Snow leopard – human conflict as a conservation challenge—a review

Zalmai Moheb1,* Todd K. Fuller2 Peter I. Zahler3

1 Wildlife Conservation Society, Kabul, Afghanistan
2 Department of Environmental Conservation, University of Massachusetts, Amherst, Massachusetts, USA.
3 Woodland Park Zoo, Seattle, Washington, USA.
* Corresponding author Zalmai Moheb.
E-mail: mohebzalmai@yahoo.com

Key words
Human wildlife conflict, conflict domains, mitigation schemes, Panthera uncia

Abstract
Human conflict with large carnivores continues to be a great conservation challenge, and conflict with snow leopards (Panthera uncia) has been studied to understand causes and propose mitigation schemes. While the nature of snow leopard-human conflict is similar in most cases, reported studies have been case- and area-specific with mitigation strategies not necessarily based on a synthesis of relevant literature. We reviewed snow leopard literature published from 1970-2020 to identify the main drivers of human-snow leopard conflict (HSLC) and describe conservation and conflict mitigation strategies commonly employed. Based on 47 relevant peer-reviewed articles, review papers, book chapters, project reports, and other grey literature, we identified four major conflict domains: livestock management-related, socio-economic/
human-related, ecological, and policy-related. Most articles suggested more than one conflict mitigation scheme. Three conflict mitigation domains – preventive, supportive, and compensatory – were widely reflected in the snow leopard-human conflict literature. The most commonly reported mitigation schemes included: 1) building or predator-proofing corrals; 2) training shepherds and improving livestock guarding; 3) livestock insurance schemes; 4) compensation for livestock predation; 5) capacity building, education, and awareness programs; and 6) improved breeding and use of guard dogs. Future management efforts need to tailor their approach depending on cultural, economic, and ecological circumstances.

Introduction

Coexistence of humans and large carnivores has been among the greatest conservation challenges (Lamb et al. 2020). Human-snow leopard (Panthera uncia) conflict (HSLC) is a continuing conservation challenge across the snow leopard's global range (Young et al. 2010, Redpath et al. 2013), and includes ecological, socio-economic, cultural, and commercial dimensions. The ecological aspects of HSLC include abundance and distribution of wild prey species, snow leopard abundance and distribution, its rugged and remote habitat, and the presence of sympatric large carnivores (Robinson and Weckworth 2016). Among the socio-economic and cultural aspects of HSLC are excessive numbers of livestock, livestock predation with devastating economic loss for people, socio-economically and culturally diverse communities with different poverty levels, and negative perception of local communities about carnivore species (Moheb et al. 2012, Kansky et al. 2014). In addition, some wildlife management programs might also have roots in HSLC in some parts of snow leopard range (Hussain 2003, Kachel et al. 2017, Rashid et al. 2020); for example Hussain (2003) reported that snow leopard and other predator species in Northern Pakistan where trophy hunting happens for ibex are killed not only to protect livestock but also to protect the wild ungulate subject to trophy hunting.

Here we aim to describe human-snow leopard conflict circumstances at the range-wide level, conflict assessment methods, and provide recommendations on best mitigation strategies based on documented scientific research across the species range. We assess conflicts across snow leopard range and compile the best conflict mitigation practices reported in snow leopard-human conflict literature. We review predation and conflict related articles published since the 1970s that have reported snow leopard and other sympatric predators’ conflicts with livestock. Our main focus was to understand the circumstances of livestock predation, the retaliatory killing of predator species, and conflict mitigation schemes applied throughout the entire range of snow leopards.

Methods

We assessed snow leopard and human conflict literature, published in English from 1970-2020, by retrieving peer-reviewed snow leopard conflict-related articles online using the PRISMA (Preferred Reporting of Items for Systematic Review and Meta-Analysis) review method (Moher et al. 2009). We used the Web of Science and Google Scholar databases, and also reference-mined where we searched for snow leopard conflict-related article titles within relevant scientific publications (Fig. 1). We used the word combinations of either “snow leopard” or “Panthera uncia” with any of the following
keywords or phrases: human-wildlife conflict; livestock predation; depredation; coexistence; attack; killing; wildlife hunting; predator-prey relationship; food habit; retaliatory killing; conflict management; livestock insurance; poaching; compensation; prey preference; attitude; conflict hotspots; and surplus killings. We also added, one by one, the name of all 12 range countries with the combination of the aforementioned key words to obtain any HSCLC related peer-reviewed journal articles for all the snow leopard range states.

We screened relevant articles and extracted information on: 1) data collection methods, 2) study region, 3) livestock, wild prey, and predator densities, 4) predation rates of snow leopards and other predators, 5) contributing factors to livestock predation, 6) suggested conflict mitigation schemes and best practices, and 7) whether or not any of the suggested mitigation schemes were tested for their efficacy. We tested the overall snow leopard contribution to livestock predation versus wolf and lynx predation using t-tests. While compiling the literature, we identified four major conflict factor domains: livestock management related factors, ecological factors, socio-economic or human related factors, and policy related factors. A variety of factors were identified within each domain.

The data collection methods used in the reviewed articles were coded as:

1. Social science method that includes interview, questionnaire, and focused group discussion data.
2. Ecological method that includes camera trap data, diet study, and scat analysis.
3. Compensatory and supportive record methods that include the compensation records, insurance programs and other project/status reports.
4. Combined methods that include articles that have used a combination of the above-mentioned data collection methods, and
5. Review method covering the review data.

Results

We found 35 peer-reviewed journal articles, 4 review papers, 4 book chapters, 2 proceedings, and 2 reports (total = 47) related to snow leopard-human conflict from eight of the 12 snow leopard range countries (Fig. 2). No peer-reviewed English articles were identified for Kazakhstan,
Kyrgyzstan, Russia, and Uzbekistan (Appendix 1).

Data collection methods used by most of the articles were based on social science methods (49%, n = 23) (e.g., questionnaires, interviews, and focus group discussions), followed by research based on scat analysis (9%, n = 4), compensation records kept by the government or other organizations responsible for compensation (6%, n = 3), mix of interview, scat analysis and camera trap surveys (6%, n = 3), camera trap data (2%, n = 1), and GPS telemetry (2%, n = 1). Another 26% (n = 12) consisted of review papers and of project reports that were mainly general overview papers which had not used any data collection methods.

Some articles (17%, n = 8) that appeared in the search considered wild prey density in evaluation of the snow leopard human conflict, while only 15% (n = 7) and 6% (n = 3) used or mentioned livestock and snow leopard densities, respectively. The papers that had included predator and prey (wild or domestic) densities only represented the southern part of the snow leopard range (Table 1).

The amount of livestock predation by snow leopards reported in the literature ranged from 0.3% to 7.6% of total livestock holdings, with an average loss of 2.5% across its range (Fig. 3). Studies of snow leopard predation on livestock have also included a range of other sympatric predators, including brown bear (Ursus arctos), black bear (Ursus thibetanus), leopard (Panthera pardus), tiger (Panthera tigris), red fox (Vulpes vulpes), and dhole (Cuon alpinus); however, wolf (39%) and lynx (Lynx lynx, 17%) appeared most often in snow leopard predation-related articles. The overall snow leopard contribution to livestock predation when multiple predators were assessed (range = 0-89%, mean 40%, median 38%) was not statistically different (P = 0.90) than what was reported for wolf (range = 8-100% mean 39%, and median 36%) (Table 2). However, the amount of predation by lynx (range = 0.1-34.6%, mean 9%, median 2%) was different than for snow leopard (P = 0.005) and wolf (P = 0.007).

The literature compilation resulted in identification of four major conflict factor domains: livestock management related factors (59% of the literature), ecological factors (30%), socio-economic or human related (9%), and policy related (2%). A variety of factors were identified within each domain (Table 3).

A range of conflict mitigation schemes have been reported in snow leopard-human conflict literature (Table 4). Most of the articles either reported or suggested more than one conflict mitigation scheme. Over 21% (n = 10) of the reviewed articles have evaluated the effectiveness of the conflict mitigation schemes by either monitoring over time the amount of livestock loss, monitoring people’s action in favor of conservation, people’s tolerance towards the predator, and assessments of snow leopard retaliatory killings. Three conflict mitigation
Table 1
Peer-reviewed articles that considered livestock and wild prey in their analysis.

| DENSITY | SNOW LEOPARD | LIVESTOCK | WILD PREY | LOCATION | REFERENCE |
|---------|--------------|-----------|-----------|----------|-----------|
| -       | 27.5         | -         | -         | Big Pamir, Afghanistan | Karimov et al. 2018 |
| -       | 1500         | -         | -         | Trans-Himalaya, India  | Mishra 1997 |
| -       | -            | 4.0       | -         | Spiti Valley, India   | Mishra et al. 2003 |
| -       | 29.7-13.9    | 2.6-6.1   | -         | Pin Valley NP/Kibber WS, India | Bagchi & Mishra 2006 |
| 0.46-3.3| 1.9-19.5     | 0.1-3.1   | -         | Various sites\(^2\), India/Mongolia | Suryawanshi et al. 2017 |
| -       | -            | 0.3       | -         | Ladakh, India         | Namgail et al. 2007 |
| -       | 57.23        | 0.05-3.9  | -         | Spiti Valley, India   | Sharma et al. 2015 |
| -       | 1,500        | -         | -         | Hemis NP, India       | Jamwal et al. 2019 |
| -       | 35.74        | -         | 8.4       | Phu Valley, Nepal     | Wegge et al. 2012 |
| 0.4-4   | -            | 0.5       | -         | Baltistan, Pakistan   | Husain 2003 |
| 0.24    | -            | 0.41      | -         | Torkhow Valley, Pakistan | Din & Nawaz 2011 |

\(^1\) No./100 km\(^2\) for snow leopards, No./km\(^2\) for livestock and wild prey.

\(^2\) = Spiti Valley, Jammu and Kashmir in India, and Tost in Mongolia

Table 2
Percent snow leopard wolf and lynx predation on livestock loss reported in human-snow leopard conflict literature.

| PERCENT LIVESTOCK LOSS DUE TO |
|-------------------------------|
| SNOW LEOPARD | WOLF | LYNX | OTHER PREDATORS | REGION, COUNTRY | REFERENCE |
|----------------|------|------|-----------------|-----------------|-----------|
| 88.7           | 11.1 | 0.1  | 0               | KPTB, Pakistan-China | Khan et al. 2014 |
| 74.5           | 8.4  | 4.0  | 13.1            | Mustang region, Nepal | Aryan et al. 2014 |
| 64.9           | 35.1 | 0    | 0               | Misgar/Chuparsan, Pakistan | Din et al. 2017 |
| 60.0           | 37.0 | 0    | 3.0             | Hushey Valley, Pakistan | Khan et al. 2018 |
| 58.0           | 32.0 | 2.0  | 8.0             | Hemis NP, India | Jackson et al. 2003 |
| 38.0           | 60.0 | 2.0  | 0               | Ladakh, India | Namgail et al. 2007 |
| 30.4           | 69.6 | 0    | 0               | Wakhan NP, Afghanistan | Din et al. 2017 |
| 27.5           | 24.5 | 0    | 47.9            | Spiti Valley, India | Suryawanshi et al. 2013 |
| 21.7           | 37.7 | 34.6 | 6.0             | Qomolangma NNR, China | Chen et al. 2016 |
| 0.0            | 100.0| 0    | 0               | Tajik Pamir, Tajikistan | Din et al. 2017 |

KPTB = Karakoram Pamir Trans-Border, NP = National Park, CA = Conservation Area, NNR = National Nature Reserve, L = Landscape.
Table 3
Livestock predation factors reported within the snow leopard-human conflict related peer-reviewed and grey literature.

| HUMAN-SNOW LEOPARD CONFLICT FACTORS | CONTRIBUTION TO SLHC | NO. OF REFERENCES |
|-------------------------------------|----------------------|-------------------|
| **Livestock management**            |                      |                   |
| Lax and traditional herding practice| ElsP                 | 13                |
| Poorly constructed livestock corrals | ElsP                 | 7                 |
| Free ranging animals                 | UlsEP                | 4                 |
| Increase in the number of livestock  | MCE                  | 4                 |
| Types of livestock                   | SlsPP                | 2                 |
| Livestock herd size                  | LHMCE                | 1                 |
| Repeated use of pastures where predators are active | ElsP        | 1                 |
| Poor veterinary care                 | DlsEC                | 1                 |
| **Ecological**                      |                      |                   |
| Prey depletion                       | PAlsS                | 8                 |
| Higher predator density              | MCE                  | 4                 |
| Topography and ground cover help predation | ICPA              | 4                 |
| Wild prey abundance                  | IP                   | 1                 |
| **Socio-economic/Human-related**    |                      |                   |
| Negative perception of local communities | ICPK                | 2                 |
| Increase in human population         | MCEP                 | 1                 |
| Limited external resources and low income | CAPIs            | 1                 |
| **Policy-related**                  |                      |                   |
| Conservation measures e.g., wildlife protection laws, creation of protected areas | IP        | 1                 |

1 Chetri et al. 2019, 2 Khan et al. 2018, ^ Suryawanshi et al. 2017, 3 Chen et al. 2016, 4 Mishra et al. 2016, * Johansson et al. 2015, 5 Khorozyan et al. 2015, 6 Khan et al. 2014, 7 Meheswari et al. 2013, 8 Suryawanshi et al. 2015, 9 Meheb et al. 2012, 10 Jackson et al. 2010, 11 Qamar et al. 2010, 12 Sangay & Vernes 2008, 13 Ogra 2008, 14 Namgail et al. 2007, 15 Bagchi & Mishra 2006, 16 Wang & Macdonald 2006, 17 Mishra & Fitzherbert 2004, 18 Jackson et al. 2003, 19 Jackson et al. 2002, 20 Jackson & Wangchuk 2001, 21 Linnell et al. 1999, 22 Mishra 1997, 23 Jackson et al. 1996

Contribution to SLHC: ElsP = Expose Livestock (ls) to Predator; UlsEP = Unattended ls Easy Prey; MCE = More Chance of Encounter; SlsPP = Some ls more Prone to Predation than others; LHMCE = Larger Herds More Chance of Encounter; DlsEC = Diseased ls Easy to Catch; PAlsS = Predator Attack ls for Survival; ICPA = Increase the Chance of Predator Ambush; IP = Increase Predators; ICPK = Increase the Chance of Predator Killing; MCEP = More Chance of Encounter with Predator; CAPIs = Can't Afford to Protect Livestock

domains – preventive, supportive, and compensatory – are widely reflected in the snow leopard-human conflict literature (Table 4). Most articles focused on predator-proof corrals (47% of articles), training shepherds and improving livestock guarding (42%), livestock insurance schemes (36%), and compensation for livestock predation (33%). Capacity building and education (25%), improved breeds of (or just use of) guard dogs (25%), and conservation of wild prey (19%) were also prominent in the literature (Appendix 2).
Discussion

Snow leopard-human conflict factors are numerous and understanding them is key in conflict mitigation and overall conservation of the species as well as community livelihood. Sangay and Vernis (2008) divided the conflict factors into two main categories: 1) herder-induced factors, such as poor herding and livestock management practices, overgrazing, and bigger herd sizes (Wang and Macdonald 2006, Chetri et al. 2019), and 2) factors that are out of herders’ control; e.g., predator density and behavior, wild prey populations, and predator-prey interactions (Mishra et al. 2001, Sangay and Vernis 2008). Our review, however, not only focuses on those factors but also identified socio-economic and policy related domains. Rashid et al. (2020) recently published a review of snow leopard-human conflict literature, including the spatio-temporal distribution of research articles, data collection.
methodologies, conflict mitigation factors, and potential options for snow leopard-human conflict management. Our review, not surprisingly, aligns with the findings of Rashid et al. (2020) to a great extent, although we also investigated: 1) livestock, wild prey, and predator densities; 2) percent snow leopard, wolf and lynx predation within the snow leopard’s range; and 3) the contributing factors to livestock predation reflected within the literature.

Understanding livestock, wild prey, and predator densities inform management decisions and conflict mitigation strategies, which eventually help predator species conservation as well as community livelihood. The amount of livestock predation can differ by every predator species in multi-predator landscapes (Moheb 2020), which sometimes result in accusing one predator species more than the others while the reality could be otherwise. While predation strategies differ by predators (Alexander et al. 2015), understanding the scope and amount of predation by every predator species is key for identifying species-specific solutions.

Our literature review reveals that not many of the conflict mitigation schemes are tested for effectiveness in their respective areas. The snow leopard-human conflict literature, in most cases (>78%), only suggest or report conservation and conflict mitigation measures rather than follow-up studies to test the effectiveness of those measures. Some conflict mitigation measures could be area- and species-specific and testing the effectiveness of such programs will help snow leopard and other carnivores throughout their global range.

Rashid et al. (2020) listed compensation programs, livestock management strategies, and community interventions as the most common interventions, and they recommended more focus on “rangeland management” for future HSLC mitigation. However, in terms of intervention practices, we found that predator-proofing of corrals, training shepherds and improving livestock guarding, and livestock insurance were more commonly identified mitigation interventions as compared to compensation programs. Compensation for livestock loss, although widely used as compared to some other conflict-mitigation interventions, has different challenges including an exhaustive case verification process, and in many cases it is unsatisfactory for the impacted herders as the amount of loss is often far higher than the compensation herders receive (Jackson and Wangchuk 2001, Chen et al. 2016, Valentova 2017). Also, compensation for livestock loss frequently struggles with long-term sustainability due to insufficient funding resources.

Snow leopard predation on livestock pose varying amount of economic loss to local communities’ dependent on livestock for their livelihood. The average economic loss due to snow leopard predation was up to 23.9%, ranging from 0.6–52% of herders’ family per capita income. Supportive and compensatory mitigation measures relate to alleviating the economic hardship for the communities; however, these measures are rarely effective because they rarely match the actual loss, and other restrictions cause communities to remain unhappy with the process. This affects their attitude towards snow leopard and overall conservation programs in their areas. Although less than one third of the reviewed articles (n = 14) have reported the attitudes of local communities towards snow leopard and overall conservation programs, over 57%, 43%, and 7% of the articles reported positive, negative, and neutral attitudes, respectively.
It appears that conservation programs are imbalanced (Samelius et al. 2020) in at least two directions. First and most important, conservation biologists usually focus on the ecological outcome of their mitigation efforts as they aim to see the number of the target species increase (Redpath et al. 2015); this is different than the approach that considers both community livelihood and protection of predator species. Second, most snow leopard conservation programs only focus on the snow leopards and do not involve other relatively common and less threatened predators, although they co-occur in the landscape. For example, wolves and lynx share habitats with snow leopards and they also depredate livestock (Din et al. 2017, Namgail et al. 2007, Chen et al. 2016). Predation by sympatric predators also poses a threat to local community livelihoods, which often exacerbates negative attitudes of herder communities towards all predators (Samelius et al. 2020). However, abundance of other predator species may also decrease snow leopard predation on livestock. Din et al. (2019) have associated relatively limited snow leopard predation with the abundance of wolves in the Pamir region; however, they did not provide a reason or hypothesize why this might be the case.

Because protected areas cover only around 10% of snow leopard global range (Rashid et al. 2020), more than just land conservation designation is needed to ensure long-term sustainability of snow leopard populations. Reducing carnivore predation on livestock is essential for successful carnivore conservation (Linnell et al. 1999), and recent scientific literature has suggested a number of conflict mitigation measures. Future management efforts need to take into account the full range of possibilities, and then tailor an approach depending on specific cultural, economic, and ecological circumstances.

References

Alexander, J.S., Chen, P., Damerell, P., Youkui, W., Hughes, J., Shi, K., Riordan, P., 2015. Human wildlife conflict involving large carnivores in Qilianshan, China and the minimal pawprint of snow leopards. Biological Conservation, 187:1–9.

Alexander, J.S., Jeremy, J., Cusack, Pengju, C., Kun, S., Riordan, P., 2016. Conservation of snow leopards- spill-over benefits for other carnivores? Oryx, 50:239–243.

Aryal, A., Brunton, D., Ji, W., Barraclough, R.K., Raubenheimer, D., 2014. Human–carnivore conflict: ecological and economical sustainability of predation on livestock by snow leopard and other carnivores in the Himalaya. Sustainability Science 9:321–329.

Bagchi, S., Mishra, C., 2006. Living with large carnivores: predation on livestock by the snow leopard (Uncia uncia). Journal of Zoology, 268:217-224.

Bhatia, S., Redpath, S.M., Suryawanshi, K. Mishra, C., 2016. The relationship between religion and attitudes toward large carnivores in Northern India. Human Dimensions of Wildlife, 22:30–42.

Chen, P., Gao, Y., Lee, A.T., Cering, L., Shi, K., Clark, S.G. 2016. Human–carnivore coexistence in Qomolangma (Mt. Everest) Nature Reserve, China: Patterns and compensation. Biological Conservation, 197:18–26.

Chetri, M., Odden, M., Devineau, O., Wegge, P., 2019. Patterns of livestock depredation by snow leopards and other large carnivores in the Central Himalayas, Nepal. Global Ecology and Conservation, 17: e00536.

Chetri, M., Odden, M., Wegge, P., 2017. Snow Leopard and Himalayan Wolf: Food Habits and Prey Selection in the Central Himalayas, Nepal. PLoS ONE 12(2): e0170549.

Din, J.U., Nawaz, M.A., Mehmoood, T., Ali, H., Ali, A., Adli, D.S.H., Norma-Rashid, Y., 2019. A transboundary study of spatiotemporal patterns of livestock predation and prey preferences by snow leopard and wolf in the Pamir. Global Ecology and Conservation 20:e00719.

Din, J.U., Ali, H., Ali, A., Younus, M., Mehmoood, T. Norma-Rashid, Y., Nawaz, M.A., 2017. Pastoralist-predator interaction at the roof of the world: Conflict dynamics and implications for conservation. Ecology and Society, 22(2):32.

Din, J.U., Nawaz, M.A., 2011. Status of snow leopard and prey species in Torkhow Valley, District Chitral, Pakistan. The Journal of Animal & Plant Sciences, 21:836–840.

Gurung, G.S, Thapa, K., Kunkel, K., Thapa, G.J., Kollmair, M., Müller-Böker, U., 2011. Enhancing herders’ livelihood and conserving the snow leopard in Nepal. CATNews, 55:17–21.
Hussain, S. 2000. Protecting the Snow leopard and enhancing farmers' livelihoods. Mountain Research Development, 20:226–231.

Hussain, S., 2003. The status of the snow leopard in Pakistan and its conflict with local farmers. Oryx, 37:26–33.

Ikeda, N., 2004. Economic impacts of livestock depredation by snow leopard Uncia uncia in the Kanchenjunga Conservation Area, Nepal Himalaya. Environmental Conservation, 31:322–330.

Jackson, R.M., Wangchuk, R., 2001. Linking Snow Leopard Conservation and People-Wildlife Conflict Resolution: Grassroots Measures to Protect the Endangered Snow Leopard from Herder Retribution. Endangered Species UPDATE, 18:138–141.

Jackson, R.M., Wangchuk, R., Dadul, J., 2003. Local people’s attitudes toward wildlife conservation in the Hemis National Park, with special reference to the conservation of large predators. SLC field series document No 7. Sonoma, CA: The Snow Leopard Conservancy.

Jackson, R.M., Wangchuk, R., 2004. A community-based approach to mitigating livestock depredation by snow leopards. Human Dimension of Wildlife, 9:1–16.

Jackson, R.M., Mishra, C., McCarthy, T.M., Ale, S.B., 2010. Snow leopards: conflict and conservation. In: Macdonald, D.W., Loveridge, A.J. (Eds.), the biology and conservation of wild felids. Oxford University Press, Oxford, UK, pp.417–430.

Jackson, R.M., 2015. HWC ten years later: Successes and shortcomings of approaches to global snow leopard conservation. Human Dimensions of Wildlife, 20:310–316.

Jackson, R., Wangchuk, R., Hillard, D. 2002. Grass roots measures to protect the endangered snow leopard from herder retribution: lessons learned from predator-proofing corrals in Ladakh. In: Proceedings of the snow leopard survival summit. Seattle, p 104–117.

Jackson, R., Wangchuk, R., 2001. Linking snow leopard conservation and people-wildlife conflict resolution: grassroots measures to protect the endangered snow leopard from herder retribution. Endangered Species UPDATE, 18:138–141.

Jackson, R.M., Ahlborn, G., Gurung, M., Ale, S.B., 1996. Reducing livestock depredation losses in the Nepalese Himalaya. University of California, 241–247.

Jamwal, P.S., Takpa, J., Parsons, M.H., 2019. Factors contributing to a striking shift in human–wildlife dynamics in Hemis National Park, India: 22 years of reported snow leopard depredation. Oryx, 53:58–62.

Johansson O, McCarthy, T., Samelius, G., Andren, H., Tumursukh, L., Mishra, C., 2015. Snow leopard predation in a livestock dominated landscape in Mongolia. Biological Conservation, 184:251–258.

Kachel, S.M., McCarthy, K.P., McCarthy, T.M., Oshurmamadov, N., 2017. Investigating the potential impact of trophy hunting of wild ungulates on snow leopard Panthera uncia conservation in Tajikistan. Oryx, 51:597–604.

Kansky, R., Kidd, M., Knight, A.T., 2014. Meta-analysis of attitudes toward damage-causing mammalian wildlife. Conservation Biology, 28:924–938.

Karimov, K., Kachel, S.M., Hackländer, K., 2018. Responses of snow leopards, wolves and wild ungulates to livestock grazing in the Zorkul Strictly Protected Area, Tajikistan. PloSone, 13(11).

Khan, B., Ablimit, A., Nawaz, M.A., Ali, R., Khan, M.Z., Din, J.U., Karim, R., 2014. Pastoralist experience and tolerance of snow leopard, wolf and lynx predation in Karakoram Pamir Mountains. Journal of Biodiversity and Environmental Sciences, 5:214–229.

Khan, M.Z., Khan, B., Awan, M.S., Begum, F., 2018. Livestock depredation by large predators and its implications for conservation and livelihoods in the Karakoram Mountains of Pakistan. Oryx, 52:519–525.

Khorozyan, I., Ghoddousi, A., Soofi, M., Waltert, M., 2015. Big cats kill more livestock when wild prey reaches a minimum threshold. Biological Conservation, 192:268–275.

Lamb, C.T., Ford, A.T., McLellan, B.N., Proctor, M.F., Mowat, G., Ciarniello, L., Nielson, S.E., Boutin, S. 2020. The ecology of human–carnivore coexistence. Ecology, 1–8.

Li, J., Yin, H., Wang, D., Jiagong, Z., Lu, Z., 2013. Human-snow leopard conflicts in the Sanjiangyuan Region of the Tibetan Plateau. Biological Conservation, 166:118–123.

Li, C., Jiang, Z., Li, C., Tang, S., Li, F., Luo, Z., Ping, X., Lii, Z., Chin, J., Fang, H., 2015. Livestock depredations and attitudes of local pastoralists toward carnivores in the Qinghai Lake Region, China. Wildlife Biology, 21:204–212.

Linnell, J.D.C., Odden, J., Smith, M.E., Aanes, R., Swenson, J.E., 1999. Large carnivores that kill livestock: do problem individuals really exist? Wildlife Society Bulletin, 27:698–705.

Maheshwari, A., Sharma, D., Sathyakumar, S., 2013. Snow leopard (Panthera uncia) surveys in the Western Himalayas, India. Journal of Ecology and the Natural Environment, 5:303–309.

Mijiddorj, T.N., Alexander, J.S., Samelius, G., Badola, R., Rawat, G.S., Dutta, S., 2018. Corrigendum to: Livestock depredation by large carnivores in the South Gobi, Mongolia. Wildlife Research, 45:381–381.

Mishra, C., Fitzherbert, A., 2004. War and wildlife: a post-conflict assessment of Afghanistan’s Wakhan Corridor. Oryx, 38:102–105.

Mishra, C., Prins, H.H.T., Van Wieren, S.E., 2001. Overstocking in the trans-Himalayan rangelands of India. Environmental Conservation, 28:279–283.
Mishra, C., 1997. Livestock depredation by large carnivores in the Indian trans-Himalaya: conflict perceptions and conservation prospects. Environmental Conservation, 24:338–343.

Mishra, C., Allen, P., McCarthy, T., Madhusudan, M.D., Bayarjargal, A., Prins, H.H.T., 2003. The role of incentive programs in conserving the snow leopard. Conservation Biology, 17:1512–1520.

Mishra, C., Redpath, S.R., Suryawanshi, K.S. 2016. Livestock predation by snow leopards: conflicts and the search for solutions. pp.59–67 In T. McCarthy, D. Mallon, and P. J. Nyhus (Eds.) Snow Leopards: Biodiversity of the World: Conservation from Genes to Landscapes. Elsevier Inc., Academic Press, London, UK.

Moheb, Z., Paley, R., 2016. Central Asia: Afghanistan. pp.409–417 In T. McCarthy, D. Mallon, and P. J. Nyhus (Eds.) Snow Leopards: Biodiversity of the World: Conservation from Genes to Landscapes. Elsevier Inc., Academic Press, London, UK.

Moheb, Z., Lawson, D., Mostafawi, S.N., 2012. Brown bear status and threats in Darwaz, Northern Badakhshan, Afghanistan. Ursus, 23:237–241.

Moher D, Liberati, A., Tetzlaff, J., Altman, D.G., 2009. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed.1000097.

Namgail, T., Fox, J.L., Bhatnagar, Y.V., 2007. Carnivore-caused livestock mortality in Trans-Himalaya. 490–496.

Oli, M.K., Taylor, I.R., Rogers, M.E., 1994. Snow leopard Panthera uncia predation of livestock: an assessment of local perceptions in the Annapurna Conservation Area, Nepal. Biological Conservation, 68:63–68.

Ogra, M., 2008. Human-wildlife conflicts and gender in protected area borderlands: a study of costs, perceptions and vulnerabilities from Uttarakhand, India. Geoforum, 39:1408–1422.

Qamar, Q.Z., Dar, N.I., Ali, U., Minhas, R.A., Ayub, J., Anwar, M., 2010. Human–leopard conflict: An emerging issue of common leopard conservation in Machiara National Park, Azad Jammu and Kashmir, Pakistan. Pakistani Journal of Wildlife, 1:50–56.

Rashid, W., Shi, J., Rahim, I. ur., Sultan, H., Dong, S., Ahmad, L., 2020. Research trends and management options in human-snow leopard conflict. Biological Conservation, 242:108413.

Redpath, S.M., Bhatia, S., Young, J., 2015. Tilting at wildlife: Reconsidering human-wildlife conflict. Oryx, 49:222–225.

Redpath, S.M., Young, J., Evely, A., Adams, W.M., Sutherland, W., Whitehouse, A., Amar, A., Lambert, R.A., Linnell, J.D.C., Watt, A., 2013. Understanding and managing conservation conflicts. Trends in Ecology and Evolution, 28:100–109.

Robinson, H., Weckworth, B., 2016. Landscape Ecology: Linking Landscape Metrics to Ecological Processes, in: McCarthy, T., Mallon, D., Nyhus, P.J. (Eds.), Snow Leopards: Biodiversity of the World: Conservation from Genes to Landscapes. Elsevier, Academic Press, pp. 345–353.

Samelius, G., Suryawanshi, K., Frank, J., Agvaantseren, B., Baasandamba, E., Mijiddorj, T., Johansson, Ö., Tumursukh, L., Mishra, C., 2020. Keeping predators out: testing fences to reduce livestock depredation at night-time corrals. Oryx, 1–7.

Sangay, T., Vernes, K., 2008. Human-wildlife conflict in the Kingdom of Bhutan: patterns of livestock predation by large mammalian carnivores. Biological Conservation, 141:1272–1282.

Sharma, K.S., Bhatnagar, Y.V., Mishra, C., 2015. Does livestock benefit or harm snow leopards? Biological Conservation, 190:8–13.

Snow Leopard Network. 2014. Snow Leopard Survival Strategy, Seattle, Washington, USA. 1e145.

Sullivan, C.D., Pengju, C., Alexander, J.S., Defeng, B., Kun, S., 2018. Conflict on the range: evaluating driving factors of attitudes toward prey species in Qilianshan. Journal of Resources and Ecology, 9:554–565.

Suryawanshi, K.R., Bhatnagar, Y.V., Redpath, S., Mishra, C., 2013. People, predators and perceptions: patterns of livestock depredation by snow leopards and wolves. Journal of Applied Ecology, 50:550–560.

Suryawanshi, K.R., Redpath, S.M., Bhatnagar, Y.V., Ramakrishnan, U., Chaturvedi, V., Smout, S.C., Mishra, C., 2017. Impact of wild prey availability on livestock predation by snow leopards. Royal Society Open Science, 4(6), p.170026.

Valentová, K.A., 2017. Abundance and threats to the survival of the snow leopard—a review. European Journal of Environmental Sciences, 7:73–93.

Wang, S.W., Macdonald, D.W., 2006. Livestock predation by carnivores in Jigme Singye Wangchuck National Park, Bhutan. Biological Conservation, 129:558–565.

Wegge, P., Shrestha, R., Flagstad, Ø., 2012. Snow leopard Panthera uncia predation on livestock and wild prey in a mountain valley in northern Nepal: implications for conservation management. Wildlife Biology, 18:131–141.

Wilman, E.A., Wilman, E.N., 2016. Modeling outcomes of approaches to sustained human and snow leopard coexistence. Conservation Biology, 30:50–58.

Young, J.C., Marzano, M., White, R.M., McCracken, D., Redpath, S., Cars, D., Quine, C.P., Watt, A., 2010. The emergence of biodiversity conflicts from biodiversity impacts: Characteristics and management strategies. Biodiversity Conservation, 19:3973–3990.
Appendix 1. Research articles appeared in the literature search for the snow leopard range countries.

| COUNTRY AND REGION | MAIN PREDATOR SPECIES | TYPE OF DATA | REFERENCE |
|--------------------|-----------------------|--------------|-----------|
| **Afghanistan (3)** |                       |              |           |
| Wakhan National Park | wolf                  | Interview    | Din et al. 2019 |
| Wakhan National Park | wolf                  | Interview    | Din et al. 2017 |
| Wakhan National Park | wolf, lynx            | Interview, field survey | Misra & Fitzherbert 2004 |
| **Bhutan (1)**     |                       |              |           |
| Entire country     | leopard, tiger, black bear | Compensation records | Sangay & Vernes 2008 |
| **China (5)**      |                       |              |           |
| Qomolangma National NR | wolf, lynx            | Compensation records | Chen et al. 2016 |
| Qilianshan National NR | wolf, lynx, brown bear | Interview | Alexander et al. 2015 |
| Qilianshan National NR | wolf, fox, dhole, lynx | Camera trap data | Alexander et al. 2016 |
| Tashkorgan          | wolf, lynx, brown bear | Interview | Khan et al. 2014 |
| Sanjiangyuan, Qinghai | wolf, lynx, brown bear | Interview | Li et al. 2013 |
| **India (11)**     |                       |              |           |
| Hemis National Park |                       | Camera trap data | Sharma et al. 2015 |
| Spiti Valley       |                       | Interview and scat analysis | Maheshwari et al. 2013 |
| Uttarakhland       |                       | Field surveys and interview | Suryawanshi et al. 2013 |
| Spiti Valley/Jammu & Kashmir | wolf | Surveys, trapping, scat analysis | Suryawanshi et al. 2017 |
| Ladakh             |                       | Interview | Namgai et al. 2007 |
| Pin Valley NP/Kibber Wildl Sanc | | Scat analysis | Bagchi & Mishra 2006 |
| Hemis National Park |                       | Project report | Jackson & Wangchuk 2004 |
| Kibber in Spiti Valley |                   |             | Mishra et al. 2003 |
| Hemis National Park |                       | Interview | Jackson & Wangchuk 2001 |
| Trans-Himalaya     |                       | Interview and field survey | Mishra 1997 |
| **Mongolia (4)**   |                       |              |           |
| Great Gobi Protected Area |              | Project report | Mishra et al. 2003 |
| Tost and Bayasah, South Gobi | | Interview | Mijidjordj et al. 2018 |
| Tost in South Gobi |                       | Surveys, trapping, scat analysis | Suryawanshi et al. 2017 |
| Tost Mountain      |                       | GPS Telemetry | Johansson et al. 2015 |
| **Nepal (7)**      |                       |              |           |
| Annapurna-Manaslu landscape | wolf | Semi-structure questionnaire | Chetri et al. 2019 |
| Annapurna-Manaslu landscape | wolf | Scat analysis-genetics | Chetri et al. 2017 |
| Mustang region     | wolf, fox, jackal, lynx | Interview | Aryal et al. 2014 |
| Phu Valley         |                       | Scat analysis-genetics | Wegge et al. 2012 |
| Kangchenjunga Conserv. Area | | Interview | Gurung et al. 2011 |
| Kanchenjunga Conserv. Area | | Interview | Ikeda 2004 |
| Annapurna Conserv. Area | | Interview | Oli et al. 1994 |
| **Pakistan (7)**   |                       |              |           |
| Misgar, and Chuparsan | wolf | Interview | Din et al. 2019 |
| Misgar, and Chuparsan | wolf | Interview | Din et al. 2017 |
| Hushey Valley      | wolf                  | Interview    | Khan et al. 2018 |
| Khunjerab          | wolf, lynx, brown bear | Interview | Khan et al. 2014 |
| Torkhow Valley     |                       | Sign survey/Questionnaire | Din & Nawaz 2011 |
| Baltistan          |                       | Interview, field survey | Hussain 2003 |
| Baltistan          |                       | Project report | Hussain 2000 |
| **Tajikistan (3)** |                       |              |           |
| Tokhtamish, Shymak, Alichur | wolf | Interview | Din et al. 2019 |
| Zorkul Reserve     | wolf, bear            | Scat analysis, Camera trap | Karimov et al. 2018 |
| Tokhtamish, Shymak, Alichur | wolf | Interview | Din et al. 2017 |

Note: no peer-reviewed research article appeared in the literature search for Kazakhstan, Kyrgyzstan, Russia, and Uzbekistan.

* = Double observer survey, interview, camera trapping, scat analysis
## Appendix 2. Details of the proposed/reported conflict mitigation schemes.

| CONFLICT MITIGATION SCHEMES | CITATION |
|----------------------------|----------|
| **Building predator proof corrals** |  |
| Improving corrals | Din et al. 2019 |
| Predator-proof corrals construction | Mijiddorj et al. 2018 |
| Use of predator-proof corrals | Alexander et al. 2016 |
| Building predator-proof corrals | Moheb & Paley 2016 |
| Subsidizing the predator-proof corral construction | Wilman & Wilman 2016 |
| Predator-proofing of high-risk corrals | Jackson 2015 |
| Predator-proof corrals | Qamar et al. 2010 |
| Building proper corralling facilities | Wang & Macdonald 2006 |
| Predator-proof livestock corrals | Ikeda 2004 |
| Building predator-proof corrals | Jackson & Wangchuk 2001 |
| Building predator-proof corrals | Mishra 1997 |
| **Compensation for livestock predation** |  |
| Self-financed compensation schemes | Mishra 1997 |
| Predation compensation programs | Din et al. 2017 |
| Compensation schemes | Alexander et al. 2015 |
| Compensation for livestock losses | Jackson 2015 |
| Compensation schemes for livestock losses | Khan et al. 2014 |
| Efficient compensation | Bagchi & Mishra 2006 |
| Financial compensation | Wang & Macdonald 2006 |
| Compensatory programs | Ikeda 2004 |
| Compensation schemes | Jackson & Wangchuk 2001 |
| Financial compensation program | Oli et al. 1994 |
| **Livestock management** |  |
| Better husbandry practices | Alexander et al. 2016 |
| Improved animal husbandry | Jackson & Wangchuk 2001 |
| Improved animal husbandry practice | Oli et al. 1994 |
| Stricter livestock herding practices | Chetri et al. 2019 |
| Livestock management | Mijiddorj et al. 2018 |
| Measures to address other livestock mortalities | Alexander et al. 2015 |
| Improving animal husbandry techniques | Jackson & Wangchuk 2001 |
| Animal husbandry modifications | Linnell et al. 1999 |
| Preventing livestock increase in the future | Mishra 1997 |
| **Training shepherds and improving livestock guarding** |  |
| Training shepherds | Din et al. 2019 |
| Improved livestock guarding | Khan et al. 2018 |
| Livestock herding practice | Mijiddorj et al. 2018 |
| Training shepherds how to guard their livestock | Moheb & Paley 2016 |
| Improved daytime livestock guarding | Jackson 2015 |
| Enhanced livestock guarding | Qamar et al. 2010 |
| Improved livestock herding practice | Bagchi & Mishra 2006 |
| Improving shepherds’ herding and guarding practices | Wang & MacDonald 2006 |
| **Livestock insurance schemes** |  |
| Livestock insurance schemes | Din et al. 2019 |
| Livestock insurance schemes | Din et al. 2017 |
| Livestock insurance schemes | Wilman & Wilman 2016 |
| Community-managed livestock insurance schemes | Jackson 2015 |
| Livestock insurance schemes | Qamar et al. 2010 |
| Livestock insurance schemes | Bagchi & Mishra 2006 |
| Livestock insurance schemes | Wang & Macdonald 2006 |
| CONFLICT MITIGATION SCHEMES | CITATION |
|----------------------------|----------|
| Removal of the carnivore species (either based on previous literature or suggested by the respondents) | Eradication (30% of respondents suggested in KWS) | Bagchi & Mishra 2006 |
| | Mechanisms to remove animals responsible for predations | Ikeda 2004 |
| | Removal of carnivores reported in earlier literature | Linnell et al. 1999 |
| | Elimination of trouble causing animals | Mishra 1997 |
| | Extermination suggested by most of the respondents | Oli et al. 1994 |
| Livelihood schemes | Wildlife tourism in the area | Oli et al. 1994 |
| | Handicrafts training, marketing, ecotourism trekking | Jackson & Wangchuk 2001 |
| | Handicrafts production | Jackson 2015 |
| | Involve herders in ecotourism activities | Ikeda 2004 |
| Capacity building and awareness programs | Education | Din et al. 2017 |
| | Capacity building & awareness at local & national levels | Moheb & Paley 2016 |
| | Educating herders on the importance of protecting natural prey | Jackson & Wangchuk 2001 |
| | Education program | Oli et al. 1994 |
| Conservation of wild prey species | Leasing pastures for wild prey | Wilman & Wilman 2016 |
| | Prey species restoration | Jackson 2015 |
| | Wild prey protection | Khan et al. 2014 |
| | Conservation of wild prey species | Moheb et al. 2012 |
| Livestock vaccination | Livestock vaccination | Din et al. 2019 |
| | Livestock disease control | Din et al. 2017 |
| | Livestock vaccination | Wilman & Wilman 2016 |
| | Immunization of livestock against diseases | Jackson 2015 |
| Avoiding predator habitats | Avoid predator habitats for grazing | Qamar et al. 2010 |
| | Land use zoning (avoidance of predator areas) | Linnell et al. 1999 |
| | Avoidance of depredation hotspots | Jackson 2015 |
| Guard dogs | Good breeds of dogs | Qamar et al. 2010 |
| | Introduction of guard dogs | Ikeda 2004 |
| | Use of guard dogs | Khan et al. 2018 |
| Community based conservation initiatives | Paying herders for snow leopard conservation | Wilman & Wilman 2016 |
| | Community perceived ownership of the conservation projects | Jackson et al. 2002 |
| | Initiation of a community-based conservation program | Din & Nawaz 2007 |
| Pasture management | Adapting grazing restrictions | Alexander et al. 2015 |
| | Pasture improvement | Wang & Macdonald 2006 |
| Other conflict mitigation measures | Mapping conflict hotspots and investing in those areas | Chetri et al. 2019 |
| | Wire and stone fencing, flags, fire and scarecrows (reported by herders) | Mijiddorj et al. 2018 |
| | Creation of core areas for snow leopard conservation | Ikeda 2004 |