Ecol Res (2007) 22: 25–31
DOI 10.1007/s11284-006-0015-y

ORIGINAL ARTICLE

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Habitat shift and time budget of the Tibetan argali: the influence of livestock grazing

Received: 24 October 2005 / Accepted: 6 March 2006 / Published online: 27 July 2006

Abstract Livestock production is the primary source of livelihood and income in most of the high steppe and alpine regions of the Indian Trans-Himalaya. In some areas, especially those established or proposed for biodiversity conservation, recent increases in populations of domestic livestock, primarily sheep and goats, have raised concern about domestic animals competitively excluding wild herbivores from the rangelands. We evaluated the influence of domestic sheep and goat grazing on the habitat use and time budget of the endangered Tibetan argali *Ovis ammon hodgsoni* in the proposed Gya-Miru Wildlife Sanctuary, Ladakh, India. We asked if the domestic sheep and goat grazing and collateral human activities relegate the argali to suboptimal habitats, and alter their foraging time budgets. Data were collected on habitat use and time budget of a population of c. 50 argalis before and after c. 2,000 sheep and goats moved onto their winter pasture in the Tsabra catchment of the aforementioned reserve. Following the introduction of domestic sheep and goats, argalis continued to use the same catchment but shifted to steeper habitats, closer to cliffs, with lower vegetation cover, thus abandoning previously used plant communities with denser cover. Argalis' active time spent foraging also decreased by 10% in response to the presence of livestock. These results suggest a clear disturbance effect of livestock on argalis, and indicate a potential for competition, conceivably a significant disadvantage for argalis in winter when forage availability is minimal.

Keywords Tibetan argali · Livestock · Habitat shift · Time budget · Trans-Himalaya

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Introduction

Pastoralism is the primary source of livelihood in many arid and semi-arid regions of the world, especially in central Asia and sub-Saharan Africa (Brown 1971; Goldstein et al. 1990; Homewood and Rodgers 1991; Prins 1992). In most of these regions, domestic livestock share pastures with the native wildlife (Prins 1992; Schaller 1998), and a conflict of interest between pastoralists and wildlife managers is common. Livestock production is the mainstay of the economy in many parts of the Tibetan plateau region, and in some areas pastoralists tend to increase their livestock populations beyond the carrying capacity of the rangelands (Mishra et al. 2001).

In many areas of the Tibetan plateau region, hunting has been recognised as a primary factor affecting wild ungulate populations (Fox et al. 1991b; Schaller 1998), but the conservation challenge of competition with domestic livestock has received little attention until recently (Bagchi et al. 2004; Mishra et al. 2004; Fox and Tsering 2005). Although these studies and reviews deal primarily with resource competition between wild and domestic ungulates, other than anecdotally there is no information on the issue of interference competition. Owing to the importance of livestock production in the local economy, pastoralists herd their livestock cautiously, often using guard dogs which harass adults and occasionally prey on juvenile wild ungulates (Namgail et al. 2004b). Thus, livestock grazing and collateral human activities can interfere in resource acquisition by wild ungulates. Although the herding decisions made by humans provide an artificial component to the interaction, the results for the wild ungulates may be essentially the same as a typical interference competitive interaction.

The effect of interspecific competition, either exploitative or interference, on animal distribution is a central theme in ecology (Connell 1961; Case and Bolger 1991). When sympatric species are asymmetric in their competitive abilities, the dominant species usually secures the highest quality habitats (Connell 1961; Case and Gilpin 1974). Therefore, the dominant species reduces the fitness of the subordinate species more than the reciprocal effect (Lawton and Hassell 1981; Schoener 1983; Morin and Johnson 1988). Such competitive asymmetry has been demonstrated between domestic and wild ungulates in grazing systems of Africa and North America, where livestock cause shifts in habitat by the wild species (Stevens 1966; Loft et al. 1991; Fritz et al. 1996). Such shifts result in reduced foraging opportunities for some mammalian species (Lima and Dill 1990), and can demonstrate interspecific competition (Diamond 1978).

We evaluated the impact of the presence of domestic sheep and goats (hereafter referred to as 'livestock') on the habitat use and time budget of the Tibetan argali *Ovis ammon hodgsoni* (hereafter 'argali'), which is highly endangered in India (Fox and Johnsingh 1997) as well as globally (Schaller 1998). Livestock and argalis are similar in their dietary requirements (Harris and Bedunah 2001) and the latter's preference for open areas (Namgail et al. 2004a) makes them especially vulnerable to disturbance by livestock herding, for the herders have a bias towards herding on more open terrain (Namgail et al. 2004b). Hence, there is likely to be a substantial overlap in their ranges, especially in winter when argalis descend to areas commonly used by livestock (Mallon 1991; Fox et al. 1991a). Since the livestock are accompanied by herders as well as herding dogs, the overall effect may be to relegate argalis to marginal areas. If forage quality is also lower in these areas, and handling and digestion require more time, then argalis may also have a decreased foraging time budget and greater movement in the presence of livestock. We thus asked the following questions: (1) do livestock grazing and collateral activities relegate argalis to sub-optimal habitats, and (2) do these activities also force argalis to spend less time foraging and more time moving (and resting, including handling/digesting) in the marginal habitats?

Methods

Study area

The study was carried out in the c. 60 km^2 Tsabra catchment (33°N, 77°E; Fig. 1) of the Gya-Miru Wildlife Sanctuary (proposed), Ladakh, India. Due to the rain-shadow effect of the Greater Himalaya, this Trans-Himalayan region receives low precipitation, mostly in the form of snow. During the December–February study period, the 4,300–5,700-m elevation study area received several snowfalls of up to 10 cm on the lower slopes where the study animals were present, but this generally melted off within a week. The upper reaches of the catchment, however, had a snowpack of up to c. 60 cm, which remained until April. Temperatures during the study period ranged from −5°C to −25°C. Primary productivity in the reserve is low. The vegetation cover is generally less than 20%, and plant communities are dominated by *Caragana* spp., *Artemisia* spp. and *Eurotia* spp. (Namgail et al. 2004b).

The Tsabra catchment is earmarked by pastoralists for livestock grazing in mid-winter, and for the rest of the year there is no ungulate grazing, except by a population of c. 50 argalis and a few blue sheep *Pseudois nayaur* (Namgail et al. 2004b). In early January of each year, about 2,000 livestock are brought into the catchment for about 2 months, providing an opportunity for assessing the impact of livestock grazing on argalis' habitat use and foraging behaviour. The livestock were herded in eight smaller groups on discrete pastures demarcated by ridgelines and streams. There were three herder-camps in the Tsabra catchment, with at least two livestock herds per camp. These camps were located near

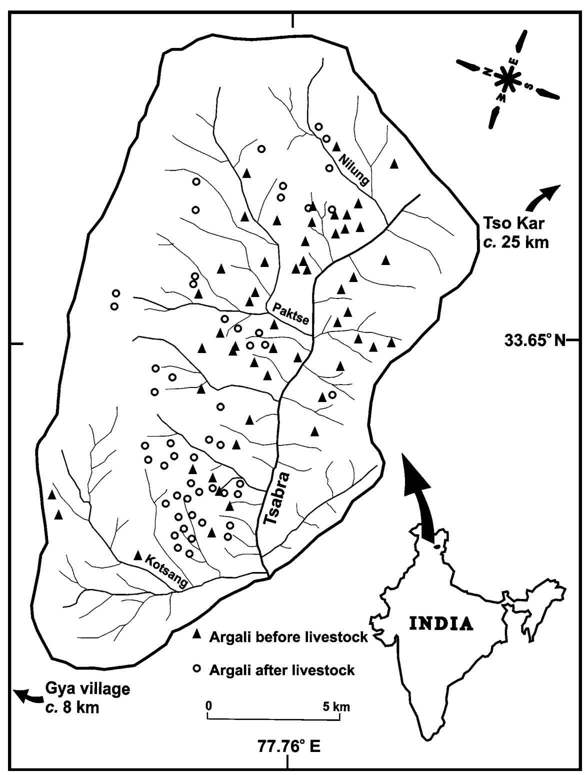

Fig. 1 Locations of Tibetan argali with and without livestock (sheep/goats) in the Tsabra catchment of the Gya-Miru Wildlife Sanctuary, Ladakh, India

the bank of Tsabra stream, and the distance between them ranged from 1–5 km. Every livestock herd had at least one herding dog that accompanied the livestock to the higher pastures. These dogs closely followed the livestock herds, but sometimes wandered off on their own.

Apart from the Tibetan argali, other ungulates in the study catchment include a few blue sheep *Pseudois nayaur*, and large predators include the snow leopard *Uncia uncia*, wolf *Canis lupus*, and lynx *Lynx isabellina*. We recorded 30 species of birds, including the Golden Eagle *Aquila chrysaetos* and Lammergeier *Gypaetus barbatus* (Namgail 2005).

Field methods

Habitat use

Data on argali habitat use were collected prior to (12 Dec 2002–10 Jan 2003) and following the livestock's arrival (13 Jan–10 Feb 2003). Argalis were observed by walking on four trails (lengths ranging from 2–4 km), and also by searching from two vantage points, which were selected without a priori knowledge of the ungulate occupancy, but with views of most areas in the catchment. Each trail and vantage point was visited at least three times a month.

When a group of argalis was first observed, its size, age/sex composition, the time, date and habitat variables at its location were recorded. Physical habitat variables—viz., slope angle and distance to cliff (both visually estimated)—were recorded, as these have been suggested as the most important variables that determine habitat use by argalis in Ladakh (Namgail et al. 2004a). In addition, we estimated percentage vegetation cover within a c. 30-m radius around each argali-group location. Data on the livestock habitat use were collected during the period 20 Jan–13 Feb 2003. The habitat variables at their locations were determined in the same way as described for argali.

Time budget

Data on argalis' foraging, surveillance, movement and 'other' (other social activities) were collected during the same periods prior to and following the livestock's arrival, as mentioned earlier. We used focal-animal sampling to observe the argalis' time budget (Altmann 1974). An active (non-lying) animal was selected randomly from a group and observed for 20 min at a stretch, using a stopwatch. Activities of the focal animal were observed through a spotting scope, and reported by the observer to an assistant, who recorded them.

An animal was deemed to be foraging when it fed on a plant species or moved with its head lowered, oriented towards food plants. When it stood still with its head above its shoulder observing its surroundings, it was considered to be surveying, and when it moved with its head upright above its shoulder, it was deemed to be moving. On average, we observed the focal animal from a distance of about 250 m, and care was taken not to disturb the animals prior to, or during the observation.

Observations of argalis were spread across the daylight hours to avoid over/underestimating behavioural activities associated with time of the day, as there are diurnal patterns in the time-budgets of ungulates (Schaller 1977; Rukstuhl 1998). Individuals were not marked and could not be consistently individually identified during the present investigation. To avoid pseudo-replication (Machlis et al. 1985), we observed different groups of argalis on different days, and to avoid re-sampling of the same individual, we systematically shifted our focus to different animals in a group. Males segregated from the female and nursery groups after 10 Feb 2003, and because foraging behaviour of ungulates varies between rutting and non-rutting periods (Pelabon and Komers 1997), we did not observe them after this segregation.

Analytical methods

Habitat use

To determine the variables that best distinguish between argali habitat use with and without livestock, we used an exploratory Generalised Linear Model (GLM) using argali before and after livestock as a binary response variable and distance to cliff, slope angle and vegetation cover as predictor variables. The Akaike's Information Criterion for small sample size (AIC_c; Burnham and Anderson 1998) was used to select the best model from a set of a priori candidate models. The model with the lowest AIC_c indicates the best fit to the observed data (Burnham and Anderson 1998).

Two sample t tests were performed to check for significant differences between the mean values of important habitat features for the following pairs: (a) argali with and without livestock, and (b) livestock and argali with livestock. Nonmetric Multidimensional Scaling (NMDS) was used to provide a graphic view of the differential use of habitat by the aforementioned pairings. Multidimensional scaling attempts to find the structure in a set of distance measures between objects or cases. This is accomplished by assigning observations to specific locations in a conceptual space such that the distances between points in the space match the given similarities as closely as possible (Norussis 1997).

Time budget

We calculated the percentage of time allocated by active argalis to different activities during the two periods:

prior to and following the livestock's arrival. Pairwise Wilcoxon Signed Rank Test was used to check for statistical differences in argali time allocation to various activities before and after the livestock's arrival. Although observations were made on all age and sex classes, only those on adult females were numerous enough and thus used in the analysis, which also eliminated problems of sex/age differences known to occur in time budget analysis (see Clutton-Brock et al. 1982; Rukstuhl 1998). All statistical procedures were performed with SPSS 8.0 for Windows and Statistica 6.0.

Results

There were about 50 argalis and about 2,000 livestock in the c. 60-km^2 Tsabra catchment. Forty-eight identified argalis consisted of 15 males (31%), 20 females (42%), 4 yearlings (8%) and 9 lambs (19%).

Habitat use

A total of 53 observations were made on argali habitat use prior to, and 51 observations following, the livestock's arrival. Besides these, 45 observations were obtained on livestock habitat use. The Akaike Information Criterion for small sample size (AIC_c) indicated that differential habitat use by argalis before and after livestock was best modelled by using vegetation cover and distance to cliff as predictor variables (Table 1). However, as the best models within an AIC_c difference (Δ) of 2 can all be considered useful in explaining variability in the data (Burnham and Anderson 1998), the first four models in Table 1 are all of interest. Vegetation cover is important in all of them.

Although argalis remained in the same catchment after the livestock were moved in (Fig. 1), there were significant before–after differences in the argalis' habitat use (data provided as Mean ± SE). For instance, argalis used habitat away from cliffs (243.6 ± 20 m) in the absence of livestock, but shifted to habitats close to cliffs (182 ± 15 m) in their presence ($t = 2.41$, $P < 0.05$; Fig. 2a). Similarly, argalis without livestock used moderate slopes (24.5 ± 1 degrees), but shifted to steeper slopes (28.0 ± 1) following the latter's arrival ($t = 2.15$, $P < 0.05$; Fig. 2b). Argalis also used areas with higher vegetation cover (23.8 ± 2%) in the absence of livestock, and shifted to areas with lower vegetation cover (13.7 ± 1%) in response to livestock's presence ($t = 3.09$, $P < 0.005$; Fig. 2c).

The result of the Nonmetric Multidimensional Scaling shows that livestock after their arrival in the Tsabra

Table 1 Results of the AIC_c-based model selection for the determination of argali habitat use before and after livestock, ranked from best to worst

Number	Model	K	AIC_c	Δ
1	VC + DTC	3	136.87	0.00
2	VC + DTC + SA	4	137.68	0.81
3	VC	2	138.15	1.28
4	VC + SA	3	138.69	1.82
5	DTC + SA	3	141.12	4.25
6	DTC	2	142.62	5.75
7	SA	2	143.76	6.89

K the number of parameters in the model, *AIC_c* Akaike Information Criterion for small sample size, Δ AIC_c differences, *DTC* distance to cliff, *SA* slope angle, *VC* vegetation cover

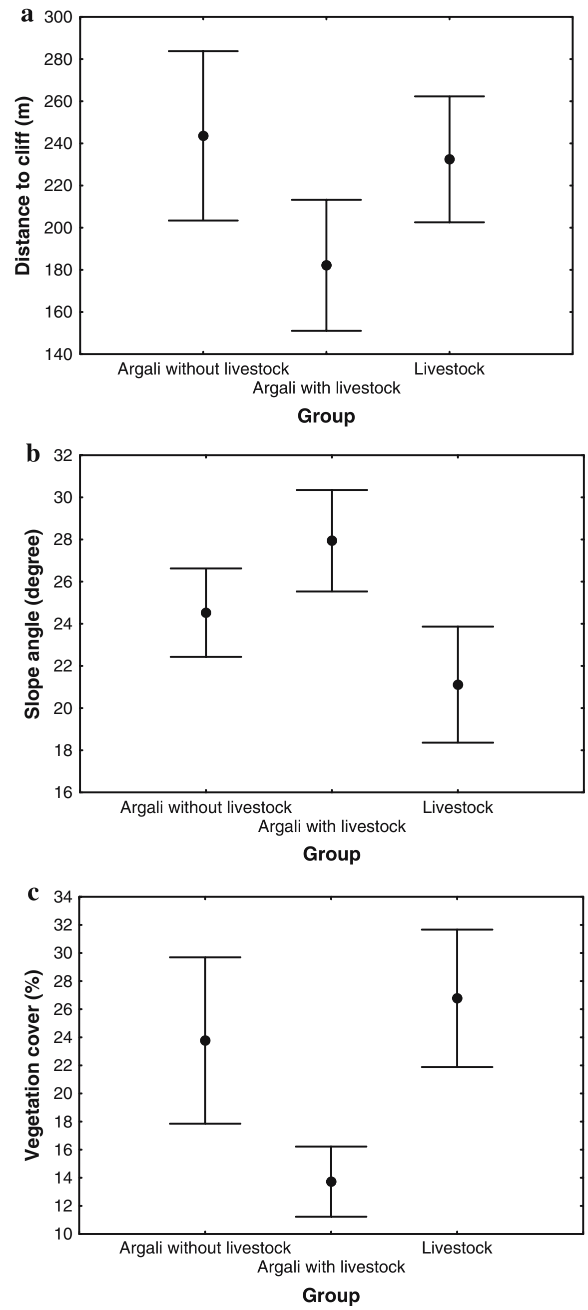

Fig. 2 Mean (±95% confidence intervals) of **a** distance to cliff, **b** slope angle, and **c** vegetation cover used by livestock (sheep/goats), 'argali without livestock' and 'argali with livestock'

catchment usurped open areas farther from cliffs with higher vegetation cover, which prior to their arrival were used by argalis (Fig. 3). This is substantiated by the fact that argalis, in the presence of livestock, occurred in areas significantly closer to cliffs ($t = 2.33$, $P < 0.05$; Fig. 2a) and on steeper slopes than the livestock themselves ($t = 3.77$, $P < 0.05$; Fig. 2b). Argalis also occurred in areas with significantly lower vegetation cover compared to the livestock ($t = 4.95$, $P < 0.001$; Fig. 2c).

Time budget

We observed 80 focal argali individuals (ewes) for time budget evaluation, 40 prior to (714 min) and 40 after (745 min) the livestock's arrival in the study area. Active argalis' time allocation to foraging in the absence of livestock differed significantly from that allocated in their presence ($z = 2.11$, $P < 0.05$), with a mean (± SE) percent time of 52% (± 3.0) spent foraging when the livestock were absent, and 43% (± 3.7) in this activity when they were present (Fig. 4). Although argalis' movement activity increased by almost 6% after the livestock were brought in, its low total amount and high variability contributed to a non-significant statistical result ($z = 1.15$, $P = 0.245$). The argalis' surveillance ($z = 0.63$, $P = 0.547$) and 'other' behavioural activities ($z = 0.26$, $P = 0.795$) did not differ before and after the livestock's arrival (Fig. 4).

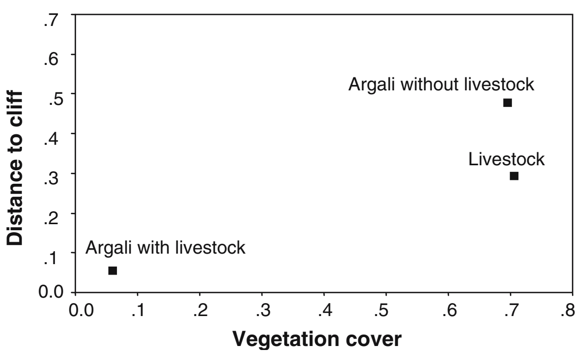

Fig. 3 Result of the Nonmetric Multidimensional Scaling, showing the relative positions of livestock (sheep/goats), and argali with and without livestock in a conceptual space related to habitat characteristics

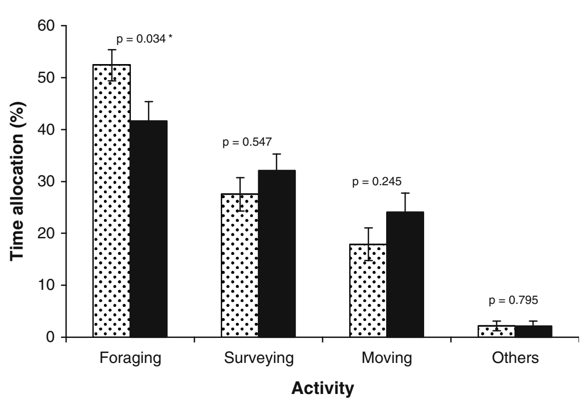

Fig. 4 Mean (± SE) percent time allocated by Tibetan argali to different behavioural activities without (*spotted bars*) and with livestock (*black bars*). The significance levels above the bars are based on Wilcoxon Signed Rank Test, and the *asterisk* indicates statistical significance

Discussion

Ladakh is the stronghold of the argali population in India (Fox and Johnsingh 1997). Within the region, it is confined to the eastern part (Fox et al. 1991b), which is an important area of cashmere wool production, and livestock populations here have apparently increased almost twofold over the last 2 decades (Bhatnagar et al. 2006). Such increases are attributed largely to the increase in livestock numbers of Tibetan refugees that originally came in the 1960s, as well as to recent government emphasis on increased cashmere wool production (Anonymous 2002). Despite this increasing livestock population, and the precarious status of argali in India as well as globally (Fox et al. 1991a; Schaller 1998), there has been no apparent effort to assess the impact of livestock grazing on argalis. Our results show that livestock relegate argalis to sub-optimal habitats, where they spend less time foraging.

Argalis continued to use the same catchment after the livestock arrived, but they changed their use of habitat. This is in concordance with results obtained by Cohen et al. (1989), where the white-tailed deer *Odocoileus virginianus* shifted its habitat use in response to the presence of cattle. During the present investigation, argalis shifted to areas with less vegetation cover after livestock entered their habitat. Similarly, argalis moved to steeper areas near the cliffs in response to the livestock's presence. On at least five occasions, foraging argalis were observed to slowly move away as livestock approached, leading either to complete abandonment of the feeding site or resumed foraging at a distance of > 500 m from the livestock. Such avoidance of livestock by argalis has also been observed in other parts of Ladakh (Namgail 2001) and on the Tibetan Plateau (Harris and Bedunah 2001), and could be attributed to direct interference by livestock grazing.

Since the livestock are tended prudently, usually using herding dogs (Namgail et al. 2004b), argalis' avoidance of livestock may be related not just to the presence of these domestic animals, but to the recognition of herders and their dogs as potential threats. In contrast, argalis have been observed foraging in close proximity to untended livestock such as yaks (Namgail 2001) and camels (Harris and Bedunah 2001). The high density of livestock may also influence its avoidance by argalis, as with similar relationships reported elsewhere (Ellisor 1969; Cohen et al. 1989), and can also interfere in the latter's resource acquisition. These results show a clear disturbance effect of livestock presence on argalis' habitat use in winter, and suggest a potential for competition between these domestic and wild ungulates. Other factors such as snowfall after livestock arrival or changes in vegetation nutrient quality also have the potential to influence the results. In the case of this study, however, the small amounts of snow, which rapidly disappeared, did not appear to influence the argalis' behaviour, and nutrient quality is not expected to change during this time period.

The change in the argali's time budget following the livestock's arrival could be attributed to changes in argali forage acquisition (quantity and quality) brought about by livestock grazing and collateral herding activities. In any case, the decrease in argalis' active time spent foraging in response to livestock presence may have important fitness consequences, for an animal's reproductive success may decline because of energetic constraints associated with decreased foraging opportunities in marginal sites, as quantity and quality of forage available to females determine their body condition and fecundity (Clutton-Brock et al. 1982). Such possible fitness consequences and their impact on argali population performance need to be investigated in detail due to the overall precarious status of argali.

Conclusion

Livestock grazing and collateral activities affect argalis' habitat use and foraging behaviour, and these are changes that may also affect argali population performance in the Gya-Miru area. Nevertheless, although past population estimates are known to be very crude, current evidence suggests no drastic reductions in the population of argali in the Tsabra catchment within the last 2 decades (Namgail et al. 2004b). Such population stability could possibly be ascribed to the relatively short duration (c. 2 months) of livestock grazing in this catchment. In any case, although the argali population appears to be persisting in this area of relatively low grazing intensity, any expansion of its population or habitat use is conceivably restricted by its displacement from productive pastures and a consequent reduced foraging opportunity during the critical winter season. Growth of the small argali population in the reserve would therefore appear to require some limitation of livestock grazing within the core areas of argali habitat.

Acknowledgments The study was funded by the University of Tromsø–Wildlife Institute of India (WII) Norwegian Aid for Development (NORAD)-supported Institutional Cooperation Program. The International Snow Leopard Trust (ISLT) and the Wildlife Protection Society of India (WPSI) are also acknowledged for additional support. We are thankful to Mr. Salim Ul-Haq and Mr. Jigmet Takpa, Department of Wildlife Protection, Leh for assisting us in the permission process for our work in the area. We thank Dr. Charudutt Mishra for his comments on the manuscript. We also thank reviewers Drs. Richard B. Harris, Marco Festa-Bianchet and Barry W. Brook for their comments on an earlier draft of the manuscript. The field assistance of Messrs. Thinles Dorjey, Tashi Gyatso, Tsewang Morup and Thinles Yangjor is gratefully acknowledged.

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