ISSN 1027-2992

Special Issue

N° 15 | Summer 2022

CAT news

The Persian Leopard

SPECIES SURVIVAL COMMISSION

CAT SPECIALIST GROUP

CATnews is the newsletter of the Cat Specialist Group, a component of the Species Survival Commission SSC of the International Union for Conservation of Nature (IUCN). It is published twice a year, and is available to members and the Friends of the Cat Group.

For joining the Friends of the Cat Group please contact Christine Breitenmoser at ch.breitenmoser@kora.ch

Original contributions and short notes about wild cats are welcome
Send contributions and observations to ch.breitenmoser@kora.ch.

Guidelines for authors are available at www.catsg.org/catnews

This **Special Issue of CATnews** has been produced with support from the Foundation Segré.

Design: barbara surber, werk'sdesign gmbh
Layout: Eline Brouwer and Tabea Lanz
Print: Stämpfli AG, Bern, Switzerland

ISSN 1027-2992

Editors: Christine & Urs Breitenmoser
Co-chairs IUCN/SSC
Cat Specialist Group, KORA
Villettengässli 4, 3074 Muri,
Switzerland
Mobile ++41(79) 789 84 65 (C)
Mobile ++41(79) 410 14 39 (U)
<u.breitenmoser@kora.ch>
<ch.breitenmoser@kora.ch>

Cover Photo: Persian Leopard in Kazakhstan © USNR/CADI/ACBK, camera trap picture taken 1 January 2020, photo was provided by Tatjana Rosen

MAHMOOD SOOFI[1,2*], IGOR KHOROZYAN[3] AND BENJAMIN GHASEMI[4]

Coexistence between leopards and local people – challenges and solutions

Human-predator conflict can significantly affect rural livelihoods and the survival of many predator species worldwide. The Persian leopard *Panthera pardus tulliana* is not an exception, and its distribution range has markedly shrunk to a few Middle Eastern and Central Asian countries. Economic growth and various human activities such as livestock husbandry practices are increasingly overlapping with leopard habitats, making human-leopard conflicts inevitable. Such conflicts are particularly common in areas with reduced wild prey availability, which force leopards to prey on domestic animals. As a result, leopards have often been killed in retaliation or as a preventive measure to reduce livestock losses. To ensure the long-term population persistence of leopards, it is crucial to mitigate conflicts by promoting human-leopard coexistence in shared landscapes. In this paper, we describe potential approaches and related case studies where efforts have been made to foster positive interactions between humans and leopards in their range countries. We synthesized published evidence and suggest practical interventions, including: (i) protective collars for livestock, (ii) predator-proof corrals, (iii) deterrents, (iv) financial incentives and compensation programmes, and (v) livestock guarding dogs and herding. We underline that the success of these interventions will require systematic monitoring and evaluation plans allowing the objective assessment of outcomes to facilitate informed and effective management decisions.

Human-wildlife conflicts continue to challenge conservation efforts (Khorozyan et al. 2020) and need to be managed to reduce negative impacts on biodiversity, local livelihoods and human well-being (Redpath et al. 2013). A typical example of human-wildlife conflict is when a species, or a group of species, damages local economic assets such as crops or livestock (Fig. 1), causing anger and fear among affected people, and leading to retaliatory or preventive removal of the animals. Socio-psychological effects of and responses to the conflict may vary greatly among different social groups (local people, NGOs, government, international organisations) because they usually hold different values, and the situation can escalate through rumours, social media, and social networks.

The Persian leopard (*Panthera pardus tulliana*) is a flagship big cat whose distribution has contracted dramatically and is now restricted only to several Middle Eastern and Central Asian countries (Jacobson et al. 2016). A number of key threats continue to contribute to population declines and range contraction, particularly in the Iranian stronghold (Kiabi et al. 2002), as well as in other range countries. These threats include, but are not limited to, wild prey depletion (Ghoddousi et al. 2019, Soofi et al. 2019) and illegal killing of leopards (Parchizadeh & Belant 2021a, Soofi et al. 2022). Persian leopards have been persecuted for multiple reasons, such as social conflicts and financial costs induced by livestock depredation (Khorozyan et al. 2015), in retaliation to and for preventing attacks on humans (Parchizadeh & Belant 2021b), or to make money by trading skins. The amounts of livestock depredation and, correspondingly, the intensity of human-leopard conflict have been worsened by inadequate livestock grazing and handling practices (Ghoddousi et al. 2016, Babrgir et al. 2017, Soofi et al. 2018, 2022).

The availability of wild and domestic prey on which leopards depend for their survival is one of the main factors of this conflict. For example, when wild prey becomes scarce, leopards may switch to domestic species (Fig. 1; Khorozyan et al. 2015, Braczkowski et al. 2018). However, leopard predation on livestock may also exist when wild prey abundance is high because wild prey availability may support larger predator populations and thus increase encounters of predators with livestock (Soofi et al. 2022). Either way, livestock becomes vulnerable to predation by leopards, which ultimately triggers a conflict.

Human-predator interactions can go far beyond the competition for space, food, and human safety (Treves & Karanth 2003) and represent a multifaceted process incorporating different social, psychological, and legal issues (Brouwer 2021, Carter et al. 2021). Clearly, the Persian leopard's charismatic status is insufficient to avert it from the risk of extinction. Laws, regulations, and high financial penalties for violators fail to halt leopard killings across the region since they are rarely enforced (Soofi et al. 2022), and their effectiveness is questionable. Therefore, it is vital to ensure the long-term persistence of the leopard population (Bleyhl et al. 2021) by promoting coexistence with humans in shared landscapes. This is a daunting task as the wide-ranging behaviour of leopards (Farhadinia et al. 2018) coupled with rural development and urbanization lead to an increased risk of encounters between people, grazing livestock and leopards (Soofi et al. 2018, 2022). Reducing all kinds of illegal leopard killings (shooting, poisoning, trapping and vehicle collisions) related to livestock losses

Fig. 1. A female leopard feeding on a cattle carcass in Mazandaran Province, northern Iran (Photo K. Rabie, Mazandaran provincial office of the Department of Environment).

(Babrgir et al. 2017, Soofi et al. 2019) and attacks on humans (Parchizadeh & Belant 2021b, Soofi et al. 2022) is essential to recover the leopard population (Bleyhl et al. 2021). Coexistence between humans and leopards should become a long-term strategy, especially in and around protected areas where leopard densities are usually higher, and land sharing between people and leopards becomes most problematic (Lukarevsky 2003, Soofi et al. 2019, 2022). Conservation programmes for leopard population recoveries should be geared toward preventing the escalation of human-leopard conflicts and developing and applying practical coexistence mechanisms.

Procedures for developing human-leopard coexistence practices are generally lacking across the range of this big cat. Threats and opportunities related to human-leopard coexistence should be clearly identified concerning the financial costs of conservation measures, social acceptance (perceptions, traditions and beliefs), and education and outreach (awareness-raising, capacity building and alternative livelihoods; Carter et al. 2021). Implementa-tion of conflict mitigation and other measures required to promote coexistence should not only be based on the global experience, but also be meticulously considered in terms of their applicability and associated risks in the Middle East and Central Asia. In this paper, we describe a number of practices and their potential impacts on fostering positive interactions between humans and leopards in shared landscapes of the region. We focus on ways to minimise leopard-caused damage to livestock, which is the main cause of human-leopard conflicts in some parts of the region, including Iran (Memarian et al. 2018, Soofi et al. 2019, 2022), the Talysh Mts. in Azerbaijan (Khorozyan et al. 2022) and northern Afghanistan (Karlstetter 2008). Our aims were to:

1. Introduce practical and socially acceptable measures facilitating human-leopard coexistence;
2. Describe roadmaps that can be embedded within the regional conservation strategy and national action plans related to the resolution of human-leopard conflicts and the establishment of coexistence practices;
3. Suggest insights for a regionally standardised and nationally adapted monitoring programme for collecting, maintaining, reporting, analyzing, and disseminating information on human-leopard conflict resolution practices;
4. Summarise the information on the extent of illegal killings occuring in the region and their impact on the Persian leopard population.

Human-leopard conflict in the range countries

Livestock losses to leopards are likely the main cause of human-leopard conflicts in some parts of the Middle East and Central Asia (Khorozyan et al. 2022, Soofi et al. 2022). Hence, here we synthesize the existing evidence from the literature, case studies of conflicts and their practical solutions in the region. Illegal killings cause a strong adverse effect on smaller leopard populations existing in neighbouring countries, which depend on immigrant leopards from Iran.

For instance, in 2013, a leopard was camera-trapped in Hirkan National Park located in the Talysh Mts. of south-eastern Azerbaijan, but after a year, the same individual was poached by a hunter in Gilan Province of Iran (Maharramova et al. 2018). Such incidents suggest a vital role of protected areas that are adjacent to the borders (e.g., Hirkan National Park in Azerbaijan, Lisar Protected Area and Dorfak no-hunting area in Iran). These areas can bridge the source population in Iran and the recipient populations in the Talysh and other areas of the South Caucasus (Moqanaki et al. 2013, Breitenmoser et al. 2017, Shokri et al. 2020). Consequently, continuing illegal killing of leopards in the source population may hamper the dispersal of individuals from Iran (Breitenmoser et al. 2017, Bleyhl et al. 2021). This highlights the need for international cooperation in the areas such as the Caucasus Ecoregion where transboundary conservation is crucial to leopard conservation (Breitenmoser et al. 2017), including cooperation in mitigating human-leopard conflicts. Illegal killing in retaliation to livestock depredation also occurs in northern Afghanistan, where the Persian leopard is the second most frequently livestock-killing predator (52%), provoking local people to often hunt leopards and sell the skins on the black market (Karlstetter 2008). Karlstetter (2008) further reported that leopard attacks on humans were relatively rare, but occurred as a result of precautionary or retaliatory killings.

Drivers of conflict

Socio-ecological factors

In response to losses to leopards, some livestock owners might seek to kill problem predators to retaliate and prevent future depredations (Soofi et al. 2022). A decision "to kill or not to kill" and its follow-up actions depend on the tolerance levels of individual herders (Treves & Bruskotter 2014) and a number of other factors. For example, predators have often been killed in response to livestock predation when solutions such as compensation payments or other interventions are not in place and livestock is the main, or the only, source of income. Farmers receiving compensation payments for livestock losses tend to tolerate predators more than those who do not (Karlsson & Johansson 2010).

Social media

As an iconic large predator, the leopard always attracts attention from the public and the media. Social media have become an important platform for driving public perceptions and opinions. People rapidly share wildlife-related news such as livestock depredation and human injuries/deaths caused by predators on online social networks (Nanni et al. 2020). The social media audience participates in active discussions over human-predator conflict issues and thus influences each other's opinions and perceptions. However, pub-lic perceptions are not uniform, and they can be shaped differently in various professional and social groups such as rural communities, herder and hunter associations, non-governmental organizations, urban people, scientists, and authorities. Eventually, the outcomes of such interactions can directly or indirectly influence the process and direction of decision-making by individuals and organisations involved in the conflict (Redpath et al. 2013). Constant engagement of scientists in the media is required to increase public support for conflict mitigation measures. This would promote disseminating accurate information and halting the flow of misinformation before it becomes widespread (Nanni et al. 2020).

Protective collars for livestock

Leopards often kill their prey by biting the animal's throat, which blocks the pharynx and causes suffocation (Kitchener et al. 2010). Therefore, it is reasonable to protect the animal's neck with a physical barrier, which could reduce the chance of death (McManus et al. 2015). In parts of Iran, cattle often graze within dense vegetation without shepherds or dogs, which provides a favourable condition for the ambush predators like leopards to hunt (Farhadinia et al. 2018). A studded leather collar (Fig. 2) was developed to protect freely grazing cattle in Iran. Such collars can

Fig. 2. Studded leather collars fitted on the necks of cattle in Mazandaran Province, northern Iran to protect from leopard bites (Photos S. Ghoddousi & I. Khorozyan).

be readily made by local people (Khorozyan et al. 2020). The collar resembles a regular belt and can be fitted to different neck sizes. Its effectiveness still needs to be tested on sheep and goats as well as in non-forest landscapes. McManus et al. (2015) successfully applied all-metal mesh collars to sheep in South Africa. However, in Iran they did not work on cattle, sheep and goats because they irritated the neck skin, disturbed animals, and changed their feeding and offspring caring behaviour (Khorozyan et al. 2020).

Predator-proof corrals

Samelius et al. (2019) set up protective nighttime electric fences (18×18 m in size, 2 m high, aluminum nets supported by metal poles and electric wires set on the top) around corrals and found that predation of sheep and goats by snow leopards *Panthera uncia* decreased to nil, resulting in better attitudes towards predators among the livestock owners. Their findings suggested that fenced night corrals can be an effective tool to create and maintain coexistence between people and predators. That study was carried out in Mongolian mountainous habitats similar to those of leopards in the Middle East and Central Asia. Testing this approach on the Persian leopard may provide an important knowledge transfer to this region (Fig. 3). Alternatively, predator-proof corrals can be constructed without fences. In this case, the reinforced sheds are made of stones or concrete with a solid roof and have no openings through which leopards could sneak into the corral. Such sheds are very common in the region's villages, but they are often weak, poorly maintained, and easily accessible to predators. Simple maintenance of sheds, such as fixing strong, well-fit doors and covering openings with metal mesh, can be a cheap and effective way to minimise livestock losses (Khorozyan & Waltert 2019). At the same time, corrals hinder the mobility of herders and their livestock as in many areas of the Middle East and Central Asia transhumant practices are used with seasonal long-distance movements in search of green pastures. For this reason, it is logistically and economically most practical for the pastoralist communities to set up temporary and mobile fenced corrals, primarily within the conflict hotspot areas (Samelius et al. 2019).

Predator deterrents

The effectiveness of predator deterring tools, such as shock collars and devices producing frightening lights and sounds, varies across different predator species and has not yet been sufficiently tested on wild cats (Table 1; Miller et al. 2016). Deterrents are highly sensitive to environmental conditions, vulnerable to malfunctioning, and difficult to use in the field. Another problem that hampers the application of these techniques is that their effectiveness usually diminishes within three months or less (Breitenmoser et al. 2005). Inefficacy of deterrents results from fast habituation of predators to harmless novelties, especially in human-dominated landscapes where predators are adapted to lights and sounds (Khorozyan & Waltert 2019). Also, the effectiveness of deterrents may depend greatly on the individual characteristics of predators and more studies are needed on this aspect. Despite these limitations, predator deterrents can be effectively used during short periods of high predation risks, such as calving/lambing seasons or when livestock is grazed close to predator habitats (Miller et al. 2016, Khorozyan & Waltert 2019). Adopting short-term livestock protection techniques and the alternating usage of different interventions can be the most practical and harmless solution for herders.

Financial incentives and compensation programmes

A local livelihood-enhancing programme of selling handcrafted products in the Altai Mountains of Mongolia was shown to offset livestock losses by snow leopards (Mishra et al. 2003). Thus, alternative livelihoods (e.g., ecotourism and associated businesses) can be applied to increase tolerance towards predators, protect them from illegal killing, and improve local livelihoods (Mishra et al. 2003). Financial incentives have been widely practiced in many regions of the world to promote coexistence between people and large predators. In Sweden, for example, a conservation performance payment system was designed to pay to the Sami communities upon confirmed reproduction of predators such as Eu-

rasian lynx *Lynx lynx* to compensate for the projected predation of grown-up offsprings of semi-domestic reindeer (Zabel & Holm-Müller 2008). In another example, the payment scheme was based on mere occurrence records of brown bears *Ursus arctos* regardless of density and reproductive events (Rauset et al. 2016). A similar approach could be applied to Persian leopards. More specifically, performance payments (also known as 'pay for presence') could be paid through state-funded programmes, community-led funds, private insurers and other sources for observations of leopard offspring in breeding areas or generally for observations of leopards, especially females, in the areas where this species is rare or locally extinct. These payments should not be based on the number of killed livestock but should instead reduce potential threats to leopards in the future. This approach seems promising but is potentially prone to misuse or abuse as people would most likely increase false reporting in anticipation of payments. Also, this could create conflicts between targeted persons or communities because they have intrinsically different chances of seeing leopards or their offspring. However, it can be a promising tool for protected areas as a state-managed system of bonus payments to rangers in order to motivate them to better monitor leopards, their prey, and habitats.

Financial incentives, especially compensation programmes, are prone to problems such as poor management, high transaction costs, lack of trust and transparency, and significant time lags in payments (Madhusudan 2003, Jacobs & Main 2015, Babrgir et al. 2017). Compensations are usually based on confirmed evidence, e.g. livestock carcasses, which is difficult to find especially in challenging terrain (mountains, forest). That is why compensation programmes tend to pay much less than expected and usually do not cover indirect costs such as reduced productivity of stressed animals, which are hard to prove but incur much cost (Widman et al. 2019). Moreover, Babrgir et al. (2017) reported that despite existing compensation schemes in Iran, herders claimed they were unaware of them. Therefore, awareness-raising among local people about the goals and procedures of compensation schemes and conservation interventions is essential for success. However, even if local people are aware of compensation payments, their support is not guaranteed as they may be reluctant to pay premiums because livestock losses are rare and unpredictable.

Performance and compensation payments can reduce the illegal killing of predators when combined with other techniques applied in the same area, such as payments to local people for participation in wildlife monitoring, livestock protection, or research (Hazzah et al. 2014). To build public trust, it is vital to make such payments compliant with local culture, involve a broad spectrum of local communities, and secure the long-term availability of funds (Zabel & Holm-Muller 2008, Hazzah et al. 2014).

An interesting example of a compensation programme in Turkmenistan can be replicated elsewhere in the Middle East and Central Asia. A community-based compensation payment scheme was developed by World Wide Fund for Nature (WWF) in the Sari-Su River basin of Turkmenistan (Lukarevsky 2003). Since 1999, the local community purchased and managed a sheep flock to become an economically sustainable compensation stock for replacing sheep killed by leopards in the area. This approach can work effectively to compensate for sheep losses, improve local attitudes toward leopards, and reduce retaliatory killing of leopards if well managed and coordinated. Like other financial incentives and compensation payments, this compensatory stock programme may fail because of false reports of livestock mortality (e.g., deaths from diseases, lack of care, or other predators assigned to leopards) and misuse of this intervention (Sh. Karryeva, pers. comm.), urging for proper monitoring of the whole process to secure its efficacy.

Livestock guarding dogs

Livestock guarding dogs have been used in the region for millennia and are still being globally used to reduce livestock predation (Abade et al. 2014, Landry et al. 2020, Leib et al. 2021). Several global reviews suggest that guarding dogs are among the most effective interventions in reducing predation rates by predators (Miller et al. 2016, van Eeden et al. 2017, Khorozyan & Waltert 2019). Khorozyan et al. (2017) further reported that the presence of guarding dogs reduced surplus killings (two and more killed per attack) of sheep and goats in north-eastern Iran but did not reduce the total numbers killed by leopards. The most recent study in the same area also confirmed that guarding dogs could reduce sheep and goat losses per leopard attack (down to 1.4 individual/attack; Soofi et al. under review) but not eliminate losses. This means that guarding dogs should not only be present but essentially be properly trained (Rigg et al. 2017, Leib et al. 2021) to deter leopards effectively. However, dog training and handling (vaccination, feeding, shelter) are expensive and time-consuming.

Also, the effectiveness of guarding dogs in deterring predators relies on their personality (Landry et al. 2020). For instance, disobedient dogs may stray around without being present near the grazing herd, and generally, such individuals should not be used in stock guarding (Leib et al. 2021). Such disobedience can be an individual trait and a result of improper care forcing dogs to search for food away from livestock. A usual practice of feeding dogs with human leftovers cannot raise a good guarding dog. Many guarding dogs are trained only to bark and inform the herder about the predator's presence but this behaviour may provoke leopards to attack livestock and even a shepherd or his dog (Khorozyan et al. 2017). In this case, dogs are counter-effective and cause more harm.

Fig. 3. A fenced corral commonly used to protect sheep and goats in Iran, which is generally ineffective (Photo M. Soofi).

Table 1. Different types of interventions proposed to promote coexistence between humans and Persian leopards.

Intervention	Effectiveness	Advantages	Disadvantages	Country and references
Protective collars for livestock	Cattle: very effective; sheep and goats require further testing	Inexpensive, easy to use, flexible, locally producible, and durable	Not reported, but need more testing	Iran - Khorozyan et al. 2020
Predator-proof corrals	Variable	Only strong corrals are effective. Protective against various predators. Inexpensive if only minor maintenance works (e.g. closure of openings on roof and walls) are required	Costs of time, effort, and budget required for construction and maintenance. Inappropriate for seasonally moving (transhumant) societies	Not tested in the region, but see Khorozyan & Waltert (2019) and Samelius et al. (2019) for details
Deterrents	Effective but only for a short period	Effective against various predators during short periods of high depredation risk (e.g., lambing or calving seasons)	Fast habituation of predators, especially in human-modified landscapes, difficult to set up and use, sensitive to environmental conditions, and vulnerable to malfunctioning	Not tested in the region, but see Miller et al. (2016) and Khorozyan & Waltert (2019) for details
Financial incentives and compensation programmes	Variable	Can increase local people's trust in conservation	Need for secured funding and good management, risks of bureaucracy, misuse and abuse, high costs, false reports of kills, no motivation to change behaviour and attitudes	Iran - Babrgir et al. 2017; Turkmenistan - Lukarevsky 2003
Livestock guarding dogs and shepherds	Variable	Effective if dogs are properly trained and kept, and if shepherds are skilled	Costs of time, effort and budget, lack of motivation among local men to become shepherds	Georgia - Rigg et al. 2017; Iran - Khorozyan et al. 2017, Soofi et al. under review

Another problem with untrained dogs is that they may harass and kill wildlife, sometimes even predators (Ekernas et al. 2017, Drouilly et al. 2020, Landry et al. 2020). Dogs can also transmit lethal diseases, including canine distemper, which is an imminent danger for tigers *P. tigris* and leopards in the Russian Far East (Seimon et al. 2013) and to lions *P. leo* in East Africa and India (Davidson-Phillips et al. 2019, Mourya et al. 2019). This threat can be mitigated by dog vaccination (Woodroffe et al. 2007). This work should be done in close cooperation with herders who can manage their dogs, which are generally aggressive to unfamiliar people, and incorporate regular monitoring of the process (Soofi et al. under review).

Shepherds

Training of local shepherds will increase their skills in various aspects. Shepherds need to know how to effectively use interventions (such as protective collars) and also to train and care for their dogs. Also, shepherds should have necessary skills to minimise predator attacks on their livestock, e.g., grazing away from dense vegetation and rocks, staying present and vigilant near livestock, keeping livestock in compact groups and not letting them disperse widely. Moreover, considering how sharply the numbers of shepherds are decreasing in the modern urbanised world, shepherds should be financially and emotionally motivated to do their job. A growing number of shepherd schools and training courses in the EU (Mettler 2021) can serve as a good model for shepherd training within the Persian leopard range. Eventually, trained shepherds will not only successfully protect their livestock but also become an integral and committed part of wildlife conservation.

Potentially effective interventions to reduce livestock losses to leopards

Developing and applying practical and socially acceptable interventions is vital to reducing conflicts and promoting coexistence between people and leopards. Multiple approaches have been described in the literature (van Eeden et al. 2017, Khorozyan & Waltert 2019), but priority should be given to the long-lasting interventions which reduce the ability of predators to become habituated (Khorozyan & Waltert 2019). The appropriateness of interventions depends on the sufficiency of wild prey for leopards in a given area. If livestock is successfully protected by interventions, but wild prey is limited or absent, then leopards will die from hunger or move away to other areas. In this case, it is most effective to pay compensations for killed livestock or translocate individual problem leopards to other places (Breitenmoser et al. 2005). In contrast, when prey densities are moderate to high, such as in the Hyrcanian forest of Iran, livestock protection by shepherds, dogs, or protective predator-proof corrals is appropriate and safe as leopards will switch to preying on wild species, especially abundant wild boars *Sus scrofa* (Ghoddousi et al. 2019). Ineffective interventions are costly, time-consuming, and demotivating, and may even lead to increased livestock losses compared to business-as-usual practices without interventions.

Our synthesis of the published information suggests a number of livestock protection interventions (Table 1) as the most appropriate and potentially effective ones in the Middle East and Central Asia.

Insights into future developments

We underline that the interventions suggested above for the Persian leopard will succeed only if they rely on effective systematic monitoring plans. The monitoring here refers to how data related to human-leopard conflicts and associated livestock protection inter-

ventions are being systematically collected over time. In the absence of monitoring, it is not possible to evaluate the effectiveness of interventions (e.g., the incidence of livestock kills, locality, date, time of predation) and adjust them to improve their performance. Interventions should be able not only to reduce livestock losses but also to change people's intentions to kill leopards in retribution. We suggest strengthening the linkage between the effectiveness of interventions and the conservation outcomes, such as leopard densities, which is a weak point and a missing link in many conservation efforts. Monitoring of conflict situations should be implemented in close cooperation with local communities and with their participation. Encouraging local communities' participation in monitoring and evaluation of conservation interventions would help increase transparency and mutual trust. Information on conflict situations and their solutions obtained through participatory monitoring could then be disseminated through online platforms for general discussions and scientific research on intervention effectiveness. This would ensure the bottom-up flow of information and the involvement of multiple stakeholders in conflict mitigation.

To avoid propagation of disinformation related to human-leopard conflicts, scientists should be actively engaged in the media, especially on the Internet and TV, to provide accurate and understandable explanations, give timely updates, and shape public attitudes based on existing evidence (Nanni et al. 2020, Schell et al. 2021). People living in urban areas tend to be much more supportive of predator conservation (Schell et al. 2021) compared to rural populations, especially those affected by living close to predators (Montgomery et al. 2018). As a result, the views of different stakeholders may collide with each other and ultimately increase the perceived risks of predators regardless of the actual risk (Montgomery et al. 2018). Strategic planning of human-leopard coexistence should essentially incorporate several components including: (a) collaboration with diverse stakeholders such as local communities, NGOs, universities, and conservation authorities; (b) application of effective livestock protection measures such as protective collars, predator-proof collars, deterrents, financial incentives, compensation payments, livestock guarding dogs and shepherds; and (c) science-based monitoring of human-leopard conflicts (determinants, socio-economic and psychological effects, conflict hotspots) and their solutions (effectiveness of livestock protection measures).

References

Abade L., Macdonald D. W. & Dickman A. J. 2014. Assessing the relative importance of landscape and husbandry factors in determining large carnivore depredation risk in Tanzania's Ruaha landscape. Biological Conservation 180, 241–248.

Babrgir S., Farhadinia, M. S. & Moqanaki E. M. 2017. Socio-economic consequences of cattle predation by the endangered Persian leopard *Panthera pardus saxicolor* in a Caucasian conflict hotspot, northern Iraq. Oryx 51, 124–130.

Bleyhl B., Ghoddousi A., Askerov E., Bocedi G., Breitenmoser U., Manvelyan K., Palmer S. C. F., Soofi M., Weinberg P., Zazanashvili N., Shmunk V., Zurell D. & Kuemmerle T. 2021. Reducing persecution is more effective for restoring large carnivores than restoring their prey. Ecological Applications 31, e02338.

Braczkowski A. R., O'Bryan Ch. J., Stringer M. J., Watson J. E. M., Possingham H. P. & Beyer H. L. 2018. Leopards provide public health benefits in Mumbai, India. Frontiers in Ecology and the Environment 16, 176–182.

Breitenmoser U., Angst C., Landry J. M., Breitenmoser-Würsten C., Linnell J. D. C. & Weber J. M. 2005. Non-lethal techniques for reducing depredation. In People and wildlife: Conflict or coexistence? Woodroffe R., Thirgood S. & Rabinowitz A. (Eds.) Cambridge University Press, Cambridge, UK, pp. 49–71.

Breitenmoser U., Askerov E., Soofi M., Breitenmoser-würsten C., Heidelberg A., Manvelyan K. & Zazanashvili N. 2017. Transboundary leopard conservation in the Lesser Caucasus and the Alborz Range. Cat News 65, 24–25.

Brouwer E. 2021. Human-Pantherinae conflicts in South and Southeast Asia and their implications for conservation. Master thesis. University of Utrecht, Netherlands.

Carter N. H., Nelson P. & Easter T. 2021. A call for a national collaborative predator coexistence Programme. People and Nature 3, 788–794.

Davidson-Phillips S., Davidson-Phillips P., Canning G., Schroder B., Swart J. & Berger A. 2019. Canine distemper virus management in lions (*Panthera leo*) on Welgevonden Game Reserve. African Journal of Wildlife Research 49, 155–166.

Drouilly M., Kelly C., Cristescu B., Teichman K. J. & O'Riain M. J. 2020. Investigating the hidden costs of livestock guarding dogs: a case study in Namaqualand, South Africa. Journal of Vertebrate Biology 69, 20033.

Ekernas L. S., Sarmento W. M., Davie H. S., Reading R. P., Murdoch J., Wingard G. J., Amgalanbaatar S. & Berger J. 2017. Desert pastoralists' negative and positive effects on rare wildlife in the Gobi. Conservation Biology 31, 269–277.

Farhadinia M. S., Johnson P. J., Macdonald D. W. & Hunter L. T. B. 2018. Anchoring and adjusting amidst humans: Ranging behavior of Persian leopards along the Iran-Turkmenistan borderland. PLoS One 13, e0196602.

Ghoddousi A., Soofi M., Hamidi A. Kh., Lumetsberger T., Egli L., Khorozyan I., Kiabi B. H. & Waltert M. 2016. Assessing the role of livestock in big cat prey choice using spatiotemporal availability patterns. PLoS One 11, e0153439.

Ghoddousi A., Soofi M., Hamidi A. K., Ashayeri S., Egli L., Ghoddousi S., Speicher J., Khorozyan I., Kiabi, B. H. & Waltert M. 2019. The decline of ungulate populations in Iranian protected areas calls for urgent action against poaching. Oryx 53, 151–158.

Hazzah L., Dolrenry S., Naughton L., Edwards C. T. T., Mwebi O., Kearney F. & Frank L. 2014. Efficacy of two lion conservation programs in Maasailand, Kenya. Conservation Biology 28, 851–860.

Jacobs C. E. & Main M. B. 2015. A conservation-based approach to compensation for livestock depredation: The Florida panther case study. PLoS One 10, e0139203.

Jacobson A. P., Gerngross P., Lemeris J. R. Jr., Schoonover R. F., Anco C., Breitenmoser-Würsten C., ...& Dollar L. 2016. Leopard (*Panthera pardus)* status, distribution, and the research efforts across its range. PeerJ 4, e1974.

Karlsson J. & Johansson O. 2010. Predictability of repeated carnivore attacks on livestock favours reactive use of mitigation measures. Journal of Applied Ecology 47, 166–171.

Karlstetter M. 2008. Wildlife surveys and wildlife conservation in Nuristan, Afghanistan. Wildlife Conservation Society & United States Agency for International Development. 62 pp.

Khorozyan I., Askerov E., Beruchashvili G., Kütükçu A. E., Lortkipanidze B., Malkhasyan A., ...& Heidelberg A. 2022. Distribution and status of the Persian leopard in the Caucasus Ecoregion. Cat News Special Issue 15, 19–28.

Khorozyan I. & Waltert M. 2019. How long do anti-predator interventions remain effective? Patterns, thresholds and uncertainty. Royal Society Open Science 6, 190826.

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.

Khorozyan I., Soofi M., Soufi M., Hamidi A. Kh., Ghoddousi A. & Waltert M. 2017. Effects of shepherds and dogs on livestock depredation by leopards (*Panthera pardus)* in north-eastern Iran. PeerJ 5, e3049.

Khorozyan I., Ghoddousi S., Soufi M., Soofi M. & Waltert M. 2020. Studded leather collars are very effective in protecting cattle from leopard (*Panthera pardus*) attacks. Ecological Solutions and Evidence 1, e12013.

Kiabi B. H., Dareshouri B. F., Ghaemi R. A. & Jahanshahi M. 2002. Population status of the Persian leopard (*Panthera pardus saxicolor* Pocock, 1927) in Iran. Zoology in the Middle East 26, 41–47.

Kitchener A. C., Van Valkenburgh B. & Yamaguchi N. 2010. Felid form and function. In Biology and conservation of wild felids. Macdonald D. W. & Loveridge A. J. (Eds.) Oxford University Press, Oxford, UK, pp. 83–106.

Landry J. M., Borelli J. L. & Drouilly M. 2020. Interactions between livestock guarding dogs and wolves in the southern French Alps. Journal of Vertebrate Biology 69, 20078.

Leib Z., Tumurbaatar B., Elfström B. & Bull J. 2021. Impact of livestock guardian dogs on livestock predation in rural Mongolia. Conservation Science and Practice 3, e509.

Lukarevsky V. 2003. Saving the Central Asian leopard in Turkmenistan. Carnivore Damage Prevention News 6, 13–15.

Madhusudan M. D. 2003. Living amidst large wildlife: livestock and crop depredation by large mammals in the interior villages of Bhadra Tiger Reserve, South India. Environmental Management 31, 466–475.

Maharramova E., Moqanaki E. M., Askerov E., Faezi S., Alinezhad H., Mousavi M., Kuemmerle T., Heidelberg A. & Zazanashvili N. 2018. Transboundary leopard movement between Azerbaijan and Iran in the Southern Caucasus. Cat News 67, 8–10.

McManus J. S., Dickman A. J., Gaynor D., Smuts B. H. & Macdonald D. W. 2015. Dead or alive? Comparing costs and benefits of lethal and non-lethal human-wildlife conflict mitigation on livestock farms. Oryx 49, 687–695.

Mettler D. 2021. The shepherd's challenge: learning by being. Carnivore Damage Prevention News 22, 32–35.

Memarian I., Ostrowski S., Kordestani H., Khakpour H. & Pouyanshad N. 2018. The illegal use of snares and gin traps threatens endangered leopards in Iran. Cat News 67, 10–14.

Miller J. R. B., Stoner K. J., Meyer T. K., Middleton R. D. & Scmitz O. J. 2016. Effectiveness of contemporary techniques for reducing livestock depredations by large carnivores. Wildlife Society Bulletin 40, 806–815.

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.

Montgomery R. A., Elliott K. C., Hayward M. W., Gray S. M., Millspaugh J. J., Riley S. J., ...& Macdonald D. W. 2018. Examining evident interdisciplinarity among prides of lion researchers. Frontiers in Ecology and Evolution 6, 49.

Moqanaki E., Breitenmoser U., Kiabi B. H., Masoud M. & Bensch S. 2013. Persian leopards in the Iranian Caucasus: a sinking 'source' population? Cat News 59, 22–25.

Mourya D. T., Yadav P. D., Mohandas S., Kadiwar R. F., Vala M. K., Saxena A. K., ...& Bhargava B. 2019. Canine distemper virus in Asiatic lions of Gujarat State, India. Emerging Infectious Diseases 25, 2128–2130.

Nanni V., Caprio E., Bombieri G., Schiaparelli S., Chiorri C., Mammola S., Pedrini P. & Penteriani V. 2020. Social media and large carnivores: sharing biased news on attacks on humans. Frontiers in Ecology and Evolution 8, 71.

Parchizadeh J. & Belant J. L. 2021a. Human-caused mortality of large carnivores in Iran during 1980–2021. Global Ecology and Conservation 27, e01618.

Parchizadeh J. & Belant J. L. 2021b. Brown bear and Persian leopard attacks on humans in Iran. PLoS OneE 16, e0255042.

Rauset G. R., Andre H., Swenson J. E., Samelius G., Segerstro P., Zedrosser A. & Persson J. 2016. National parks in northern Sweden as refuges for illegal killing of large carnivores. Conservation Letters 9, 334–341.

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

Rigg R., Goldthorpe G., Popiashvili, T. & Sillero-Zubiri C. 2017. Livestock guarding dogs in Georgia: a tradition in need of saving? Carnivore Damage Prevention News 15, 19–27.

Samelius G., Suryawanshi K., Frank J., Agvaantseren B., Baasandamba E., Mijiddorj T., Johnsson O., Tumursukh L. & Mishra C. 2019. Keeping predators out: testing fences to reduce livestock depredation at nighttime corrals. Oryx 55, 46–472.

Schell C. J., Stanton L. A., Young J. K., Angeloni L. M., Lambert J. E., Breck S. W. & Murray M. H. 2021. The evolutionary consequences of human–wildlife conflict in cities. Evolutionary Applications 14, 178–197.

Seimon T. A., Miquelle D. G., Chang T. Y., Newton A. L., Korotkova I., Ivanchuk G., Lyubchenko E., Tupikov A., Slabe E. & McAloose D. 2013. Canine distemper virus: an emerging disease in wild endrangered Amur tigers (*Panthera tigris altaica*). mBio 4, e00410-13.

Shokri S., Jafari A., Rabei K., Hadipour E., Zeppenfeld T., Soufi M., ...& Soofi M. 2020. Conserving populations at the edge of their geographic range: the endangered Caspian red deer (*Cervus elaphus maral*) across protected areas of Iran. Biodiversity and Conservation 30, 85–105.

Soofi M., Ghoddousi A., Zeppenfeld T., Shokri S., Soufi M., Jafari A., ...& Waltert M. 2018. Livestock grazing in protected areas and its effects on large mammals in the Hyrcanian forest, Iran. Biological Conservation 217, 377–382.

Soofi M., Ghoddousi A., Zeppenfeld T., Shokri S., Soufi M., Egli L., ...& Khorozyan I. 2019. Assessing the relationship between illegal hunting of ungulates, wild prey occurrence and livestock depredation rate by large carnivores. Journal of Applied Ecology 56, 365–374.

Soofi M., Qashqaei A. T., Mousavi M., Hadipour E., Filla, M., Kiabi B. H., ...& Waltert M. 2022. Quantifying the relationship between prey density, livestock and illegal killing of leopards. Journal of Applied Ecology 59, 1536–1547.

Treves A. & Bruskotter J. T. 2014. Tolerance for predatory wildlife. Science 344, 476–477.

Treves A. & Karanth K. U. 2003. Human-carnivore conflict and perspectives on carnivore management Worldwide. Conservation Biology 17, 1491–1499.

van Eeden L. M., Crowther M. S., Dickman C. R., Macdonald D. W., Ripple W. J., Ritchie E. G. & Newsome T. M. 2017. Managing conflict between large carnivores and livestock. Conservation Biology 32, 26–34.

Widman M., Steen M. & Elofsson K. 2019. Indirect costs of sheep depredation by large carnivores in Sweden. Wildlife Society Bulletin 43, 53–61.

Woodroffe R., Frank L. G., Lindsey P. A., le Ranah S. M. K. & Romanach S. 2007. Livestock husbandry as a tool for carnivore conservation in Africa's community rangelands: a case–control study. Biodiversity Conservation 16, 1245–1260.

Zabel A. & Holm-Muller K. 2008. Conservation Performance Payments for Carnivore Conservation in Sweden. Conservation Biology 22, 247–251.

[1] Department of Conservation Biology, University of Goettingen, Bürgerstr. 50, 37073, Goettingen, Germany
*<mahmood.soofi@biologie.uni-goettingen.de>
[2] CSIRO Land and Water, Darwin, NT, Australia
[3] Consultant, Goettingen, Germany
[4] Colorado State University, Fort Collins, CO, United States

MOHAMMAD FARHADINIA[1*], IGOR KHOROZYAN[2], POLINA ORLINSKIY[3], TATJANA ROSEN[4], BAHAREH SHAHRIARI[5], HANA RAZA[6], BENJAMIN BLEYHL[7], SHIRIN KARRYEVA[8], MARK PESTOV[9], MUHAMMAD KABIR[10], ZALMAI MOHEB[11], VLADIMIR TERENTIEV[9] AND ELSHAD ASKEROV[12]

Priority areas for transboundary conservation of Persian leopards in West Asia and the Caucasus

Large carnivores have extensive spatial requirements, with ranges that often span geopolitical borders. Consequently, management of transboundary populations is subject to several political jurisdictions, often with heterogeneity in conservation challenges. In West Asia and the Caucasus, the endangered Persian leopard *Panthera pardus tulliana* occurs with transboundary populations spanning 13 countries with 26% of the extant ranges in borderlands. Overall, in 10 of 13 countries the majority of the remaining leopard range is in borderlands, and thus in most countries conservation of this subspecies is dependent on transboundary collaboration. We nominated a total of 10 key transboundary areas that are of high importance for the survival of Persian leopards, of which only one has an ongoing transboundary initiative. We highlighted the conservation challenge and potential opportunities for transboundary conservation of Persian leopards in the region.

Large carnivores have extensive spatial requirements that may extend beyond geopolitical borders. Consequently, these wide-ranging animals can fall under several political jurisdictions, resulting in a diversity of conservation challenges and efforts (Pestov et al. 2019, Farhadinia et al. 2021). Neighbouring states may have different levels of technical expertise, knowledge, capacity and financial resources (Karlstetter & Mallon 2014). These challenges can add to the already precarious circumstances of many large carnivores, which often occur at low densities and are prone to demographic and environmental stochasticity.

In Asia, the leopard *Panthera pardus* subspecies currently occur in <16% of their historical range (Jacobson et al. 2016, Stein et al. 2016). Persistence of many small populations of leopards is dependent on source–sink dynamics across international borders (Khorozyan et al. 2014, Farhadinia et al. 2015, Maharramova et al. 2018, Askerov et al. 2019). However, transboundary conservation was not considered in the latest IUCN assessment of leopards (Stein et al. 2016).

Here, we highlighted the importance of implementing transnational strategies for the conservation of leopards that range across West Asia and the Caucasus. We focused on the conservation status and challenges of transboundary populations of Persian leopard, and identified initiatives with which conservation practitioners can facilitate effective transboundary cooperation for the conservation of leopards, and perhaps other large mammals, such as prey species. We defined borderland as a buffer zone of 80 km from the borderline on both sides of the border and we considered a habitat patch as transboundary if it overlapped with borderlands. We chose this size because it is the maximum dispersal distance for leopards in Asia, recorded by telemetry in north-east Iran (Farhadinia et al. 2018).

Transboundary ranges and conservation initiatives

In continental Asia, in 18 of 23 countries where threatened leopard subspecies occur, the majority of the current leopard range is found within 80 km of international borders (Farhadinia et al. 2021). The Persian leopard occurs across the rugged terrain of 13 countries (Fig. 1), with a total population of 800–1,000 individuals (Khorozyan 2008), spread across an area of 933,597 km² covering parts of the Middle East, Central Asia and the Caucasus (Jacobson et al. 2016). A total of 3,415 km of borderline runs through the Persian leopard range, causing 26% (247,035 km²) of this subspecies' range to be within the borderland area (Farhadinia et al. 2021).

Currently, >75% of the subspecies' extant range is located within Iran (Jacobson et

Fig. 1. The current range of the Persian leopard *Panthera pardus tulliana* and the locations of 10 key transboundary areas for Persian leopards: 1) the entire Iran-Afghanistan border, 2) Badhyz, 3) Aral Paygambar, 4) Kopetdag, 5) south-western Ustyurt, 6) Babatag, 7) Zagros, 8) Lesser Caucasus, 9) Greater Caucasus and 10) Hindu Kush range. ARM = Armenia, AZ = Azerbaijan, and GEO = Georgia.