result of this switch from sheep to yaks is the much higher winter effects on the temperate and subalpine forests.

Scarcity of natural fodder during the long winter season from November to March is the biggest hurdle in sustainable livestock production in KNP. The yak and urang pastoral systems have substantially affected the oak and fir forests with *Rhododendron* and bamboo middle storey in the 2500 m to 3500 m elevation range of Yambong valley and Barsey sanctuary. Satellite images confirm that at least 25% of these forests show a greater than 15% decrease in NDVI values between 1977 and 2000. Field study shows that these vegetation types have limited natural fodder cover and the yak herders use ingenious methods, such burning, cutting, and lopping of the woody vegetation, to create forest openings and then supplement these with exotic fodder grasses. The carrying capacity of these man-made pastures for livestock is substantially higher than the natural carrying capacity. These forests are a unique habitat whose flagship species is the endangered red panda (31). Recent studies in the Langtang National Park of Nepal indicate that the red panda has been severely affected due to disturbance from yak crossbreeds, herders, and the herders' dogs (32). Comparatively, the sheep, which descend to the agricultural fields during winter, and pack animals that are free ranging without an attendant herder have lesser impacts. Yak herding livelihood showed the highest inequity in benefit sharing with high incomes concentrated among 10 households, followed by urang herding. Relatively, the sheep and pack animal herding were found to

be more equitable and provided benefits to a larger section of society. Lower effects and greater equity in benefit sharing made the sheep and pack animal herding relatively more sustainable.

Under national wildlife laws, livestock grazing is not permitted in a national park, but lack of people's support and political will have resulted in a weak or sporadic enforcement of the stringent national forest and wildlife laws (33). Consequently, grazing is pervasive in most of the protected areas in the country (34). However, in Sikkim a determined political leadership with strong support from the local people is acting on the findings of this study to reduce the yak and urang numbers in the greater Himalayan park of KNP while providing alternative livelihood support to the herders. The Yambong Singalila ecotourism package (35) was launched jointly with The Mountain Institute nongovernmental organization (36), and a total of 314 overseas and 13 domestic tourists visited this new destination in 2006. The local ecotourism service providers, who served as porters, assistant guides, and dzo operators, earned USD 38 100. About half of this income was earned by the yak herders. Consequently, by 2007 the number of yaks in the greater Himalayan part of KNP had decreased from 779 to 505 and the number of yak crossbreeds (urang) from 469 to 15 (Table 1). The strong direction from the political level, active support from the local community, and alternative livelihood support from trekking tourism, all of which were previously lacking, were instrumental in this reduction. Multidisciplinary ecological and socioeconomic research is needed to distinguish between need- and greed-based livelihoods and their ecological effects. Such studies will provide a basis for shaping political will and mobilizing people's power, which in a democratic framework is vital for bringing about change.

References and Notes

1. Census of India. 2001. *Provisional Population Totals: Paper 1 of 2001*. Office of the Registrar General and Census Commissioner, New Delhi, India. (http://www.censusindia.net)
2. Myers, N., Mittermier, R.A., Mittermier, C.G., da Fonseca, G.A.B. and Kent, J. 2000. Biodiversity hotspots for conservation priorities. *Nature 40*, 853–858.
3. Mittermeier, R.A., Gils, P.R., Hoffman, M., Pilgrim, J., Brooks, T., Mittermeier, C.G., Lamoreaux, J. and da-Fonseca, G.A.B. (eds). 2004. *Hotspots Revisited. Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions*. CEMEX, Mexico City and Conservation International, Washington, DC.
4. Centre for Inter-disciplinary Studies of Mountain and Hill Environment (CISMHE). 2005. *Carrying Capacity Study of Tista Basin in Sikkim. Volume II Land Environment—Geophysical Environment*. Centre for Inter-disciplinary Studies of Mountain and Hill Environment, University of Delhi, Delhi, India pp. 113–114.
5. Champion, F.W. and Seth, S.K. 1968. *A Revised Survey of the Forest Types of India. Nasik, India: Manager*. Government of India Press, Delhi, India, 404 pp.
6. Maity, D. and Maiti, G.G. 2007. *The Wild Flowers of Kanchenjunga Biosphere Reserve, Sikkim*. Noya Udyog, Kolkata, India, 174 pp.
7. Critical Ecosystem Partnership Fund (CEPF) 2005. *Ecosystem Profile: Indo-Burma Hotspot, Eastern Himalayan region*. World Wildlife Fund US Asia Programme, Washington, DC, 100 pp.
8. Chettri, N. 2000. *Impact of Habitat Disturbances on Bird and Butterfly Communities along Yuksam-Dzongri Trekking Trail in Khangchendzonga Biosphere Reserve*. PhD Thesis, North Bengal University, Darjeeling, India.
9. International Union for Conservation of Nature (IUCN). 2006. IUCN Red List of Threatened Species. (http://www.iucnredlist.org)
10. Islam, M.Z. and Rahmani, A.R. 2004. *Important Bird Areas of India: Priority Sites for Conservation*. Indian Bird Conservation Network: Bombay Natural History Society and Birdlife International, Cambridge, UK, 1133 pp.
11. Risley, H.H. 1894. *The Gazetteer of Sikhim*. Bengal Secretariat Press, Calcutta, India, 392 pp.
12. Department of Animal Husbandry, Livestock, Fisheries and Veterinary Services (DAHLFVS). 2003. 17th Indian Livestock Census Sikkim—2003, DAHLFVS, Government of Sikkim, Gangtok, India, 43 pp.
13. Miller, D.J. 1997. *Rangelands and Range Management. ICIMOD Newsletter No. 27*. ICIMOD, Kathmandu, Nepal, 2 pp.
14. Saberwal, V.K. 1996. Pastoral politics: Gaddi grazing, degradation, and biodiversity conservation in Himachal Pradesh, India. *Conserv. Biol. 10*, 741–749.
15. Saberwal, V.K. 1998. Degradation and environmental conservation: response to Mishra and Rawat. *Conserv. Biol. 12*, 715–717.
16. Fox, J.L., Mathiesen, P., Yangzom, D., Naess, M.W. and Xu, Binrong 2004. Modern wildlife conservation initiatives and the pastoralist/hunter nomads of northwestern Tibet. *In Rangifier, Special Issue, 15*, 17–27.
17. Mishra, C. and Rawat, G.S. 1998. Livestock grazing and biodiversity conservation: comments on Saberwal. *Conserv. Biol. 12*, 712–717.
18. Mishra, C., Prins, H.H.T. and VanWieren, S.E. 2001. Overstocking in the Trans-Himalayan rangelands of India. *Environ. Conserv. 28*, 279–283.
19. Mishra, C. 2001. *High Altitude Survival: Conflicts between Pastoralism and Wildlife in the Trans-Himalaya*. PhD Dissertation. Wageningen University, Wageningen, The Netherlands.
20. Bagchi, S., Mishra, C. and Bhatnagar, Y.V. 2004. Conflicts between traditional pastoralism and conservation of Himalayan ibex (*Capra sibirica*) in the Trans-Himalayan mountains. *Animal Conserv. 7*, 121–128.
21. Lama, M.P. 2007. *Sikkim: Economic Survey 2006–2007*. Government of Sikkim, Gangtok, India, 195 pp.
22. Polunin, O. and Stainton, A. 1987. *Concise Flowers of the Himalaya*. Oxford University Press, New Dehli, India, 283 pp.
23. Grierson, A. J. C. and Long, D. G. 1983–1991. *Flora of Bhutan, Vols 1–3*. Royal Botanical Garden, Edinburgh.
24. NASA Landsat Program. 1977. Landsat MSS scene p149r41_2m19770123, Orthorectified, GeoCover. USGS, Sioux Falls, SD, 01/23/1977.
25. NASA Landsat Program. 2000. Landsat ETM+ scene p139r041_7t20001226, Orthorectified, GeoCover. USGS, Sioux Falls, SD, 12/26/2000.
26. Lillesand, T.M. and Kiefer, R.W. 2000. Remote Sensing and Image Interpretation. (4th ed). John Wiley and Sons, Pvt. Ltd, Singapore, 724 pp.
27. Singh, H.B. and Sundriyal, S.C. 2005. Composition, economic use, and nutrient contents of alpine vegetation in the Khangchendzonga Biosphere Reserve, Sikkim Himalaya, India. *Arct. Antarct. Alp. Res. 37*, 591–601.
28. Hooker, J.D. 1853. *The Himalayan Journal. Notes of a Naturalist. Vol. I and II*. (Reprint). Natraj Publishers, Dehra Dun, India, Vol. I 408 pp, Vol. II, 486 pp.
29. Smith, W.W. and Cave, G. H. 1911. *The Vegetation of the Zemu and Llonakh Valleys of Sikkim*. In the records of the Botanical Survey of India, Volume IV, No 5. Superintendent Government Printing, India, 272 pp.
30. Kushwaha, S.P.S., Padmanaban, P., Kumar, D. and Roy, P.S. 2005. Geospatial modeling of plant richness in Barsey Rhododendron Sanctuary in Sikkim Himalayas. *Geocarto International 20*, 63–68.
31. Pradhan, S., Saha, G.K. and Khan, J.A. 2001. Ecology of the red panda *Ailurus fulgens* in the Singhalila National Park, Darjeeling, India. *Biol. Conserv. 98*, 11–18.
32. Yonzon, P.B. and Hunter, M.L. 1991. Cheese, tourists, and red pandas in the Nepal Himalayas. *Conserv. Biol. 5*, 196–202.
33. Chhatre, A. and Saberwal, V. 2005. Political incentives for biodiversity conservation. *Conserv. Biol. 19*, 310–317.
34. Kothari, A., Pande, P., Singh, S. and Variava, D. 1989. *Management of National Parks and Sanctuaries in India: A Status Report*. Indian Institute of Public Administration, New Delhi, India.
35. Yambong Singalila ecotourism package. (http://www.yambong.com)
36. The Mountain Institute nongovernmental organization. (http://www.mountain.org)

37. We gratefully acknowledge the support received from The Mountain Institute, Department of Forest, Environment and Wildlife Management, Government of Sikkim, Wildlife Institute of India, Indo Swiss Project Sikkim and village based institutions namely Sindrabung Khangchendzonga Eco-friendly Society and Khangchendzonga Conservation Committee. We thank Trevor Price, Nakul Chettri and the anonymous reviewers for their valuable suggestions.
38. First submitted 15 July 2007. Accepted for publication 25 June 2008.

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