Conservation Biology

Essay

Globalization of the Cashmere Market and the Decline of Large Mammals in Central Asia

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Abstract: *As drivers of terrestrial ecosystems, humans have replaced large carnivores in most areas, and human influence not only exerts striking ecological pressures on biodiversity at local scales but also has indirect effects in distant corners of the world. We suggest that the multibillion dollar cashmere industry creates economic motivations that link western fashion preferences for cashmere to land use in Central Asia. This penchant for stylish clothing, in turn, encourages herders to increase livestock production which affects persistence of over 6 endangered large mammals in these remote, arid ecosystems. We hypothesized that global trade in cashmere has strong negative effects on native large mammals of deserts and grassland where cashmere-producing goats are raised. We used time series data, ecological snapshots of the biomass of native and domestic ungulates, and ecologically and behaviorally based fieldwork to test our hypothesis. In Mongolia increases in domestic goat production were associated with a 3-fold increase in local profits for herders coexisting with endangered saiga* (Saiga tatarica)*. That increasing domestic grazing pressure carries fitness consequences was inferred on the basis of an approximately 4-fold difference in juvenile recruitment among blue sheep* (Pseudois nayaur) *in trans-Himalayan India. Across 7 study areas in Mongolia, India, and China's Tibetan Plateau, native ungulate biomass is now <5% that of domestic species. Such trends suggest ecosystem degradation and decreased capacity for the persistence of native species, including at least 8 Asian endemic species: saiga, chiru* (Pantholops hodgsoni)*, Bactrian camel* (Camelus bactrianus)*, snow leopard* (Panthera uncia)*, khulan* (Equus hemionus)*, kiang* (E. kiang)*, takhi* (E. przewalski)*, and wild yak* (Bos mutus)*. Our results suggest striking yet indirect and unintended actions that link trophic-level effects to markets induced by the trade for cashmere.*

Keywords: fashion, herders, India, Mongolia, saiga, trade

Globalización del Mercado de Cachemira y la Declinación de Mamíferos Mayores en Asia Central

Resumen: *Como conductores de ecosistemas terrestres, los humanos han reemplazado a los carnívoros mayores en la mayoría de las regiones, y la influencia humana no solo ejerce presiones ecológicas severas sobre la biodiversidad en escalas locales sino también tiene efectos indirectos en rincones distantes del mundo. Sugerimos que la multibillonaria industria de la cachemira crea motivaciones económicas que ligan las preferencias de la moda occidental por la cachemira con el uso de suelo en Asia Central. Este gusto por la ropa elegante, a su vez, motiva a los pastores a incrementar la producción de ganado lo cual afecta la persistencia de más de 6 especies de mamíferos mayores en peligro en estos ecosistemas áridos y remotos. Planteamos la hipótesis de que el comercio global de cachemira tiene fuertes efectos negativos sobre mamíferos mayores nativos de desiertos y pastizales donde son criadas las cabras productoras de cachemira. Utilizamos datos de series de tiempo, instantáneas ecológicas de la biomasa de ungulados nativos y domésticos, y trabajo de campo ecológico y conductual para probar nuestra hipótesis. En Mongolia, los incrementos en la producción de cabras domésticas se asociaron con el incremento al triple de las ganancias locales para pastores que coexisten con la saiga* (Saiga tatarica) *en peligro. Con base en una diferencia de aproximadamente*

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4 veces en el reclutamiento juvenil de la oveja azul (Pseudois nayaur) en el Himalaya de India, se infirió que el incremento de la presión de pastoreo doméstico tiene consecuencias en la adecuación. En 7 áreas de estudio en Mongolia, India y la Planicie Tibetana en China, la biomasa actual de ungulados es <5% de las especies domésticas. Tales tendencias sugieren la degradación del ecosistema y la disminución en la capacidad de persistencia de especies nativas, incluyendo por lo menos 8 especies endémicas de Asia: Saiga tartarica, Panthera hodgsoni, Camelus bactrianus, Panthera uncial, Equus hemionus, E. kiang, E. przewalski y Bos mutus. Nuestros resultados sugieren acciones relevantes, aunque indirectas y no intencionales, que relacionan efectos a nivel trófico con los mercados inducidos por el comercio de cachemira.

Palabras Clave: comercio, India, moda, Mongolia, pastores, saiga

Introduction

Who decides what native species persist? The answer is easy—humans. National governance, laws, economics, local and indigenous cultures, and other nonbiological realities affect opportunities for successful conservation. The multibillion-dollar garment industry is a case in point. Cashmere, a product derived from the lightweight under hair of domestic goats and originating primarily in central Asia, is fashioned into garments for warmth and for western styles. Mongolia and China export 90% of the world's supply (Ahmed 2004; Lecraw 2005; Kerven et al. 2005, 2009). More than 100 years ago, British officer Cecil Rawlings noted Tibetan herdsmen trading goat wool (*pashm*), increasing pressures of supply and demand, and that "the animals [spend] the winter in the highest altitudes, in order that the wool may be as thick and profuse as possible" (Rawlins 1905).

We offer a contemporary perspective on this historic insight. Specifically, we describe a conservation challenge initiated by a geographically complicated mix involving Eastern and Western fashion cultures and how the resultant trade in cashmere affects ecological processes and dampens the probability of persistence of iconic wildlife in Central Asia. Although poaching was once an important local driver of change (Schaller 1998), our focus highlights the inadequacy of ecological science alone to resolve complex human issues and the need for creative social and economic solutions to assure the conservation of many of Central Asia's threatened, endangered, and large mammals—chiru (*Panthera hodgsoni*), Bactrian camel (*Camelus bactrianus*), snow leopard (*Panthera uncia*), khulan (*Equus hemionus*), kiang (*E. kiang*), saiga (*Saiga tartarica*), takhi (*E. przewalski*), wild yak (*Bos mutus)*, blue sheep (*Pseudois nayaur*), ibex (*Capra siberia*), and gazelles (*Procapra* spp).

As a working hypothesis, we suggest that global trade in cashmere has strong, negative effects on native ungulates that co-occupy deserts and grassland with cashmere-producing goats (Fig. 1). If correct, several specific preconditions in a 4-way chain must hold: (1) landscapes must be modulated by increasingly high numbers of livestock (primarily goats); (2) native species are negatively affected; (3) seminomadic pastoralists prefer economically valued fibers; and (4) a penchant for cashmere is driven by demand in the West (in this case primarily through clothing such as scarves and sweaters).

Although data are unavailable experimentally from a single place or across reasonable time series with which to assess this general hypothesis, we bring forth evidence from a variety of locations and time frames to examine the strengths and limits of available evidence. In doing so, we highlight conservation challenges steeped in global trade in which low-density herder populations attempt to improve their livelihoods through direct and indirect actions that involve both native and domestic species.

Understanding relations among markets, ecology, and wide-ranging pastoralists is highly relevant for conservation. Central Asia harbors much of the world's remaining grasslands and semideserts (Harris 2007, 2010), and this region maintains functioning biological systems that include some of Asia's most spectacular terrestrial migrations (e.g., Berger 2004; Berger et al. 2008; Olson et al. 2010; Schaller 2012). The consequences of failing to understand such interrelated pathways from local ecologies to global markets limits the creation of policies designed to protect an array of the world's iconic mammals.

Backdrop, Rationale, and Approach

If the above hypothesized relations hold, the pathways depicted in Fig. 1 should be supported by a series of predictions, which, for simplicity, we divided into general tiers: tier 1, livestock relations; tier 2, ecological implications of increasing numbers of domestic animals; and tier 3, cashmere economies. For each tier, explicit predictions are as follows. For tier 1, we predicted a disproportionate increase of goats relative to other livestock. For tier 2, we predicted a skew in ungulate biomass that favors domestic over native species, strong overlap between the diet of domestic goats and native species, ecological displacement of native species by dogs and people associated with goat herds, livestock-fostered reductions in food abundance that suppress vital rates of native ungulates, and reductions in carnivores due to increasing conflicts with goat and sheep herds. For tier 3,

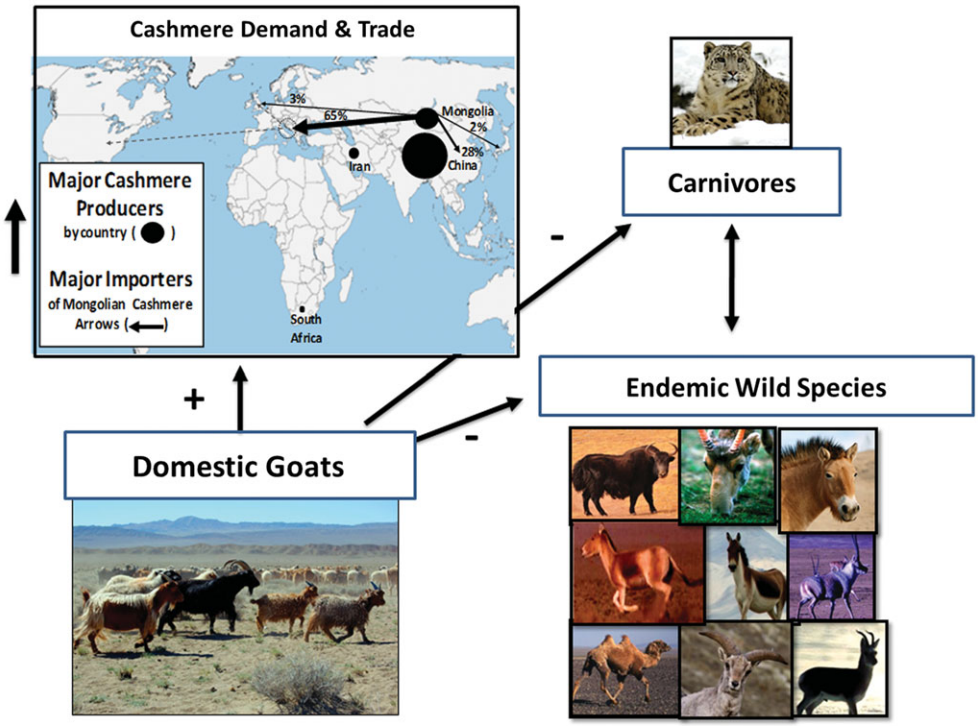

Figure 1. Map of key pathways of marketing of cashmere from Mongolia (circles, top 4 producers of raw and processed cashmere reflected by relative circle size of named countries [China and Mongolia produce 90% of world's supply]; arrows, top 4 importers [Italy, China, United Kingdom, Japan] reflected by relative arrow thickness; dashed lines, pathways to and from Italy [dotted circle]) (World Bank 2005; National Textile Association 2008; U.S. Department of Agriculture 2008). Flow diagram shows a simplification of core economic and ecological chain of cashmere pathways (+, increase in domestic goats; –, decrease in native species; arrows, direction of potential population effects to native species [e.g., increase in cashmere demand results in more goats and killing of snow leopards]). Threatened or endangered species pictured (top to bottom, left to right) wild yak, saiga tahki, khulan, kiang, chiru, and Bactrian camel. Species pictured that are not threatened (last 2 pictures) blue sheep and Tibetan gazelle.

we predicted pastoralists will raise goats because cashmere produces fiscal rewards and that cashmere exports are primarily to the West.

We examined these predictions by gathering empirical data based on field work in Mongolia, India, and China; results from peer-reviewed studies, and data from databases, gray literature, and government reports from Mongolia and India. Understandably, data availability differs by species and geography and by quality and time series length. Consequently, different analytical approaches were used. We resorted to compilations of abundance and biomass estimates of native ungulates as ecological snapshots in time because all study areas are sufficiently remote and long-term credible monitoring has not occurred. For Mongolian saiga, we used Distance sampling during fieldwork in 2006 and 2007 in the Shargyn Gobi Nature Reserve region in the Gobi Desert (Young et al. 2010). Furthermore, we explored trends in livestock abundance (goat, sheep, horse, camel, cattle, and yak from 1975 to 2006) for this region with herder registration and government records. We concentrated on the Darvi Soum District (Gobi-Altay Aimag; Mongolian Bureau of Statistics). For India the goat number time series are from Ladakh, the country's primary cashmere producing area (Bhatnagar et al. 2006*a*; Namgail et al. 2010). The numerical response of blue sheep following experimental curtailment of livestock grazing in this region is from Spiti Valley (Suryawanshi et al. 2009). Such approaches that combine existing data series with empiricism enabled ecological tests of tier 1 and tier 2 predictions (Fig. 1).

Our analyses included additional factors so that both indirect and more direct tests and field measures would enable the potential for broader inference. For instance, because of species' differences in jaw structure due to size or gender (Gordon & Illius 1988; Spaeth et al. 2001), we expected less dietary overlap between species of dissimilar size, such as domestic camels and saiga, than between comparably sized domestic goats and saiga. We examined this proposition by contrasting dimensions of the arcades of incisors on the basis of dental measures from Gordon and Illius (1988) and I. Gordon (unpublished data). We also evaluated the similarity of dietary

plant species to approximate food overlap between saiga and sympatric domesticates—camels, horses, sheep, and goats—in our Gobi Desert study area (Buuveibaatar et al. 2011).

With respect to the prediction that there will be a disproportionate increase in livestock, if greater abundance results from an enhanced food ceiling (i.e., carrying capacity), then any expected negative effect on native species may be illusory under the assumption of limited food. We used rainfall as a surrogate measure of primary plant productivity to check this possibility because peak aboveground plant biomass is strongly associated with annual precipitation in the northern Gobi Desert (Yu et al. 2004). Precipitation data are from the Khovd Aimag, where Mongolian Bureau of Statistics records are more complete than those for the Darvi region, although patterns between the 2 sites are correlated ($r = 0.38$, $p < 0.05$). We assessed relations between livestock numbers and precipitation and included as covariates total livestock biomass (all species) and goats only. Precipitation in a given year (t_0) and that in each of the 2 prior years (t_{-1}, t_{-2}) were used as explanatory variables in both linear and nonlinear regression models. The models that explained the greatest amount of variance are reported here.

Ungulate biomass was approximated using mean species mass from original publications (Supporting Information). The estimates are conservative because we made no adjustments for sex ratios, which usually were unreported, and yet in dimorphic species deviate from 50:50 to favor females and because herders generally have more female than male goats. For wild ungulates, we used biomass values of 26 kg for saiga (Berger et al. 2010), 90 kg for argali (*Ovis ammon*), 14 kg for Tibetan gazelle, 25 kg for Przewalski gazelle, 290 kg for khulan, 32 kg for chiru, 55 kg for blue sheep, 275 kg for kiang, and 413 kg for wild yaks. Values for livestock were 35 kg for goats and sheep, 191 kg for cattle, 248 kg for horses, 83 kg for donkeys, and 368 kg for domestic yaks. Density estimates from India (Spiti and Ladakh [Mishra et al. 2001, 2004; Bhatnagar et al. 2006*a*, 2006*b*]), China (Nyima & Shuangh Counties [Schaller 1998]), and Mongolia, except for Great Gobi National Park and the aimags of Omnogobi, Dundgobi, and Dornogobi (Kaczensky et al. 2008), are for the Darvi region (all years are from National Statistics Office of Mongolia except the last 2 years in Fig. 2b are from the Darvi Livestock Inspector [J.B., unpublished data]).

With respect to grazing pressure by domestic animals, if high levels of livestock significantly reduce available plant matter, we predicted fitness correlates among native species would decrease. We examined this possibility for blue sheep by comparing adult reproductive performances over 7 years at the Kibber Wildlife Sanctuary (Spiti Valley, Ladakh, India) after livestock grazing had been curtailed with reproductive performances at an adjacent site with livestock (Suryawanshi et al. 2009).

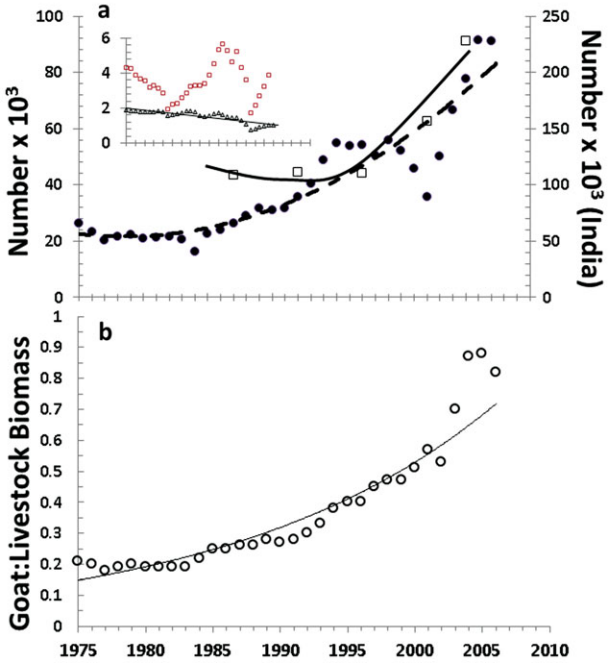

Figure 2. (a) Changes in domestic goat (solid black circles and thick dotted line), camel, and horse numbers over time in and adjacent to Shargyn Gobi Nature Reserve in the Darvi District, Gobi Altay, Aimag, Mongolia, and small-bodied livestock (primarily goats in Ladakh) in India (open squares and thin continuous line) ($y = 721.72x^2$ - 3E+06x + 3E+09; $r^2 = 0.95$ and $y = 4.5664x^2$ - 18,020 + 2E+07; $r^2 = 0.81$, respectively). Inset in (a) changes in biomass (kg $\times 10^3$) of camels (triangles) ($y = -30.058x + 61,368$; $r^2 = 0.74$; $p < 0.001$) and horses (squares) ($y = 11.546x$ - 19,435; $r = 0.01$). (b) Ratio of Mongolian goat:nongoat livestock biomass in and adjacent to Shargyn Gobi Nature Reserve in the Darvi District, Gobi Altay, Aimag, Mongolia (nongoat livestock, domestic yaks, cattle, sheep, goats, horses, and camels; dashed line, $y = 5E\text{-}45e^{0.0507x}$; $r^2 = 0.92$; $p < 0.0001$).

To assess whether herder profits increased disproportionately over time, we used the regression approaches already described. Specifically, we lagged goat abundance in the prior year(s) (e.g., t_{-1}, t_{-2}) to check for an association between goat abundance and annual payments for cashmere that Mongolian herders received. Changes in relative herder profits were evaluated using the consumer price index (CPI) as established for Mongolia (Human Development Report of the UNDP 2008). CPI is the change to an average consumer of acquiring services and goods. Year 2000 was set at zero, and change in CPI for herder payments per kilogram raw cashmere and in cost of living was explored by regression across time. These cashmere metrics stem from the Lecraw (2005), U.S. Agency for

International Development (2005), World Bank (2005), and G. Wingard (unpublished data).

Relations between Livestock and Saiga in Mongolia

The abundance of goats in and adjacent to Shargyn Gobi Nature Reserve increased over time (Fig. 2). During the period of relative equilibrium, before the change from Soviet-influenced Mongolian socialist governance to democratic reform, there was relatively little variance in livestock biomass (CV = 12.7%, 1975–1992) relative to that thereafter, when it increased 5-fold (CV = 73.3%, 1993–2007) (Fig. 2). Although extreme winter storms (Tachiiri et al. 2008) increased variability, goat abundance increased consistently more and varied less (CV = 32.0%, 1993–2007) than did other livestock during the shift to a free-market economy (Fig. 2). Whereas camel biomass declined over time ($y = -30.058x + 61368$; $r^2 = 0.74$; $p < 0.001$) (Fig. 2a), there was no relation between time and population change for horses ($y = 11.546x - 19435$; $r^2 = 0.01$). Over 30 years goats steadily increased (Fig. 2), and the relative change of goat to nongoat biomass increased exponentially ($y = 5E\text{-}45e^{0.0507x}$; $r^2 = 0.92$; $p < 0.0001$) (Fig. 2b). Overall there was an approximately 4-fold change from 21% of the livestock biomass being goats in 1975 to 82–88% in 2004–2006. The increase in goat abundance accompanied a weak but significant incremental decline in all nongoat livestock ($y = -1.411e\text{-}07x + 0.8989$, $r^2 = 0.17$; $p < 0.02$).

For 1975–2006, there was no relation between annual precipitation and time (quadratic, $r^2 = .06$; $F = 0.904$, $p = 0.42$), and there was no strong association between goat abundance and annual precipitation when lagged by 1 (quadratic; $r^2 = 0.01$; $F = 0.203$; $p = 0.82$) or 2 years (linear; $r^2 = 0.07$, $F = 1.964$; $p = 0.17$). With goat numbers log transformed for variance reduction, any relation between time and precipitation in the prior 1 or 2 years also held little predictive value ($t\text{-}1$, $r^2 = 0.07$; $F = 0.994$; $p = 0.38$; for t_{-2}: $r^2 = 0.11$; $F = 1.649$; $p = 0.21$). In other words, goat abundance was not associated with increased food production as inferred by precipitation as a proxy for plant productivity.

Among livestock most similar in body size to saiga were sheep and goats. Overlap in incisor arcade breadth and curvature (respectively) with saiga was greatest for goats (92.1, 99.8%). The largest disparities in dental measures were for cattle (228.7, 179.4%). Those for domestic sheep were slightly less than for goats (87.4, 88.3%). Given the similarity between saiga and goat incisor arcade, it was not surprising that our empirical analyses concomitantly revealed high diet similarity between the species (onions [*Allium polyrrhizum, A. mongolicum*], anabasis [*Anabasis brevifolia*], needlegrasses [*Stipa* spp.], and dwarf shrubs [*Artemisia* spp.]) (approximately 95%; Pianka's overlap index) but relatively low overlap in diet between saiga and either horses or camels (Buuveibaatar et al. 2011).

Asymmetries in Ungulate Biomass and Possible Effects on Wildlife in the Tibetan Plateau

The disproportionate increase in goats across time in Mongolia has been paralleled in India's primary cashmere-producing region of Ladakh (Fig. 2a). Native ungulates across 7 regions of northern India, Tibet (China), and the Gobi Desert (Mongolia) comprised approximately 2–7% of the total biomass of native ungulates relative to domestic species (Fig. 3). Across our study regions, including areas designated for wildlife protection, the relative proportions of khulan, kiang, Tibetan gazelle, Przewalski gazelle, Argali, blue sheep, wild yak, chiru, and saiga were low compared with livestock (Fig. 3).

Evidence for effects of domestic species on native wildlife is direct, indirect, and diverse and includes effects on saiga, Argali, ibex, chiru, and blue sheep (Table 1). For instance, where goats were restricted and livestock densities reduced, blue sheep increased in abundance and females recruited a higher proportion of young (Fig. 4). Different effects on other native species involved displacement to marginal habitats, avoidance of livestock, pursuit and predation by free-ranging or feral dogs (9 saiga and over 20 chiru), and human retaliatory killing of snow leopards (Table 1).

Cashmere Economies

That Mongolian pastoralists may be monetarily encouraged to increase goat herd sizes is nominally suggested by a weak association between goat abundance and cashmere pricing in the same year ($r^2 = 0.13$, $F = 1.923$; $p = 0.19$). However, mean cashmere price for herders in the prior year or prior 2 years and goat abundance was highly associated ($r^2 = 0.42$, $F = 10.993$, $p < 0.01$; $r^2 = 0.48$, $F = 13.619$, $p < 0.002$, respectively). Relative to the cost of living, herder profits for cashmere reflected a 3-fold increase (Fig. 5).

Preconditions and Inference in Ecological Systems and Human Economies

We offer a case-specific example of how global trade likely affects local ecologies and species (Fig. 1). While we cannot directly test our working hypothesis through rigorous manipulative experiments, it is possible to derive strong inferences. First, our study ecosystems were increasingly dominated by high numbers of livestock (Figs. 2 & 3) (see also Fernandez-Gimenez 1999;

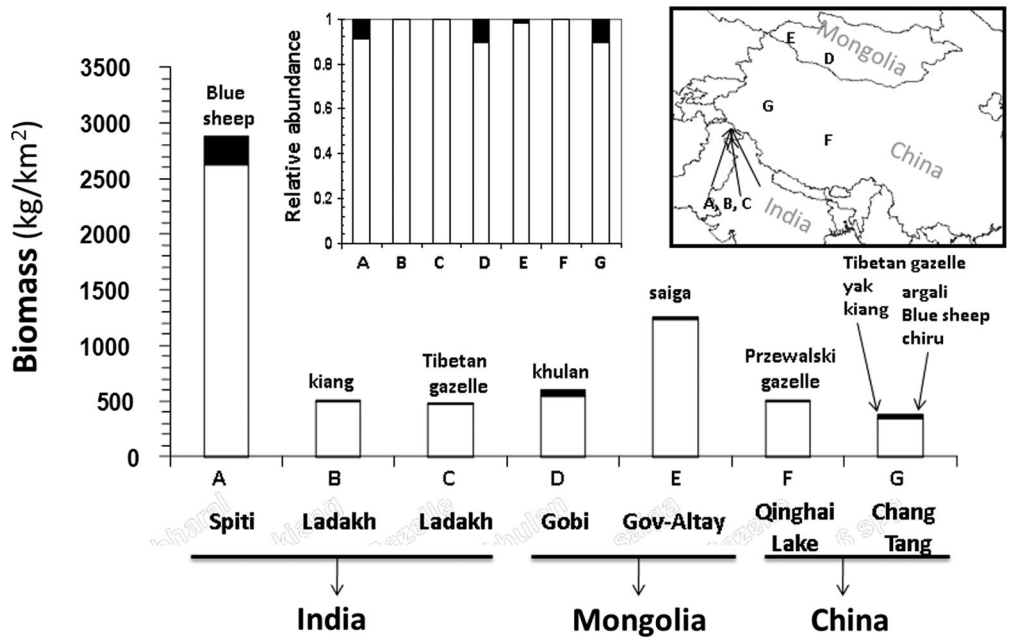

Figure 3. Contributions of domestic livestock (white bars) and native ungulate (black bars) to site-specific total large herbivore biomass across 7 study regions. Inset: relative numerical abundance by area (letters). For Chang Tang, 6 species are represented in black bars. Data sources listed in Supporting Information.

Mishra et al. 2001; Harris 2010). Second, that native species experience an intensification of ecological pressure from domestic livestock (Table 1) is suggested by their responses. These responses include reproductive debits in blue sheep (Fig. 4), range reductions and local extirpation of wild ungulates (Mishra et al. 2002; Bhatnagar et al. 2006*a*, 2006*b*), dietary similarities (saiga with goats [Buuveibaatar et al. 2011] and Argali with livestock 95% winter overlap [Wingard et al. 2011]), and other responses as noted elsewhere in Central Asia (Mishra et al. 2001, 2004; Campos-Arceiz et al. 2004). In addition, displacements of native species by livestock and the dogs of herders marginalize use of optimal habitats while the killing of snow leopards is arguably a direct or indirect effect of growing livestock numbers. The body of evidence (Table 1) therefore supports the tenet of an existing disharmony between native and domestic large mammals, with valued fiber-producing goats being favored over wildlife.

The extent to which local herders in Mongolia have benefited from market economies is inferred by their profit margins for cashmere, which have outpaced the cost of living (Fig. 5). Inevitably, there must be anticipation for financial benefits in a given period followed subsequently by a desire to increase flock sizes. Despite the complexity of trade networks at differing scales, which are complicated by export taxes, import quotas, and temporary bans (Fischer 2010), it is clear that monetary incentives for the production of cashmere exist not only in Mongolia but throughout much of Central Asia (Namgail et al. 2010). Finally, international demand for cashmere appears high. Mongolia and China are responsible for 90% of the world's production of raw and processed cashmere (Fig. 1), and the 4 leading importers of Mongolian cashmere are Italy, China, United Kingdom, and Japan (Fig. 1).

Trade, Grazing, and Herders across Space and Time

Through millennia and across biomes as different as tundra, mountains, and desert, humans have attempted to improve their lives through the use of meat and fiber. Such efforts by indigenous people include husbandry of native but now domesticated species such as reindeer (*Rangifer tarandus*), Bactrian camels, and yak. At more global scales, however, human livelihoods have been improved by use of domestic herbivores. In our study systems, domestic camels and yaks are being replaced as transport by motorcycles or trucks, a process that subsequently fuels cash needs for petrol and other synthetic goods. The present multibillion dollar garment industry with well-known fashion clothiers using products fashioned from domestic goats is an additional way by which local pastoralists garner monies.

High stocking rates have well-known ecological costs, which include grassland degradation (Fleischner 1994), diminished hydrological function and air quality (Batjargal et al. 2006), and displacement or loss of native species (du Toit et al. 2010). Although livestock grazing is the most prominent form of land use in Central Asia (Harris 2010), where domestic goats play increasing roles

Table 1. Summary of support for and weaknesses in hypothesized links between consumerism of cashmere and its effects on native mammalian species in Central Asia.

Construct	*Support*	*Type of approach*	*Evidence*	*Weakness*	*Competing explanation*	*Comment*	*Source**
Ecosystem increasingly dominated by goats							
numerical	yes	absolute counts over time	empirical (registration of livestock)	possible inaccuracies in recording	none	noted widely across Mongolia, NW India, and China	2, 3, RH
proportional	yes	relative contrasts over time	empirical (registration of livestock)	possible inaccuracies in recording	none	noted widely across Mongolia, NW India, and China	2, 3, RH
Intensification of ecological pressures on native species							
skew in biomass	yes	census across multiple sites and countries	empirical (up to 50:1 livestock skew)	sympatry does not equal negative effects	none	widespread support but site and season dependent	2, 3, RH
diet overlap	yes	food habits	inference (overlap in body and tooth arcade), diet	inferential (overlap is not competition)	none		1
habitat displacement by:							
dogs or herders	yes (saiga, chiru, argali)	observations	interviews and observations	frequency and effects unclear; movement is not a measure of fitness	none	other than predation, effects difficult to document; expectation of fitness measures is unrealistic	2
sheep and goats	yes (ibex, argali)	BACI design	displacement to marginal habitats	frequency and effects unclear; movement is not a measure of fitness	none	expectation of fitness measures is unrealistic	this study, RH, 3
food ceiling does not increase over time	yes (saiga)	temporal trend analyses	lack of increased plant productivity	time series is 30 years	food ceiling is of no consequence	density-mediated food effects noted for wild and domestic species	this study, RH
food suppression of vital rates	yes (blue sheep)	reproduction (exclusion of goats and other livestock)	differences in juvenile survival	possible movement across exclusion zones	other factors affect vital rates	nutrition most likely explanation	4
food suppression of vital rates	yes (domestic goats and sheep)	fecundity contrasts across time in relation to stocking rates	inverse correlation between fecundity and livestock density while accounting for plant biomass	not all factors can always be measured	other factors constrain fecundity	where food limits livestock productivity, exacerbation of effects may be stronger in native species	4
killing snow leopards	yes	reports to researchers or government and our interviews	qualitative	demographic effects unclear	none	expanding livestock into snow leopard range increases conflict	5
Herder economics							
herders incentivized by cashmere profits	yes	temporal trend analyses	payments per kg measured against CPI	much complexity in CPI assessment	goat increase not driven by financial rewards	increasing production of cashmere also feeds back on the demand of the fashion industry	this study, RH
Consumer demand							
international demand remains high	yes	comparative (of key consumers)	major exports to westernized countries	inconsistent records that vary by quality, country, and periods of tracking	increased supply may facilitate more demand	import data not regularly available, and likely confounded by variation in export taxes, import quotas, and temporary bans	this study, RH

**Sources: 1- Buuveibaatar et al. (2011), Fernandez-Gimenez (1999), Harris (2010), Mishra et al. (2004), Wingard et al. (2011); 2- Buuveibaatar et al. (2009), Namgail et al. (2007), Young et al. (2011); 3- Bagchi et al. (2004), Namgail et al. (2004); 4- Mishra et al. (2001, 2004), Suryawanshi et al. (2009); 5- Bagchi and Mishra (2006), Mishra et al. (2003, 2010).*
Abbreviation: RH, references herein (e.g., cited in this paper).

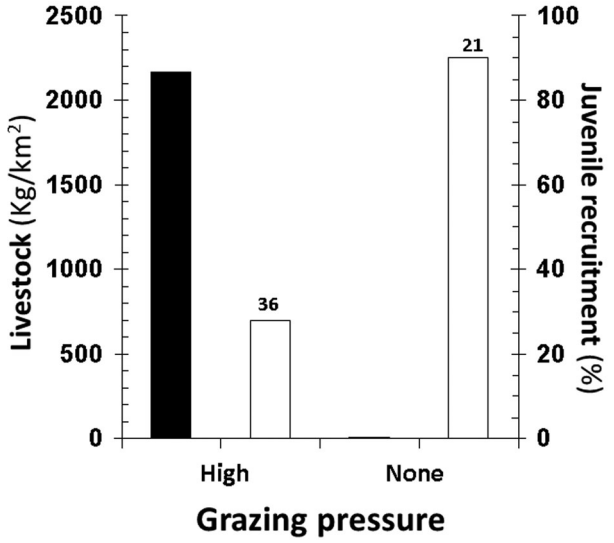

Figure 4. Contrasts among mean livestock densities and proportion of juvenile blue sheep per adult female in the Kibber Wildlife Sanctuary, India (modified from Suryawanshi [2008] and Suryawanshi et al. [2009]) (black bars, livestock; white bars, juvenile recruitment among blue sheep females).

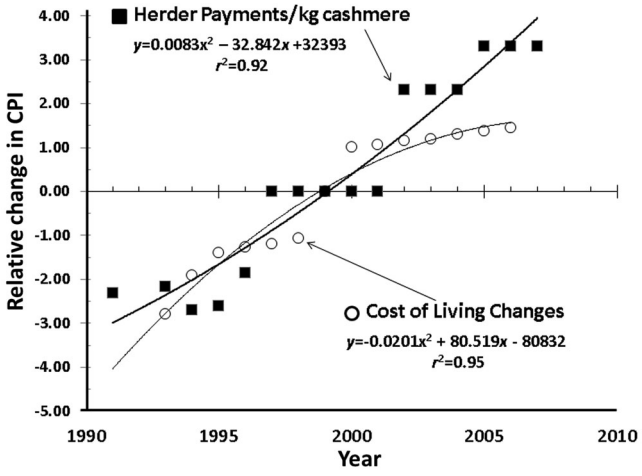

Figure 5. Changes in Mongolian consumer price index (CPI) reflected in cost-of-living change set at zero for year 2000—and relative change in herder payments for raw cashmere.

(Boyazoglu et al. 2005; Kerven et al. 2009), costs to landscape productivity are now recognized in China (Zhou et al. 2005), India (Mishra et al. 2004; Bhatnagar et al. 2006*a*), and Mongolia (Reading et al. 2006; Amgalan et al. 2009).

The challenges of reversing the direct or indirect effects of western desire for cashmere at each node in our depicted web (Fig. 1) are formidable. In Ladakh, for instance, cashmere production has been promoted by the government over the last 25 years (Jina 1995; Bhatnagar et al. 2006*a*). Their actions included establishment of goat-breeding farms and efforts to improve yield (Joshi & Morup 2003; Mital 2004). Government veterinary services have also been provided in an attempt to reduce kid mortality (Jina 1995). Nevertheless, the lack of success in increasing the production of cashmere per goat suggests that the growth in cashmere industry in Ladakh is largely achieved through an increase in the goat population.

Although goat abundance may be driven by external factors, including rainfall and human interest as in Australia (e.g., Forsyth et al. 2009), across Central Asia striking differences in abundance of goats remain between domestic and native herbivores as they do in arid environments such as Patagonia (South America) (Baldi et al. 2010) and the Great Basin (North America) (Berger 1986). Even in sparsely settled grasslands, where human and livestock densities may simultaneously be low, such as in Eastern Mongolia, the presence of herder households or dogs reduces gazelle density by 76–98% (Olson et al. 2011; Young et al. 2011). Where conservation targets are ecologically functioning alpine, steppe, and desert systems populated by robust numbers of globally rare species, cashmere production pits short-term economic opportunities against systems that have operated for millennia and affects species other than ungulates.

Snow leopards are a case in point. With large asymmetries between domestic and native ungulate (Fig. 3), carnivore-livestock interactions increase (Harris 2007; Anwar et al. 2011; Schaller 2012) along with antipathy for carnivores (Mishra et al. 2003, 2010).

A Conservation Dilemma

Options to sustain or enhance pastoralist livelihoods while protecting large areas for rare species in Central Asia appear somewhat limited. Reducing the abundance of goats and increasing number of domestic camels or yaks—with their larger mouth parts and feeding specializations—would decrease food overlap with smaller native ungulates such as gazelles, saiga, and chiru. Nevertheless, fiber products from camels and yaks are less appealing to western audiences than cashmere. Precedents for change do exist, however; what is fashionable can rapidly become unfashionable. Ostrich feathers quickly fell out of fashion in the British Empire 100 years ago. In the 1990s information campaigns in India and elsewhere halted the illicit slaughter of chiru for their fine wool (Schaller 1998, 2012; Ellis 2005). Recent efforts to control illegal harvest and poaching of saiga (Milner-Gulland et al. 2001; Kuhl et al. 2009) have refocused attention on grassland productivity (Harris 2010).

If western consumers remain ignorant to the origin of clothing products and the consequent effects borne by

the native species of Central Asia, then future prospects for chiru, saiga, khulan, kiang, wild camels, and wild yaks, and even snow leopards, will become slimmer. To reverse this trend will require creative and novel alliances.

Green labeling coupled with reduced livestock densities could represent reasonable starting points, with some operators offering sustainable products (e.g., Ecologia 2011). But well-intentioned efforts may suffer because of unverified claims, compliance, and enforcement (Howett 1991; Alves & Edwards 2008). Presently, what is most urgent are efforts to unite effectively with the garment industry under a conservation umbrella. Such actions will enable a dialog about ecological footprints, species conservation, and consumerism. To do so will require a critical amalgamation involving planners, local nomads and herders, government officials, fabric industry representatives, anthropologists, economists, and ecologists, as has often been done to facilitate first steps for complicated conservation planning. Preliminary efforts have begun for saiga and local livestock (WCS 2008; Young et al. 2009), but both high level and local involvement will be required to make a difference.

In the absence of commitment across global and local scales, the iconic wildlife of the world's highest mountains and great steppes will cease to persist as they have for millennia. Rather than serving as symbols of success, these species will become victims of fashion.

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Supporting Information

Density estimates, caveats, and citations to additional appropriate literature are available online (Appendix S1). The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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