Dissatisfaction with Veterinary Services Is Associated with Leopard (Panthera pardus) Predation on Domestic Animals

Igor Khorozyan1*, Mahmood Soofi2*, Amirhossein Khaleghi Hamidi2‡, Arash Ghoddousi1‡, Matthias Waltert1‡

1 Workgroup on Endangered Species, J.F. Blumenbach Institute of Zoology and Anthropology, Georg-August University of Göttingen, Göttingen, Germany, 2 Persian Wildlife Heritage Foundation, Tehran, Iran

These authors contributed equally to this work.
‡ Current address: Workgroup on Endangered Species, J.F. Blumenbach Institute of Zoology and Anthropology, Georg-August University of Göttingen, Göttingen, Germany

*igor.khorozyan@biologie.uni-goettingen.de

Abstract

Human-carnivore conflicts challenge biodiversity conservation and local livelihoods, but the role of diseases of domestic animals in their predation by carnivores is poorly understood. We conducted a human-leopard (Panthera pardus) conflict study throughout all 34 villages around Golestan National Park, Iran in order to find the most important conflict determinants and to use them in predicting the probabilities of conflict and killing of cattle, sheep and goats, and dogs. We found that the more villagers were dissatisfied with veterinary services, the more likely they were to lose livestock and dogs to leopard predation. Dissatisfaction occurred when vaccination crews failed to visit villages at all or, in most cases, arrived too late to prevent diseases from spreading. We suggest that increased morbidity of livestock makes them particularly vulnerable to leopard attacks. Moreover, conflicts and dog killing were higher in villages located closer to the boundaries of the protected area than in distant villages. Therefore, we appeal for improved enforcement and coordination of veterinary services in our study area, and propose several priority research topics such as veterinarian studies, role of wild prey in diseases of domestic animals, and further analysis of potential conflict predictors.

Introduction

Human-wildlife conflicts over livestock predation, crop raiding or attacks on humans are relatively common and well documented [1]. Financial and social losses from conflicts can be significant, especially for poor communities with meager opportunities for alternative incomes, thus provoking hostile attitudes and persecution of culprit animals [2]. On the other hand, the species of concern include officially protected flagship and umbrella species (e.g., African elephant Loxodonta africana, large felids of Panthera genus), keystone species disliked by some
sectors of the public (e.g., gray wolf *Canis lupus*) or lower-level biodiversity (e.g., monkeys, birds and ungulates). In this case, conflicts challenge a balance between nature conservation and livelihoods and require tremendous long-term efforts to maintain or restore the integrity of the environment in socially acceptable ways [3].

Human-carnivore conflicts over predation on domestic animals are particularly well-known. Such conflicts depend on many factors such as densities of carnivores, wild prey and livestock, habitat and livestock characteristics, socio-economic conditions and husbandry practices [1], [4–5]. Surprisingly little empirical knowledge exists about the relationships between predation and diseases of domestic prey though diseases are among the major problems for animal husbandry throughout the world, especially in developing countries [6–11]. While theoretical modeling of predator-prey-disease relationships is well-developed and consistent, the limited empirical studies demonstrate contradictory results that predators can either keep diseases down ("healthy herds" hypothesis) or do the opposite by building up the disease burden of prey hosts [12–14].

Predicting human-carnivore conflicts is an important practical task, though its development began only recently and diseases are not yet addressed as potential predictors [8], [15–17]. In the context of diseases and conflicts, the availability of true absence data (i.e., no conflicts) is of utmost importance. It is easier to obtain absence data for conflicts than, for example, for a species especially if it is rare or mobile [18]. For this, it is just required to conduct sweeping surveys over all local settlements and to record where conflicts exist and where they do not. In this case, the application of presence-only modeling approaches such as maximum entropy (MaxEnt) or ecological niche factor analysis (ENFA) is not justified and the presence-absence analysis should be used instead [18]. Moreover, presence-only models are prone to errors when their pseudo-absence records are inaccurate, i.e. they may contain true presence data, and presence data are spatially biased [19]. When all local settlements are surveyed for conflicts, a presence-absence study transforms into a case-control study, which produces an absolute and most reliable probability of conflict in a given area [20].

In this paper, we provide the results of a case-control study of human-leopard (*Panthera pardus*) conflict in Iran. We describe the conflict pattern, estimate the effect of veterinary services and other variables on the conflict through predictive modeling, and discuss the practical aspects of the model output. Ultimately, we consider conservation implications of this study and propose practical actions to mitigate the conflict.

Materials and Methods

Study Area

This study was conducted in 34 villages located in the Madarsou (Dough) River watershed around Golestan National Park (GNP, 874.02 km²) in north-eastern Iran (Fig 1). GNP abuts on Ghorkhod Protected Area (GPA, 431.50 km²) in the east, Zav 1 Protected Area (ZAV1, 50.08 km²) in the north-west, Zav 2 Protected Area (ZAV2, 93.15 km²) in the west and Loveh Protected Area (LPA, 35.89 km²) in the south-west (Fig 1). From west to east, elevations increase from 450 m to 2411 m above sea level and precipitation decreases from 700 mm to 150 mm. The main landscape zones are lush humid temperate Hyrcanian forest in the west, steppe in the central part and semi-desert in the east, with the mean annual air temperature 11.5–17.5°C [21]. Local people belong to Turkmen and Persian ethnic groups. They raise cattle, sheep and goats and keep dogs to guard livestock. Dogs are not specifically trained to protect livestock and local culture prohibits buying or selling dogs, including well-trained individuals of appropriate breeds. Shepherds usually take larger dogs to accompany their stock, which, however, do not guarantee good protection. Human population, livestock numbers and
holdings, and other characteristics of GNP villages are provided in S1 Table. High-quality stud cattle graze inside villages, whereas other cattle and all sheep and goats move out into mountains and return to stay at night in pens. In June-July, cattle graze near villages on wheat stubble fields and stay away from gadflies swarming in dense vegetation, but later return to mountains after fields are trampled down (in most places) or converted into rice paddies (some lowlands).

**Ethics Statement**

This project was reviewed and approved by the boards of Persian Wildlife Heritage Foundation, Iranian Department of Environment and Golestan National Park, in terms of project design and communication with respondents. No written permits were required for the project as it was implemented on unprotected community lands. All people whom we asked to participate gave their verbal consent, therefore filling up a questionnaire form for a respondent meant his consent. No written consent was obtained in an attempt to establish good unofficial relationships with culturally sensitive local people, which was essential to ensure study feasibility. This consent procedure was approved by the above-listed organizations. The respondents were informed beforehand about the purpose of questionnaire surveys, anonymity and security of their information and that this study was unrelated to governmental programs such as compensation or environmental compliance schemes. Interviews were conducted in full compliance with local traditions and ethical requirements, with a local scientist MS being fully involved as a Turkmen/Persian/English translator. No animal handling was conducted.

**Data Collection**

Structured questionnaire surveys were conducted in March and May 2013 among 41 council members of 34 villages, all of which are situated outside of GNP on unprotected lands. In our sample, they were 41.4 ± standard error (SE) 1.4 year-old men (range 25–74). These 41 persons represented the joint and agreed opinions of three council members (Showra) and one village
head (Deh-yar) from each of 34 surveyed villages, so our survey practically covered 136 persons. Council members and village heads are the most respected, influential and knowledgeable persons elected by locals to represent their villages. Information provided by them was retrieved from the village databases.

The response variables included conflict, killing and predation rates in each village. Conflict was a categorical variable (1, yes and 0, no) defined as a situation in which at least one individual of cattle, sheep, goats and/or dogs was killed by leopards in a village during one year (March 2012 to March 2013). Killing also was categorical (1, yes and 0, no) and defined like conflict, but measured separately for cattle, sheep and goats, and dogs. Cattle, sheep and goats, and dog predation rates indicated the numbers of these animals killed by leopards in a village during the same year. We also studied the relationships between the response variables and poaching of large mammals, including leopards. Poaching was categorized as present (1) or absent (0) in a given village based on data provided by informants, not by the interviewed council members.

The predictor variables included the following characteristics for each village: satisfaction with veterinary services (1, yes and 0, no), vegetation cover (1, overgrown by 0–25% and 0, overgrown by >25%), decimal latitude, decimal longitude, elevation (m), distance to protected areas (km), accessibility (km), pasture size (ha), number of livestock owners (persons), percentage of livestock owners to all villagers, number of shepherds (persons), percentage of shepherds to villagers, number of cattle (individuals), number of sheep and goats (individuals), number of dogs (individuals), number of households (units), population (persons), number of men (persons) and percentage of men to all villagers (S1 Table).

Distance to protected areas was taken in order to test whether conflict, killing and predation rates are stronger near the boundaries of protected areas. We measured this distance from each village to GNP, GPA, ZAV1, ZAV2 and LPA, whichever is the closest, in ArcGIS 10.1 on the digitized map of GNP. This map was created from SRTM 90 m Digital Elevation Model (DEM) and 300 m land cover map of the CGIAR Consortium for Spatial Information (http://srtm.csi.cgiar.org) and then resampled at 250 m. Persian Wildlife Heritage Foundation provided the GIS files of protected area boundaries. Village accessibility was measured in two ways, depending on village location. For 31 villages situated in the north-west, north, south-west and partly south of GNP, accessibility was a road distance from a village to Tangerah, the village from where all local roads divert. Accessibility of three other villages in the south-east was measured as a distance to the highway (Fig 1). Tangerah is the only local village having its veterinary facility, but due to its limited capacity veterinarian services are provided from the neighboring towns of Kalaleh and Galikesh. The number of village households and demographic data were obtained from the Statistical Centre of Iran (http://www.amar.org.ir).

Data Analysis
Chi-square ($\chi^2$) test and Mann-Whitney test were used to estimate differences in categorical and continuous variables, respectively, between conflict and no-conflict villages. The odds ratio was calculated to assess the magnitude of the effects of the variables in presence (conflict villages) vs. absence (no-conflict villages) samples [7, 20]. For example, the odds ratio of 0.10 describing the effect of satisfaction with veterinary services on conflict means that this satisfaction reduces the probability of conflict by 0.90 or 90%.

Correlation between variables was estimated by Spearman’s rank correlation coefficient ($r_s$) and uncorrelated biologically more meaningful variables were analyzed by Generalized Linear Models (GLM). The GLMs were applied to describe the relationships between predictors and response variables, using the Poisson model for count data of continuous response variables (predation rates) and the logistic regression model for binary data of categorical response...
variables, viz. conflict and killing [22]. Villages with Cook’s distance ($D_{\text{cook}}$) > 1 were considered as outliers and excluded from further re-analysis [22]. The area under Receiver Operating Characteristic (AUC), percentage of correct classification and the likelihood-ratio test were applied to validate the predictive power of the GLMs. A score AUC = 0.5 means that the model has no discriminatory ability and AUC = 1 means that presences and absences are perfectly discriminated [17].

Statistical analysis was done in SPSS 17.0 (IBM, Armonk NY, USA) using two-tailed significance level $P$.

**Results**

Out of 34 villages, 18 villages had conflicts with leopards and 16 did not (Fig 1). In conflict villages, local people correctly assigned livestock and dog kills to leopards from personal observations of leopards on carcasses (13 villages, 72.2%), throat bite marks on kills (11, 61.1%), signs of disemboweling (3, 16.7%), prey concealed on tree (3, 16.7%), leopard sounds (2, 11.1%), leopard tracks (2, 11.1%) and claw marks on victim’s neck (1, 5.6%). In most cases (17 villages, 94.4%), livestock and dogs were killed in the mountains far from their villages.

In total, 24 calves, 119 sheep and goats, and 30 dogs were killed by leopards in 18 conflict villages in 2012–2013. Forty-one cases of leopard predation (1–5 cases/village) were recalled and described with sufficient details. Presence of shepherds and dogs did not eliminate leopard attacks, since shepherds were present in 23 of them (56.1%) and absent in 18 (43.9%); dogs were present in 21 cases (51.2%) and absent in 20 (48.8%). When shepherds were present during leopard attacks, they reacted by shouting with or without throwing stones in 21 cases (91.3%) and stayed unaware of leopards in two cases. When dogs were present, they ran away with or without barking (10, 47.6%), were killed without resistance (4, 19.0%), barked from afar (3, 14.3%), approached but then retreated (3, 14.3%) or did not react (1, 4.8%).

Satisfaction with veterinary services was the only predictor making a significant effect on conflict and killing, but not on predation rates, which were not affected by predictors we used. Conflicts, cattle killing, sheep and goat killing, and dog killing were higher in villages where respondents were dissatisfied with veterinary services, but this relationship was less evident in cattle (Table 1; Fig 2). Logistic regression confirmed that predictability of cattle killing by leopards was lower than predictability of conflict or killing of sheep, goats and dogs (Table 2). Satisfaction with veterinary services was not correlated with accessibility of villages ($r_s = 0.099$, $P = 0.585$). There was no relationship between poaching and conflict ($\chi^2 = 2.892$, $P = 0.168$), satisfaction with veterinarian services ($\chi^2 = 0.036$, $P = 1.000$), cattle killing ($\chi^2 = 2.555$, $P = 0.152$), sheep and goat killing ($\chi^2 = 0.216$, $P = 0.729$) and dog killing ($\chi^2 = 0.384$, $P = 0.693$).

Out of 16 villages, which were dissatisfied with veterinary services, state vaccination crews did not visit five villages (31.3%) and came too late in 11 others (68.7%). As the interviewed council members claimed, in both these cases livestock became affected by diseases, which

| Response variable          | Chi-square $\chi^2$ | Significance level $P$ | Odds ratio |
|----------------------------|---------------------|------------------------|------------|
| Conflict                   | 8.93                | 0.003                  | 0.10       |
| Cattle killing             | 3.88                | 0.049                  | 0.21       |
| Sheep and goat killing     | 9.17                | 0.002                  | 0.08       |
| Dog killing                | 6.44                | 0.011                  | 0.08       |

Table 1. The significant effects of satisfaction with veterinary services on human-leopard (*Panthera pardus*) conflict, cattle killing, sheep and goat killing, and dog killing by leopards in villages around Golestan National Park, Iran.

doi:10.1371/journal.pone.0129221.t001
would be otherwise prevented by timely vaccination or treatment. Alternative private veterinarians are expensive and not affordable to villagers. Dogs are not vaccinated in GNP villages.

Conflicts were higher (Mann-Whitney = 79.000, Z = -2.243, \( P = 0.025 \)) and satisfaction with veterinary services was lower (\( r_s = 0.382, P = 0.028 \)) in villages with lower longitudes, i.e. in the west of GNP. Conflict and dog killing were inversely correlated with distance to protected areas (\( r_s = -0.382, P = 0.010 \) and \( r_s = -0.435, P = 0.010 \)). Conflict, killing and predation rates of livestock and dogs were not correlated with vegetation cover (\( r_s \) from -0.304 to 0.075, \( P \) from 0.081 to 0.789).

Discussion

This study is the first empirical evidence demonstrating that villages in which people are dissatisfied with veterinary services are more likely to lose livestock and dogs to leopard attacks (Fig 2; Tables 1 and 2). Hostility towards big cats may inflate their perceived culpability by assigning other mortality causes to predation, but in our study the description of leopard predation signs was apparently accurate. Predictability of cattle killing was lower than that of small livestock and dogs, possibly because of higher tolerance of cattle to diseases in humid conditions of villages to the west of GNP where most conflicts occurred (Fig 1). Notably, it was possible to predict probabilities of conflict or killing, but not absolute numbers of killed livestock and dogs.

In Iran, veterinary services are provided by state-supported vaccination crews. These crews are authorized to visit villages at least once a year for anthrax and foot-and-mouth vaccination and for disease diagnostics and treatment, e.g. administration of drugs against worms such as *Fasciola hepatica* and *F. gigantica*. Fascioliasis and foot-and-mouth disease are common throughout Iran, being among the highest concerns for national agriculture [23–25].

| Response variable | Equation | Parameter estimates | % | AUC | Likelihood-ratio test |
|-------------------|----------|---------------------|---|-----|----------------------|
| Conflict          | \( p = \frac{1}{1 + \exp(2.342\times VS - 0.875)} \) | Wald = 7.907, \( P = 0.005 \) | 75.8 | 0.76 | \( \chi^2 = 9.435, P = 0.002 \) |
| Cattle killing    | \( p = \frac{1}{1 + \exp(1.540\times VS - 1.540)} \) | Wald = 3.624, \( P = 0.057 \) | 66.7 | 0.68 | \( \chi^2 = 3.985, P = 0.046 \) |
| Sheep and goat killing | \( p = \frac{1}{1 + \exp(2.526\times VS - 2.015)} \) | Wald = 7.655, \( P = 0.006 \) | 75.8 | 0.77 | \( \chi^2 = 9.777, P = 0.002 \) |
| Dog killing       | \( p = \frac{1}{1 + \exp(2.521\times VS - 2.773)} \) | Wald = 4.829, \( P = 0.028 \) | 75.8 | 0.76 | \( \chi^2 = 7.018, P = 0.008 \) |

Abbreviations: AUC—area under the Receiver Operating Characteristic (ROC), \( p \)—probability of response variable, \( P \)—significance level, VS—satisfaction with veterinary services (1 if satisfied, 0 if not), \%—percentage of correct classification.

Fig 2. The effect of satisfaction and dissatisfaction with veterinary services on the probabilities of conflict, cattle killing, sheep and goat (shoat) killing and dog killing modeled by logistic regression. The error bars indicate standard error.

doi:10.1371/journal.pone.0129221.g002
Dissatisfaction with these services was common in our study, but not confined to hardly accessible remote villages, as only few of them were not visited at all. In most cases, villagers complained that vaccination crews come too late when diseases are already spread and belated vaccination is ineffective. Services provided by private veterinarians are mostly unaffordable. We suggest that poor veterinary treatment contributed to increased morbidity of livestock, which, in its turn, made them increasingly vulnerable to leopard attacks. The most common disease mentioned by respondents was hoof infection caused by *Fusobacterium necrophorum*, which was told to impede free movements of livestock. This disease was widespread in humid forest landscapes of villages to the west of GNP. Perhaps, hoof infection also limited the fleeing behavior of livestock and exposed them to higher predation. Fascioliasis, echinococcosis and tick-borne diseases are also widespread in Golestan Province where all conflict villages near GNP are located [24], [26–29].

Albeit we demonstrated higher conflict and killing of domestic animals in disease-affected villages, it is still unclear whether leopards select diseased individuals from the stock or take individuals randomly in a diseased stock. It is imperative to investigate the occurrence of diseases in living domestic animals vs. leopard kills and their impact on leopards and their relationships with key competitors (wolves) and wild prey. We are aware of only one work describing parasite infestation, but not diseases or their consequences, in leopards of GNP [30].

A particular concern is the fidelity of leopards to taking dogs in affected villages. Because dogs have not been vaccinated in our study area, high level of their off-take in villages with unsatisfactory veterinary services could be caused by leopards, which are attracted by morbid livestock. Dogs can act as reservoirs of diseases to which leopards are vulnerable and preying on them provides ideal circumstances for disease transmission [31]. Although leopards are known to be low-affected by diseases because of their strict solitary life and rarity, which limit mutual contacts, they can still be infected from dogs by canine distemper, rabies and echinococcosis [32–36]. However, solitude is not a salvation as now canine distemper threatens another solitary felid, the Siberian tiger (*P. tigris altaica*), and thus may impinge on co-existing Amur leopard (*P. p. orientalis*) [37]. Additionally, leopards can develop tuberculosis and mange or become infested by *Echinococcus* spp. by consuming diseased livestock [34]. A tick-borne protozoan *Babesia*, which is common in Golestan Province, can trigger mortality from canine distemper as found in African lions (*P. leo*) [27, 38]. Disease transmission can spread fast due to the habit of carnivores to attack domestic animals repeatedly from the same households [15].

This study is an appeal to improve the effectiveness of veterinary services so as to minimize livestock and dog losses to diseases and leopard predation. Particular attention should be paid to dog vaccination. As local villages are situated in three provinces (Golestan, North Khorasan and Semnan), good coordination between their administrative bodies is required to ensure timely vaccination, diagnostics and treatment of domestic animals. Provision of veterinary services to local communities is expected to be an important tool for increasing conservation effectiveness. An earlier study has shown that the improvement of local healthcare infrastructure and services can be a strong boost for conservation [39], and we hope for the same effect also from veterinarian services around GNP.

Quite counterintuitively, we did not find support for the hypothesis that husbandry practices such as herding and the use of guarding dogs might be important predictors of leopard predation on domestic animals in this study. Although the degree of effectiveness of husbandry methods has not been measured, they need to be improved. Dogs are physically not suitable, nor properly trained to withstand leopard attacks around GNP, but local shepherds are not allowed to carry firearms and their attempts to scare leopards away are futile. Permitting the usage of firearms by shepherds is not a solution since it will stimulate poaching and the prescription for preventive air-shooting is hard to control. Our results show that conflicts,
satisfaction with veterinarian services and poaching are not correlated in GNP, perhaps because poachers target big ungulate trophies, while leopards are shot during chance encounters [40].

We found support for a local belief that proximity of villages to protected areas is a reliable predictor of human-leopard conflicts. Conflicts and dog killing were much stronger around villages which are located closer to protected areas, indicating that leopard predation is higher along their boundaries. However, a belief that presence of overgrown scrubland pastures leads to more conflicts was refuted. More fine-scale research is required to determine the possible effect of other potential conflict predictors which were not measured in this study, such as distances between livestock kill sites and villages, numbers of active shepherd dogs that accompany livestock, and location of kill sites in relation to landscape characteristics and livestock movement routes. Moreover, we feel that differences in dietary preferences and hunting tactics of individual leopards might also be important in local predation patterns.

**Supporting Information**

S1 Protocol. The questionnaire form. (PDF)

S1 Table. Quantitative information on predictor and response variables in 34 villages around Golestan National Park, Iran. (XLS)

**Acknowledgments**

This project was reviewed and approved by Persian Wildlife Heritage Foundation, Iranian Department of Environment and Golestan National Park. We feel obliged to the Soofi family in Totli Tomak village for thorough assistance and appreciate the support by A.A. Kykha, H. Jowkar, A. Rostaghi, T. Melkumyan and S. Ghoddousi during the project course. Special thanks go to A. Braczkowski, G. Bergmann and an anonymous reviewer for constructive comments and suggestions on the earlier draft of this paper.

**Author Contributions**

Conceived and designed the experiments: IK AG MW. Performed the experiments: IK MS AKH AG. Analyzed the data: IK MW AG. Wrote the paper: IK.

**References**

1. Baker PJ, Boitani L, Harris S, Saunders G, White PCL. Terrestrial carnivores and human food production: impact and management. Mammal Rev. 2008; 38: 123–166.

2. Loveridge AJ, Wang SW, Frank LG, Seidensticker J. People and wild felids: conservation of cats and management of conflicts. In: Macdonald DW, Loveridge AJ, editors. Biology and conservation of wild felids. Oxford: Oxford University Press; 2010. pp. 161–195.

3. Dickman AJ. Complexities of conflict: the importance of considering social factors for effectively resolving human-wildlife conflict. Anim Conserv. 2010; 13: 458–466.

4. Graham K, Beckerman AP, Thirgood S. Human-predator-prey conflicts: ecological correlates, prey losses and patterns of management. Biol Conserv. 2005; 122: 159–171.

5. Inskip C, Zimmermann A. Human-felid conflict: a review of patterns and priorities worldwide. Oryx 2009; 43: 18–34.

6. Frank LG, Woodroffe R, Ogada MO. People and predators in Laikipia District, Kenya. In: Woodroffe R, Thirgood S, Rabinowitz A, editors. People and wildlife. Conflict or co-existence? Cambridge: Cambridge University Press; 2005. pp. 286–304.
7. Azevedo FCC, Murray DL. Evaluation of potential factors predisposing livestock to predation by jaguars. J Wildl Manag. 2007; 71: 2379–2386.

8. Dar NI, Minhàs RA, Zaman Q, Linkie M. Predicting the patterns, perceptions and causes of human-carnivore conflict in and around Machiara National Park, Pakistan. Biol Conserv. 2009; 142: 2076–2082.

9. Kissui BM. Livestock predation by lions, leopards, spotted hyenas, and their vulnerability to retaliatory killing in the Maasai steppe, Tanzania. Anim Conserv. 2008; 11: 422–432.

10. Hemson G, Maclennan S, Mills G, Johnson P, Macdonald D. Community, lions, livestock and money: a spatial and social analysis of attitudes to wildlife and the conservation value of tourism in a human-carnivore conflict in Botswana. Biol Conserv. 2009; 142: 2718–2725.

11. Amador-Alcalá S, Naranjo EJ, Jiménez-Ferrer G. Wildlife predation on livestock and poultry: implications for predator conservation in the rainforest of south-east Mexico. Oryx 2013; 47: 243–250.

12. Packer C, Holt RD, Hudson PJ, Lafferty KD, Dobson AP. Keeping the herds healthy and alert: implications of predator control for infectious disease. Ecol Lett. 2003; 6: 797–802.

13. Duffy MA, Housley JM, Penczykowski RM, Cáceres CE, Hall SR. Unhealthy herds: indirect effects of predators enhance two drivers of disease spread. Funct Ecol. 2011; 25: 945–953.

14. Karlsson J, Johansson Ó. Predictability of repeated carnivore attacks on livestock favours reactive use of mitigation measures. J Appl Ecol. 2010; 47: 166–171.

15. Treves A, Martin KA, Wydenhoft JE. Forecasting environmental hazards and the application of risk maps to predator attacks on livestock. Bioscience 2011; 61: 451–458.

16. Sarani M, Telmadarraiy Z, Moghaddam AS, Azam K, Sedaghat MM. Distribution of ticks (Acari: Ixodidae) infesting domestic ruminants in mountainous areas of Golestan Province, Iran. Asian Pac J Trop Biomed. 2014; 4: S246–S251. doi: 10.1016/S2221-1691(14)62703-9 PMID: 23975777

17. Elith J, Phillips SJ, Hastie T, Dudik M, Chee YE, Yates CJ. A statistical explanation of MaxEnt for ecologists. Divers Distrib. 2011; 17: 43–57.

18. Barbet-Massin M, Jiguet F, Albert CH, Thuiller W. Selecting pseudo-absences for species distribution models: how, where and how many? Meth Ecol Evol. 2012; 3: 327–338.

19. Woodroffe R, Frank LG, Lindsey PA, ole Ranah SMK, Romañach S. Livestock husbandry as a tool for carnivore conservation in Africa’s community rangelands: a case-control study. Biodiv Conserv. 2007; 16: 1245–1260.

20. Yan X, Su X. Linear regression analysis: theory and computing. Singapore: World Scientific Publishing Co.; 2009.

21. Perez AM, Thurmond MC, Grant PW, Carpenter TE. Use of the scan statistic on disaggregated province-based data: foot-and-mouth disease in Iran. Prevent Vet Med. 2005; 71: 197–207. PMID: 16169102

22. Hosseini SH, Meshgi B, Abbassi A, Eslami A. Animal fascioliasis in coastal regions of the Caspian Sea, Iran (2006–2007). Iran J Vet Res. 2012; 13: 64–67.

23. Jafarzadeh SR, Norris M, Thurmond MC. Prediction of province-level outbreaks of foot-and-mouth disease in Iran using a zero-inflated negative binomial model. Prev Vet Med. 2014; 115: 101–108. doi: 10.1016/j.prevetmed.2014.03.018 PMID: 24768434

24. Mansoorlakooraj H, Saadati D, Javadi R, Heydari S, Torki E, Gholami H et al. A survey on hydatidosis. Haghi SMM, Fakhar M, Sharbatkhori M, Tavakoli R et al. Molecular identification of Botswana. Biol Conserv. 2009; 142: 2718–2725.

25. Ghaemi P, Sadr-Shirazi N, Khayami P. Study on helminthic parasites of Persian leopard (Panthera pardus saxicolor Pocock, 1927) in Golestan National Park and Biosphere Reserve of Iran. World Appl Sci J. 2011; 13: 1471–1473.
31. Butler JRA, du Toit JT, Bingham J. Free-ranging domestic dogs (*Canis familiaris*) as predators and prey in rural Zimbabwe: threats of competition and disease to large wild carnivores. Biol Conserv. 2004; 115: 369–378.

32. Appel MJG, Yates RA, Foley GL, Bernstein JJ, Santinelli S, Spelman LH et al. Canine distemper epizootic in lions, tigers, and leopards in North America. J Vet Diagn Invest. 1994; 6: 277–288. PMID: 7948195

33. Hüttner M, Siefert L, Mackenstedt U, Romig T. A survey of *Echinococcus* species in wild carnivores and livestock in East Africa. Int J Parasitol. 2009; 39: 1269–1276. doi: 10.1016/j.ijpara.2009.02.015 PMID: 19275902

34. Munson L, Terio KA, Ryser-Degiorgis M-P, Lane EP, Courchamp F. Wild felid diseases: conservation implications and management strategies. In: Macdonald DW, Loveridge AJ, editors. Biology and conservation of wild felids. Oxford: Oxford University Press; 2010. pp. 237–262.

35. Goodrich JM, Lewis JCM, Quigley KS, Roelke M, Astafiev AA, Slabii EV et al. Infectious diseases of Amur tigers and Far Eastern leopards. In: Seryodkin IV, Miquelle DG, editors. Diseases and parasites of wildlife in Siberia and the Russian Far East. Vladivostok: Dalnauka; 2012. pp. 19–26.

36. Kagendo D, Magambo J, Agola EL, Njenga SM, Zeyhle E, Mulinge E et al. A survey for *Echinococcus* spp. of carnivores in six wildlife conservation areas in Kenya. Parasitol Int. 2014; 63: 604–611. doi: 10.1016/j.parint.2014.04.001 PMID: 24732034

37. Seimon TA, Miquelle DG, Chang TY, Newton AL, Korchkova I, Ivanchuk G et al. Canine distemper virus: an emerging disease in wild endangered Amur tigers (*Panthera tigris altaica*). mBio 2013; 4: e00410–13. doi: 10.1128/mBio.00410-13 PMID: 23943758

38. Munson L, Terio KA, Kock R, Mlengeya T, Roelke ME, Dubovi E et al. Climate extremes promote fatal co-infections during canine distemper epidemics in African lions. PLoS One 2008; 3: e2545. doi: 10.1371/journal.pone.0002545 PMID: 18575601

39. Chapman CA, van Bavel B, Boodman C, Ghai RR, Gogarten JF, Hartter J et al. Providing health care to improve community perceptions of protected areas. Oryx 2014. doi: 10.1017/S0030605313001592

40. Hamidi AK, Ghoddousi A, Soufi M, Ghadirian T, Jawkar H, Ashayeri S. Camera trap study of Persian leopard in Golestan National Park, Iran. Cat News 2014; 60: 12–14.