Status of the mountain ungulate prey of the Endangered snow leopard *Panthera uncia* in the Tost Local Protected Area, South Gobi, Mongolia

L K H A G V A S U M B E R E L T U M U R S U K H , K U L B H U S H A N S I N G H R . S U R Y A W A N S H I
C H A R U D U T T M I S H R A , T H O M A S M . M C C A R T H Y and B A Z A R T S E R E N B O L D G I V

Abstract The availability of wild prey is a critical predictor of carnivore density. However, few conservation programmes have focused on the estimation and monitoring of wild ungulate populations and their trends, especially in the remote mountains of Central Asia. We conducted double-observer surveys to estimate the populations of ibex *Capra sibirica* and argali *Ovis ammon* in the mountainous regions of Tost Local Protected Area, South Gobi province, Mongolia, which is being considered for designation as a Nature Reserve. We also conducted demographic surveys of the more abundant ibex to examine their sex-ratio and the survival of young during 2012–2013. The estimated ibex population remained stable in 2012 and 2013 and the estimated argali population increased from 108 in 2012 to 230 in 2013. The biomass of wild ungulates was c. 6% that of livestock. Mortality in young ibex appeared to increase after weaning, at the age of 12 months. We estimated the population of wild ungulates was sufficient to support 14–18 adult snow leopards *Panthera uncia*. The adult snow leopard population in our study area during 2012–2013, estimated independently using camera-trap-based mark–recapture methods, was 12–14. Based on our results we identify the Tost Local Protected Area as an important habitat for the conservation of these ungulates and their predator, the Endangered snow leopard, and recommend elevation of its status to a Nature Reserve.

Keywords Argali, Central Asia, double-observer survey, ibex, *Panthera uncia*, snow leopard, ungulate prey

Introduction

Asia's mountains support a rich diversity of ungulates that sustain large carnivores such as the Endangered snow leopard *Panthera uncia* (Schaller, 1977, 1998). Relatively little information is available on the abundance and population trends of these mountain ungulates, however, because of the remoteness of their habitats and a lack of robust scientific studies (Singh & Milner-Gulland, 2011). Changing livestock husbandry practices (Berger et al., 2013), mining and associated development (Farrington, 2005; Kaczensky et al., 2011), and poaching (Pratt et al., 2004) threaten the survival of many of these ungulate species and the predators that depend on them.

The availability of wild-ungulate prey is a critical determinant of carnivore density (Karanth et al., 2004). However, in the mountains of Asia the rugged habitat and lack of sufficient expertise have posed a challenge to the estimation and monitoring of ungulate populations (Singh & Milner-Gulland, 2011). Many of the established methods of ungulate population estimation, such as distance sampling, are difficult to implement in mountainous terrain because of the inapplicability of their assumptions (Suryawanshi et al., 2012). Alternatives such as aerial surveys are expensive and often unsafe in mountainous landscapes.

The primary occupation of the local pastoralists is cashmere production from goats. In response to demand from the global market for cashmere, the goat population in large parts of the mountains of Central Asia is increasing (Bhatnagar et al., 2006; Berger et al., 2013). Livestock species such as goats are reported to compete with wild ungulate species for forage in other regions (Bagchi et al., 2004; Mishra et al., 2004), and the presence of herders and herding dogs creates competition for space (Namgail et al., 2007). Berger et al. (2013) reported that the biomass of native wild ungulates across seven study areas in Mongolia, India, and China's Tibetan Plateau is now < 5% that of livestock. Conservation of native ungulates alongside a pastoral industry such as cashmere production will require rigorous monitoring and incentives for wildlife-friendly pastoralism (Berger et al., 2013). Monitoring of wild ungulate abundance is therefore fundamental to any such effort (Ale et al., 2007; Xu et al., 2008), and will also facilitate assessment of the size of the snow leopard population that could be sustained by the available prey.

The Tost Local Protected Area is an important corridor between the Great Gobi Strictly Protected Area A in the west and the Gobi Gurvan Saikhan National Park in the north. An ongoing radio-telemetry study of the snow leopard has

L K H A G V A S U M B E R E L T U M U R S U K H *† Snow Leopard Conservation Foundation, Peace Avenue, Ulaanbaatar, Mongolia

K U L B H U S H A N S I N G H R . S U R Y A W A N S H I ‡ (Corresponding author) and C H A R U D U T T M I S H R A ‡ Snow Leopard Trust, Sunnyside Avenue, Seattle, Washington, USA E-mail kulbhushan@ncf-india.org

T H O M A S M . M C C A R T H Y Panthera, Redmond, Washington, USA

B A Z A R T S E R E N B O L D G I V National University of Mongolia, Ulaanbaatar, Mongolia

*Also at: Snow Leopard Trust, Sunnyside Avenue, Seattle, Washington, USA
†Also at: National University of Mongolia, Ulaanbaatar, Mongolia
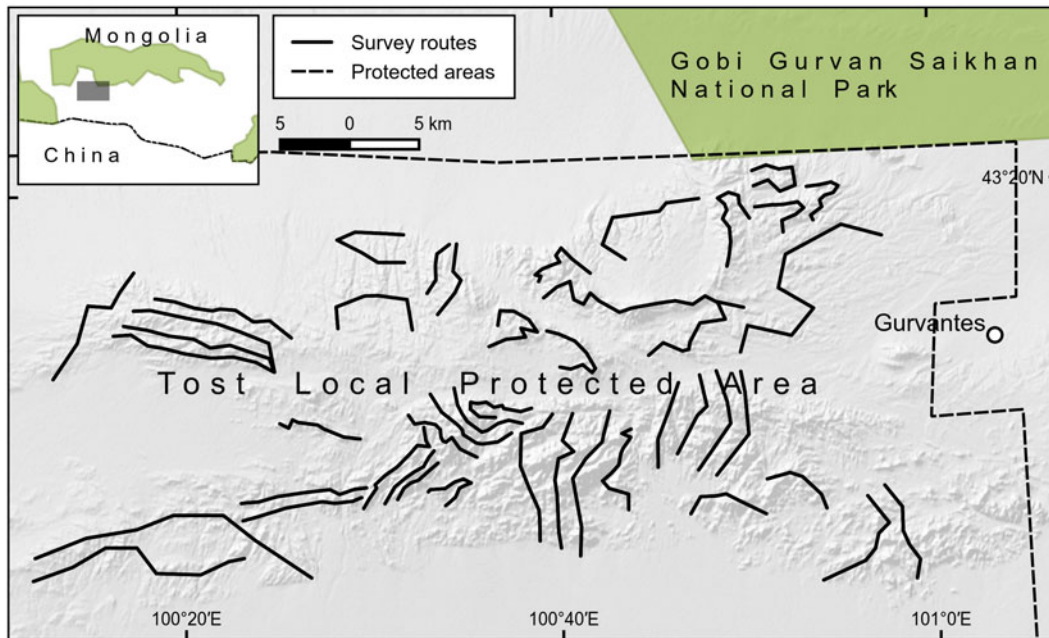‡Also at: Nature Conservation Foundation, Mysore, India

FIG. 1 Map of the survey area (dark shade). Existing Protected Areas are shaded (light). The Tost Local Protected Area is denoted by dotted line in the map and solid black in the inset of Mongolia.

already recorded one case of a subadult snow leopard dispersing from the Tost Mountains in the Local Protected Area to the Nemegt Mountains in the Gobi Gurvan Saikhan National Park. Local Protected Area status affords a relatively low level of protection under Mongolian law, however, and it is difficult to protect the area from mining. Supported by the local government authorities, local pastoralists and conservationists, the elevation of the protection status of Tost Local Protected Area to that of Nature Reserve is being considered by the National Government. Thus, there is an urgent need for robust information on the conservation value and potential of this region.

The snow leopard population of the Tost Mountains is being monitored closely using camera trap-based multiseason models (Sharma et al., 2014). However, little information has so far been available on the status of their primary wild-ungulate prey, the ibex *Capra sibirica* and argali *Ovis ammon*. The ibex is one of the preferred prey species of the snow leopard across its range (Jumabay-Uulu et al., 2014; Lyngdoh et al., 2014).

Up to 20% of the snow leopard's diet in the Tost Local Protected Area consists of livestock (Shehzad et al., 2012), and retaliatory persecution of snow leopards by local herders is an important conservation concern. The availability of wild prey has significant implications for the livestock predation behaviour of wild carnivores (Suryawanshi et al., 2012; Odden et al., 2013; Gervasi et al., 2014). Thus, understanding the availability and trends of wild ungulate prey over time is important for conservation management in the region.

The primary objective of this study was to estimate the population of ibex and argali in the Tost Mountains,

which comprise the snow leopard habitats of the Tost Local Protected Area. We also examined the demography of the two species, to understand the survival of various age–sex categories of the ibex.

Study area

Our study area comprised 1,400 km² of the mountainous region of Tost, in South Gobi province, Mongolia (Fig. 1). The Tost Local Protected Area was declared by the administration of Gurvantes *soum* (district) in October 2010, after mining leases were issued for the region. The Protected Area has high conservation value for species such as the Endangered snow leopard, and argali and ibex (McCarthy et al., 2010), and is valued by the local pastoralists for grazing livestock. The temperature in the region ranges between −35°C in winter and +35°C in summer, and the altitude is 1,600–2,400 m. The Nemegt Mountains of the Gobi Gurvan Saikhan National Park are north of the surveyed area. Towards the west the study area is connected to the Great Gobi Strictly Protected Area A via a fragmented network of hillocks. The international border with China lies c. 60 km south of the study area. The town of Gurvantes and the Noyon Mountains lie east of the study area. Livestock herding is the primary occupation of the local people. Goats (22,070) and sheep (1,263) are the most common livestock, followed by camels (414), horses (329) and cattle (47), based on a census conducted in 2013 (LT, unpubl. data). Ibex, argali and tolai hare *Lepus tolai* are the common wild herbivores in the region, and snow leopard, wolf *Canis*

lupus, red fox *Vulpes vulpes*, corsac fox *Vulpes corsac* and lynx *Lynx lynx* are the large predators.

Methods

Ibex and argali populations were estimated in 2012 and 2013 using the double-observer survey method (Forsyth & Hickling, 1997; Suryawanshi et al., 2012). In 2012 the study area was divided into 15 blocks of c. 100 km², depending upon the topography. Survey blocks were separated by flat areas between mountain chains. The 100 km² blocks were further divided into cells of c. 25 km². The shape and size of each cell depended on the terrain and the logistics of accessing and surveying the area. The surveys were conducted during late autumn (10–24 November 2012 and 9–19 November 2013), which is the mating season for the ibex and argali in the region. It is usually easier to detect ibex during the mating season as they form larger groups, remain active for longer periods and are less easily disturbed. Eight trained observers were divided into four teams, and each team surveyed one cell in 1 day, walking along predetermined trails and scanning using binoculars. Based on initial trials, the second observer started the survey c. 10–15 minutes after the first. This duration was chosen to balance potential overestimation as a result of evasive movement of ungulates after the first survey and potential underestimation if the time between the two surveys was too short, resulting in a lack of independence between the two surveys. If the first observer came within the sight of the second, the second observer waited to increase the distance between the two. The protocol precluded any unintentional visual cues; for example, prolonged interest in a particular direction by one observer could influence the other observer's survey.

The observers recorded ungulate group size, age × sex categorization, distance to group, the name of the pasture where the group was encountered, and any other matters that could help identify the observed groups. At the end of the survey the observers discussed and identified the groups seen by both observers and those seen by only one, based on group size and composition, location and any other notes. Density was estimated by dividing the abundance estimate by the area surveyed (Oli, 1994; Forsyth & Hickling, 1997; Suryawanshi et al., 2012).

The demography of the ibex population was surveyed eight times during May 2012–November 2013. The surveys were carried out over 7–10 days in the same 15 blocks used in the double-observer surveys. We surveyed 10–20 km in each block, for even coverage of the study area. Areas that were inaccessible by all-terrain vehicle or motorcycle were surveyed on foot. Groups of ibex were observed from a distance of 100–500 m using 8 × 32 binoculars and a 20–60 × 60 spotting scope, and categorized according to the following age–sex categories: kid (< 1 year old), yearling

(1–2 years old), adult female and adult male (Schaller, 1977). We conducted 10,000 bootstraps to assess the 95% confidence intervals of the young-to-female and male-to-female ratios within each survey, using herd as the sampling unit. The median values were used as the estimates of young-to-female and male-to-female ratios, and the 0.025 and 0.975 quantiles were used as 95% confidence intervals.

Results

Double-observer survey estimates of ibex and argali abundance were 899 (95% CI 727–1,071) and 108 (95% CI 47–169) individuals in 2012 and 1,051 (95% CI 857–1,245) and 230 (95% CI 120–340) in 2013, respectively. The mean group sizes of ibex encountered during the surveys were 5.24 and 5.04 in 2012 and 2013, respectively. Mean group sizes of argali were 7.72 and 7.5 in 2012 and 2013, respectively. This yields density estimates of 0.64 and 0.75 ibex km^{-2} and 0.08 and 0.16 argali km^{-2} in 2012 and 2013, respectively. The difference in ibex population estimate for the 2 years was not statistically significant ($z = 1.16$, one-tailed $P = 0.12$). The increase in the argali population estimate was significant ($z = 1.9$, one-tailed $P = 0.03$). All parameters are summarized in Table 1.

The ratio of kids (< 1 year) to adult females was 0.51 (95% CI 0.39–0.65) in May 2012 and 0.78 (95% CI 0.6–1.0) in November 2013 (Fig. 2a). The ratio of yearlings (1–2 years) to adult females was 0.09 (95% CI 0.03–0.17) in September 2012 and 0.37 (95% CI 0.23–0.54) in June 2013. The ratio of young to female decreased in summer (August) and again after winter, with a significant drop after weaning at 12 months of age. The adult male-to-female ratio showed a general decreasing trend from 0.94 (95% CI 0.6–1.44) in May 2012 to 0.67 (95% CI 0.56–0.81) in November 2012 and increased to 1.08 (95% CI 0.81–1.49) in November 2013 (Fig. 2b). This suggests male-biased mortality in 2012 and female-biased mortality in 2013. The highest mean group sizes were recorded in May 2012 (7.3) and June 2013 (7.5). The lowest mean group sizes were recorded in August 2012 (4.0) and August 2013 (4.7; Table 2).

Discussion

We used the statistically robust double-observer survey method to estimate the abundance of ibex and argali in the mountainous regions of the Tost Local Protected Area. The detection probabilities recorded (0.56 and 0.36 for ibex and argali, respectively) were lower than in other places (0.79, 0.74; Suryawanshi et al., 2012) where this method has been used but our confidence intervals were reasonable because we used a larger sample size.

Suryawanshi et al. (2012) recommended that for double-observer surveys of mountain ungulates the two observers

TABLE 1 Results of spaced double-observer surveys of ibex *Capra ibex* and argali *Ovis ammon* in the Tost Mountains, South Gobi, Mongolia (Fig. 1), in 2012 and 2013.

| Variable	2012		2013	
	Ibex	Argali	Ibex	Argali
No. of groups recorded by both surveyors	35	3	37	5
No. of groups recorded by first surveyor only	61	6	71	13
No. of groups recorded by second surveyor only	28	2	35	4
Estimated no. of groups	171.44	14	208.39	30.67
Variance in estimated no. of groups	221.12	9	351.11	39.29
Mean group size	5.24	7.73	5.04	7.5
Variance in mean group size	0.05	2.24	0.01	0.98
Estimated population	899	108	1,051	230
Variance in estimated population	7514.89	995.36	9559.01	3085.62
± 95% confidence interval	727–1,071	47–169	857–1,245	120–340
Total area (km^2)	1,400	1,400	1,400	1,400
Density	0.64	0.08	0.75	0.16
Distance walked per survey (km)	720	720	720	720
Estimated detection probability for first survey	0.56	0.6	0.51	0.55
Estimated detection probability for second survey	0.36	0.33	0.34	0.28
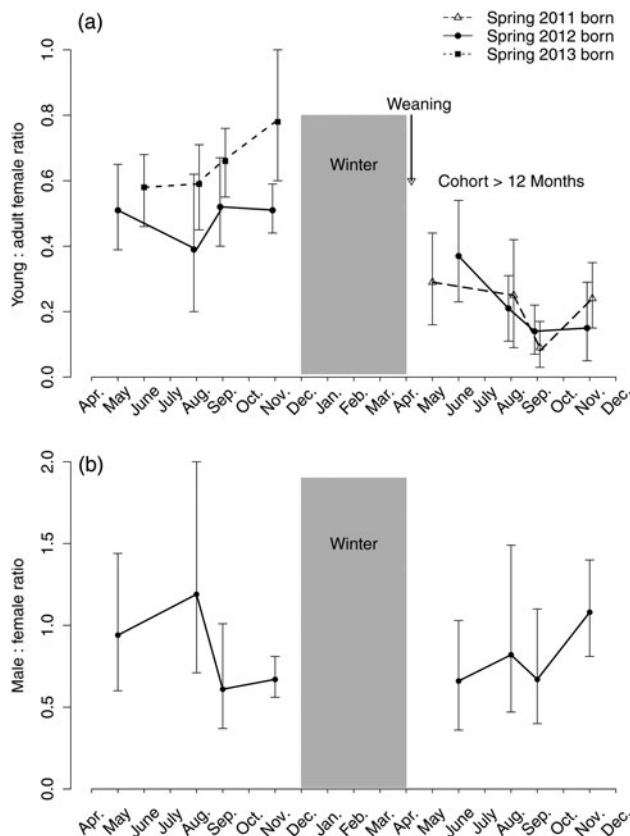
FIG. 2 (a) Young : adult female ratio and (b) male : female ratio of ibex *Capra ibex* in Tost Local Protected Area (Fig. 1), from May to November 2012 and from June to November 2013. Survival of young ibex dropped significantly during winter and post-weaning. Points are the median values of 10,000 bootstraps to estimate the 95% confidence interval (error bars), with herd as the sampling unit.

be separated in space or time to minimize potential under-estimation as a result of autocorrelation between the observers. However, this recommendation was based on their study in the Himalayas (Suryawanshi et al., 2012). In Tost the animals were comparatively shy and our initial observations indicated that such a separation was likely to result in overestimation because of animals leaving the survey area between the two surveys. We therefore used a minimal 10–15 minute separation between the observers to minimize overestimation. Despite this change, a lower detection probability was recorded consistently for the second observer, which suggests there was evasive movement by animals after the first survey. For future surveys we suggest the use of Bayesian approaches proposed by Barker et al. (2014) to address the potential biases in population estimates.

The estimated ibex population size remained similar across the 2 years of monitoring. The argali population estimate, however, doubled from 2012 to 2013. We suspect this increase may be attributed to the movement of argali from smaller hills in the north and west of the survey area, which are used by argali but do not contain ibex habitat. By November 2013 a drought in the southern Gobi region had restricted the movement of ungulates to around the remaining waterholes. Occasionally we observed aggregations of argali in the vicinity of a waterhole on the edge of our study site in late October (LT, pers. obs.).

Our demographic surveys cannot be used to estimate the ibex kid mortality for the first few weeks after birth; beyond this time up to 12 months, however, mortality rates among ibex kids are low. A lower young-to-female ratio, with wide confidence intervals, recorded in August may be attributable to sampling error, as ibex become difficult to sight as summer progresses. Importantly, the young-to-female ratio declined after 1 year, which we suspect was largely a result of predation

TABLE 2 Numbers of ibex assigned to various age–sex categories during surveys in the Tost Mountains, South Gobi, Mongolia.

Category	2012				2013			
	May	Aug.	Sep.	Nov.	June	Aug.	Sep.	Nov.
Kid	31	19	46	51	42	34	54	56
Yearling	17	12	8	12	27	12	12	11
Adult female	61	48	87	100	72	61	82	72
Adult male	59	57	54	58	48	49	55	78
Mean group size	7.3	4	5.22	5.97	7.5	4.7	5.2	5.2
Total no. of groups	23	34	37	35	25	31	38	41
Total no. of individuals	168	136	195	221	189	156	203	217

when the yearlings started feeding by themselves in the herd. The adult female-to-male ratios were lowest at the start (May 2012) and end of the monitoring (November 2013), peaking in November 2012. Such a pattern could be a result of either sighting bias in the demographic surveys (separate from the double-observer surveys) or selective (sex-biased) predation by carnivores. We consider our surveys to be unbiased as they covered the entire study area and all ibex habitats. The surrounding hills in the north and west are not suitable habitat for ibex. Such a pattern could also arise as a result of long-distance movement by male ibex. We do not think this was the cause, however, as we surveyed a relatively large area. We recommend further investigation of the hypothesis of gender-biased predation, using marked animals.

Oli (1994) recorded a 1 : 114–159 ratio of snow leopard to blue sheep *Pseudois nayaur*, by weight. Blue sheep is another preferred prey of the snow leopard (Lyngdoh et al., 2014) in other parts of the snow leopard's range. Considering the mean weight of ibex to be 60 kg (Hess, 1990), argali 90 kg (Valdez, 1990) and snow leopard 40 kg (Oli, 1994), the estimated biomass of wild herbivores in the Tost Mountains was 63,720 kg in 2012 and 83,760 kg in 2013. Using Oli's (1994) predator : prey ratios we estimate that the ibex and argali populations of the Tost Mountains could have supported c. 10–14 and 13–18 adult snow leopards in 2012 and 2013, respectively. Carbone & Gittleman (2002) suggested that 10,000 kg of prey could support c. 90 kg of carnivore biomass. Using their conversion, our estimated prey biomass would have been adequate to support 14 adult snow leopards in 2012 and 18 in 2013. Both these estimates of snow leopard populations are comparable to the estimates of 12 (95% CI 11–15) and 14 (95% CI 14–21) determined by means of camera-trap-based mark–recapture in the same (but larger, 1,684 km²) study area (Sharma et al., 2014).

Although the estimated density of wild ungulates (0.71 and 0.91 km^{-2} in 2012 and 2013, respectively) may seem sufficient to support 14–18 adult snow leopards, these densities are an order of magnitude lower than the stocking density of livestock (17.1 km^{-2}) in this region. Consistent with Berger et al. (2013), the biomass of native ungulates in Tost Local Protected Area is c. 6% of the livestock biomass. It is known that there is a significant overlap in the diet of

domestic goats and sheep and that of ibex (Bagchi et al., 2004). Other studies have found that competition for forage from livestock and disturbance from herding dogs could reduce the density of wild ungulate herbivores (Mishra et al., 2004; Namgail et al., 2007). This could be a cause of relatively low ibex biomass compared to livestock in the region, and requires further investigation.

Our results suggest that the Tost Mountains are an important site for the conservation of ibex, argali and the Endangered snow leopard. This area also serves as a corridor connecting the snow leopard and ibex habitats of the Great Gobi Strictly Protected Area and Gobi Gurvan Saikhan National Park. We are completing a management plan for the Local Protected Area, and continue to work with relevant stakeholders, including the local community and the local government, to have the Local Protected Area elevated in status to a Nature Reserve by the Mongolian parliament. Despite its significance for conservation and pastoralism, the Local Protected Area remains vulnerable to the threat of mining; designation as a Nature Reserve would protect it against this threat.

References

ALE, S.B., YONZON, P. & THAPA, K. (2007) Recovery of snow leopard *Uncia uncia* in Sagarmatha (Mount Everest) National Park, Nepal. *Oryx*, 41, 89–92.

BAGCHI, S., MISHRA, C. & BHATNAGAR, Y.V. (2004) Conflicts between traditional pastoralism and conservation of Himalayan ibex (*Capra sibirica*) in the Trans-Himalayan mountains. *Animal Conservation*, 7, 121–128.

BARKER, R.J., FORSYTH, D.M. & WOOD, M. (2014) Modeling sighting heterogeneity and abundance in spatially replicated multiple-observer surveys. *The Journal of Wildlife Management*, 78, 701–708.

BERGER, J., BUUVEIBAATAR, B. & MISHRA, C. (2013) Globalization of the cashmere market and the decline of large mammals in Central Asia. *Conservation Biology*, 27, 679–689.

BHATNAGAR, Y.V., WANGCHUK, R., PRINS, H.H., VAN WIEREN, S.E. & MISHRA, C. (2006) Perceived conflicts between pastoralism and conservation of the kiang *Equus kiang* in the Ladakh Trans-Himalaya, India. *Environmental Management*, 38, 934–941.

CARBONE, C. & GITTLEMAN, J.L. (2002) A common rule for the scaling of carnivore density. *Science*, 295, 2273–2276.

FARRINGTON, J.D. (2005) The impact of mining activities on Mongolia's protected areas: a status report with policy recommendations. *Integrated Environmental Assessment and Management*, 1, 283–289.

FORSYTH, D.M. & HICKLING, G.J. (1997) An improved technique for indexing abundance of Himalayan thar. *New Zealand Journal of Ecology*, 21, 97–101.

GERVASI, V., NILSEN, E.B., ODDEN, J., BOUYER, Y. & LINNELL, J.D.C. (2014) The spatio-temporal distribution of wild and domestic ungulates modulates lynx kill rates in a multi-use landscape. *Journal of Zoology*, 292, 175–183.

HESS, R. (1990) Siberian ibex (*Capra ibex sibirica*). In *Grzimek's Encyclopedia of Mammals Volume 5* (ed. S.P. Parker), pp. 527–528. McGraw-Hill, New York, USA.

JUMABAY-UULU, K., WEGGE, P., MISHRA, C. & SHARMA, K. (2014) Large carnivores and low diversity of optimal prey: a comparison of the diets of snow leopards *Panthera uncia* and wolves *Canis lupus* in Sarychat–Ertash Reserve in Kyrgyzstan. *Oryx*, 48, 529–535.

KACZENSKY, P., KUEHN, R., LHAGVASUREN, B., PIETSCH, S., YANG, W. & WALZER, C. (2011) Connectivity of the Asiatic wild ass population in the Mongolian Gobi. *Biological Conservation*, 144, 920–929.

KARANTH, K.U., NICHOLS, J.D., KUMAR, N.S., LINK, W.A. & HINES, J.E. (2004) Tigers and their prey: predicting carnivore densities from prey abundance. *Proceedings of the National Academy of Sciences of the United States of America*, 101, 4854–4858.

LYNGDOH, S., SHROTRIYA, S., GOYAL, S.P., CLEMENTS, H., HAYWARD, M.W. & HABIB, B. (2014) Prey preferences of the snow leopard (*Panthera uncia*): regional diet specificity holds global significance for conservation. *PLoS ONE*, 9(2), e88349.

MCCARTHY, T.M., MURRAY, K., SHARMA, K. & JOHANSSON, O. (2010) Preliminary results of a long-term study of snow leopards in South Gobi, Mongolia. *Cat News*, 53, 15–19.

MISHRA, C., VAN WIEREN, S.E., KETNER, P., HEITKÖNIG, I.M.A. & PRINS, H.H.T. (2004) Competition between domestic livestock and wild bharal *Pseudois nayaur* in the Indian Trans-Himalaya. *Journal of Applied Ecology*, 41, 344–354.

NAMGAIL, T., FOX, J.L. & BHATNAGAR, Y.V. (2007) Habitat shift and time budget of the Tibetan argali: the influence of livestock grazing. *Ecological Research*, 22, 25–31.

ODDEN, J.D., NILSEN, E.B. & LINNELL, J.D.C. (2013) Density of wild prey modulates lynx kill rates on free-ranging domestic sheep. *PLoS ONE*, 8(11), e79261.

OLI, M.K. (1994) Snow leopards and blue sheep in Nepal: densities and predator : prey ratio. *Journal of Mammalogy*, 75, 998–1004.

PRATT, D.G., MACMILLAN, D.C. & GORDON, I.J. (2004) Local community attitudes to wildlife utilisation in the changing economic and social context of Mongolia. *Biodiversity & Conservation*, 13, 591–613.

SCHALLER, G.B. (1977) *Mountain Monarchs. Wild Sheep and Goats of the Himalaya*. University of Chicago Press, Chicago, USA.

SCHALLER, G.B. (1998) *Wildlife of the Tibetan Steppe*. University of Chicago Press, Chicago, USA.

SHARMA, K., BAYRAKCISMITH, R., TUMURSUKH, L., JOHANSSON, O., SEVGER, P., MCCARTHY, T. & MISHRA, C. (2014) Vigorous dynamics underlie a stable population of the Endangered snow leopard *Panthera uncia* in Tost Mountains, South Gobi, Mongolia. *PLoS ONE*, 9(7), e101319.

SHEHZAD, W., MCCARTHY, T.M., POMPANON, F., PUREVJAV, L., COISSAC, E., RIAZ, T. & TABERLET, P. (2012) Prey preference of snow leopard (*Panthera uncia*) in South Gobi, Mongolia. *PLoS ONE*, 7(2), e32104.

SINGH, N.J. & MILNER-GULLAND, E.J. (2011) Monitoring ungulates in Central Asia: current constraints and future potential. *Oryx*, 45, 38–49.

SURYAWANSHI, K.R., BHATNAGAR, Y.V. & MISHRA, C. (2012) Standardizing the double-observer survey method for estimating mountain ungulate prey of the endangered snow leopard. *Oecologia*, 169, 581–590.

VALDEZ, R. (1990) Giant wild sheep or argali (*Ovis ammon*). In *Grzimek's Encyclopedia of Mammals* (ed. S.P. Parker), pp. 550–553. McGraw-Hill, New York, USA.

XU, A., JIANG, Z., LI, C., GUO, J., DA, S., CUI, Q. et al. (2008) Status and conservation of the snow leopard *Panthera uncia* in the Gouli Region, Kunlun Mountains, China. *Oryx*, 42, 460–463.

Biographical sketches

LKHAGVASUMBEREL TUMURSUKH studies the ecology of the snow leopard and its prey, with applications for the conservation of these species in Mongolia. KULBHUSHANSINGH SURYAWANSHI is interested in the ecology and conservation of large carnivores and their ecosystems. CHARUDUTT MISHRA studies the ecology of large carnivores and herbivores, rangelands, human ecology and conservation conflicts in the Himalayas and Central Asia. TOM MCCARTHY has spent more than 2 decades studying and seeking to conserve snow leopards across their range in Central Asia. BAZARTSEREN BOLDGIV is an experimental ecologist focusing on the effects of climate change and land use on biodiversity and ecological system dynamics in Mongolia.