ARTICLE IN PRESS

Biological Conservation xxx (2009) xxx–xxx

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Predicting the patterns, perceptions and causes of human–carnivore conflict in and around Machiara National Park, Pakistan

Naeem Iftikhar Dar [a,b], Riaz Aziz Minhas [a], Qamar Zaman [a], Matthew Linkie [b,*]

[a] *Machiara National Park, Department of Wildlife and Fisheries, Azad Jammu and Kashmir, Pakistan*
[b] *Durrell Institute of Conservation and Ecology, University of Kent, Canterbury, Kent CT2 7NR, United Kingdom*

ARTICLE INFO

Article history:
Received 3 December 2008
Received in revised form 7 April 2009
Accepted 10 April 2009
Available online xxxx

Keywords:
Development
Livelihood
Livestock
Panthera
Predator
Wildlife
Ursus

ABSTRACT

Human–carnivore conflict is considered to be a major conservation and rural livelihood issue because many carnivore species have been heavily persecuted due to elevated conflict levels with communities. To mitigate such conflicts requires a firm understanding of their underlying patterns. This situation is epitomized in Pakistan, where carnivore populations have been greatly reduced, but where no research has investigated the conflict patterns of large carnivore guilds with humans. Focusing in and around Machiara National Park (MNP), Azad Jammu and Kashmir region, we conducted the first such scientific study in Pakistan. From January 2004 to May 2007, 148 people lost their livestock to four carnivore species. Leopard was responsible for the majority (90.6%) of the 363 livestock killed, mainly goats (57.3%) and sheep (27.8%). Information-theoretic evaluation of a candidate set of regression models found that leopard kills inside villages were significantly higher for areas without electricity, while leopard kills outside villages were higher for pastoralists with larger herds that were further from MNP, with no effect from several guarding strategies used. Temporal leopard attacks were significantly and positively related to temperature, but not to rainfall, for goat kills, but not for other livestock kills. While leopard kills caused the greatest overall financial loss (19.8%) amongst carnivores, which negatively affected local tolerance towards leopard, disease caused greater livestock losses (72.7%). To improve both large carnivore and local livelihood prospects around MNP and across rural Pakistan, conservation and development projects should install village electricity supplies and vaccinate livestock, while the cost-effectiveness of different conflict mitigation strategies should be trialed.

1. Introduction

The continued growth of human populations and the concomitant increase in resource use and habitat loss is causing human–carnivore conflict to increase worldwide (Treves and Karanth, 2003). Large carnivores in particular are predisposed to such conflicts due to their large home ranges and dietary requirements that increasingly overlap with people (Linnell et al., 2001; Macdonald and Sillero-Zubiri, 2002). As large carnivores are forced to live in increasing proximity to humans, competition for space and ungulate prey species leads to conflict. Such conflict can be the most important cause of adult carnivore mortality in and around protected areas, and most conflict incidents occur when animals range around and beyond protected area borders into human-dominated landscapes (Gurung et al., 2008).

Human–carnivore conflict can have a substantial and disproportionate financial impact on rural communities, because those who live in closest proximity to carnivores tend to be within the lowest income category. Conflict can therefore reduce local tolerance towards carnivores, their conservation and also conservation of other non-conflict species. Furthermore, local people often incorrectly identify culprits that cause most losses to their livelihoods (Naughton-Treves, 1998; Linkie et al., 2007) and underplay the role of other threats to their livestock, such as disease.

Any attempts to mitigate human–carnivore conflict and improve the conservation of the culprit species, and possibly other wildlife also, should be based on an explicit understanding of the conflict patterns. This is particularly relevant in Asia, which has some of the highest human population densities living within large carnivore ranges. The leopard (*Panthera pardus*) in Machiara National Park (MNP), Pakistan, clearly illustrates this problem. It was once widely distributed across the Azad Jammu and Kashmir region in north-east Pakistan, as well as the rest of the country, but has been heavily persecuted, partly because of increasing levels of conflict with rural communities. This issue remains a national priority because the Pakistani Wildlife Department is under

* Corresponding author. Present address: Fauna and Flora International-Indonesia Programme, Banda Aceh, Nanggroe Aceh Darussalam, Indonesia. Tel.: +62 (0)813 85258091; fax: +62 (0)651 7551483.
E-mail address: matthew.linkie@ffi.or.id (M. Linkie).

0006-3207/$ - see front matter Crown Copyright © 2009 Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.biocon.2009.04.003

intense pressure from rural communities who are vociferously and frequently complaining to them and demanding compensation for their livestock losses to leopards, as well as other carnivore species.

To date, there has been no scientific study on conflicts between humans and the guild of large carnivore species in Pakistan. So, by focussing on conflict that occurred in and around MNP over a 4-year period, this study aimed to investigate the: (1) extent of livestock kills by different carnivore species; (2) injuries and deaths of both humans and carnivores resulting from conflict incidents; (3) spatial and temporal patterns of conflict between humans and the main culprit species; (4) financial livestock losses caused by carnivores and other factors; and, (5) local perceptions and tolerance towards the main carnivore conflict species and its conservation.

2. Study area

Located in the Azad Jammu and Kashmir Himalayan area of Pakistan and 165 km northeast of Islamabad is the ca. 334 km^2 MNP (34°-31′ N, 73°-77′ E). Upgraded from a Game Reserve in 1996, the stand-alone MNP has an altitudinal range of 1350–5000 m a.s.l. that supports a mixed forest/alpine scrub rangeland ecosystem, with alpine meadows surrounding. The study area has a mean annual temperature range of 13.6–27.3 °C and four distinct seasons, winter (December–February), spring (March–April), summer (May–August) and autumn (September–November; Pakistan Meteorological Department, 1990). The mean annual rainfall is 1526.7 mm, with an 84.5 rainy day average per year; the wettest month is July (327.6 mm), which is during the monsoon (July–August), while the driest month is November (35.4 mm; Pakistan Meteorological Department, 1990).

MNP is located within a Himalayan biodiversity hotspot (Myers et al., 2000), the western Himalayan Endemic Bird Area and an Important Bird Area itself (BirdLife International, 2007). The carnivore species living within the study area include the leopard, snow leopard *Uncia uncia*, leopard cat *Prionailurus bengalensis*, Himalayan black bear *Ursus thibetanus*, Asiatic jackal *Canis aureus*, red fox *Vulpes vulpes*, yellow throated martin *Martes flavigula* and golden eagle *Aquila chrysaetos*.

Around MNP, there are an estimated 29,680 people living within 4654 households in 30 villages that cover the three Union Councils of Bheri, Machiara and Serli Sacha (District Census Reports, Muzaffarabad District, 2001). Due to the harsh environment, the households and villages are spread out to enable better access to resources for farmland, grazing lands and from the forests in and around MNP. Livestock (goats, sheep, cows, buffaloes, horses, mules and donkeys) constitute a major proportion of the local economy, with 37,233 livestock heads recorded in the villages surrounding MNP (Table 1). Cows and buffaloes are kept as dairy animals, while goats and sheep are kept for their meat and wool and are the animals most commonly sold in the market. Due to the lack of modern communication and infrastructure, horses, mules and donkeys are still used for transportation of goods, particularly in remote villages.

Table 1
Livestock population around Machiara National Park, Pakistan (AJK Wildlife and Fisheries Department, 2004).

Livestock type	Number	Composition (%)
Water buffalo	2234	6.0
Cow	12,658	34.0
Bull	3351	9.0
Goat	11,541	31.0
Sheep	6702	18.0
Equine (horse, mule and donkey)	745	2.0
Total	37,231	100

3. Methods

3.1. Questionnaire survey

The study area focused on all villages that were within 5 km of MNP. This included 30 villages in three union councils that were predominantly located along the southern side of MNP. In 2007, field data were collected using a combination of qualitative methods (unstructured interviews, participatory observation and focus group discussions) and quantitative methods (structured interviews), which formed the main data source. Interviews were conducted by 31 Azad Jammu and Kashmir Wildlife and Fisheries Department staff who had already worked with these communities for many years. Interviews were monitored in the field by four community extension officers, in order to ensure accuracy in data collection.

Unstructured interviews and participatory observations were conducted with employees of the wildlife department, community representatives and people who had experienced conflict with carnivores. The main aims of the questionnaire surveys were to explore the different aspects of human–carnivore conflict patterns and the perceptions and attitudes of local people towards the main conflict species. The questionnaire developed was tested, and then modified where necessary, through a pilot study of 50 respondents from rural villagers and wildlife department employees. The final questionnaire consisted of five main sections: demographic and socio-economic characteristics of respondents; human–carnivore conflict experience; financial loss of livestock; perceptions towards carnivores; and, tolerance towards carnivores.

Information on seven demographic and socio-economic factors, namely name, sex, age, level of formal education, occupation, livestock holding (type and number of livestock kept) and purpose of keeping livestock, was obtained for each respondent. Respondents were asked a series of questions about the circumstances surrounding their livestock-carnivore attacks, including the carnivore species responsible, based on: (i) direct sightings, which were also possible during the night if the respondent was alerted, e.g. by a dog, or if the attack took place within a shed, which then slowed the escape time down; (ii) indirect signs left near the kill; and, (iii) if still remaining, marks left on the carcass, e.g. nape or throat bite indicating a leopard. While there is always the possibility of misidentification with any study on human–wildlife conflict, the number of livestock predators, especially large carnivores, in the study site was limited to a few species, which would have minimised this. Next, questions were asked on the type and number of livestock killed, number of predator individuals, place, location (inside village or outside village; in forest, meadow, or grazing near village), date, time and season of attack, action taken against the predator, livestock guarding (none, humans only, dogs only or humans and dogs) and available habitat cover for leopard (open or closed). Carnivore attacks were then divided between those occurring inside the village and those occurring outside. For the former, information on local conditions, such as the presence of an electricity supply in the area and whether livestock were penned in at night, or not, were included. The locations of leopard attacks identified through the questionnaire survey were then visited in the field and their geographic position was recorded using a GPS unit.

Information was obtained on local perceptions of three most problematic carnivore species that affected each respondent, the temporal attack trends of the main conflict species, reasons for any perceived increase in attacks, the relationship between attacks and MNP, knowledge about the authority responsible for conserving the main conflict species and their conservation status and,

Please cite this article in press as: Dar, N.I., et al. Predicting the patterns, perceptions and causes of human–carnivore conflict in and around Machiara National Park, Pakistan. Biol. Conserv. (2009), doi:10.1016/j.biocon.2009.04.003

finally, the respondents′ willingness to conserve the main conflict species. Qualitative discussions were then used, where necessary, to further explore these responses.

To assess tolerance towards the conservation of the main conflict species, we followed a method developed by Naughton-Treves et al. (2003). Thus, respondents were presented with five possible management options for mitigating predator attacks on livestock: (1) do nothing; (2) repel the predator using disruptive stimulants; (3) habitat improvement for the predator; (4) translocation; and, (5) lethal control. The responses were then recoded into management strategies that did not remove the predator from the area (#1, #2 and #3) and those that did (#4 and #5).

3.2. Sampling

Before administering the questionnaire surveys, a meeting was held with the Department of Wildlife and Fisheries staff to identify the villages that had experienced losing livestock to leopards from January 2004 to May 2007. The presidents of Village Conservation Committees (VCCs), set up through a project funded by Global Environment Facility (GEF), were interviewed to assess the history of human–carnivore conflict in their village and to identify each household (the sampling unit) that had experienced conflict. From these households, the head, or most senior person available, was then interviewed in a local dialect (either *Pharri* or *Hindko*). Each survey took between 30 and 40 min to complete.

3.3. Data analysis

All data from the fixed response questions were numerically coded and entered into SPSS v.14 software package (SPSS Inc., Chicago, USA). To test for collinearity between the continuous covariates, a Spearman's rank correlation was performed to identify significant ($p < 0.05$) non-independence. For each predator, the number of livestock killed in total and for each type was determined. For the main livestock predators, a regression analysis was performed to investigate whether total livestock loss outside of villages was related to $\log_{10}$ herd size, $\log_{10}$ distance to MNP and $\log_{10}$ elevation (calculated within ArcView v3.2 GIS software, ERSI Inc. Redlands, USA), as well as guarding, location and habitat cover.

This analysis was then repeated for conflict inside villages, with the additional factors of presence of an electricity supply in the village and whether the livestock were penned in, or not, during the attack. Comparisons of the explanatory power of the candidate regression models were based on their delta Akaike Information Criterion (ΔAIC) values, adjusted for small sample sizes (ΔAIC_c), and their Akaike weights (w_i) (Burnham and Anderson, 2002). The influence of covariates from models that were within two ΔAIC_c units of the top ranked model were discussed. Model performance was evaluated by calculating the area under the curve of the receiver operating characteristics (ROC) plot (Osborne et al., 2001). Next, the number of human injuries and deaths caused by each predator and the number of predators killed were calculated for the study period.

To investigate seasonal attacks, the mean daily livestock losses to the main conflict predators per month were calculated. Temperature and rainfall data for the study area were obtained from the nearest weather station in Muzaffarabad (32 km away). These data were unavailable for the study period because of a massive earthquake in October 2005 that destroyed the station. Instead, climatic data from 1961 to 1990 were used, for which it is conceivable that there may have been a difference between historical and current temperature and rainfall data. The mean monthly temperature and daily rainfall per month were calculated. A Spearman's rank correlation coefficient was performed to investigate the relationship between mean monthly predator attacks and mean monthly temperature and then mean daily rainfall per month.

The financial loss for each respondent from livestock killed by predators was calculated based on the average annual market prices in Pakistani rupees (which was then converted to US dollars) for the different livestock types based on their sex, age and condition. Similarly, the costs of livestock losses to disease and accident, as well as the costs required to guard the livestock, such as infrastructure development and guarding hours, were calculated.

Local perceptions and tolerance towards the main livestock predators and their management were compiled using descriptive statistics. The influence of several potential predictors (number of livestock loss to main predators, financial loss to main predators) on local tolerance towards predator management was tested. A Mann Whitney *U* test was performed to determine if any of these factors explained whether a respondent thought that: (i) the predator should be protected, or not; and, (ii) the predator should be removed from the study area, or not.

4. Results

4.1. Livestock holdings and losses

From the 4654 households in the study area, 148 respondents (each from a different household) experienced attacks on their livestock from January 2004 to May 2007. Most of these respondents kept poultry, then livestock (95%); goats (52%), sheep (35%), cattle (10%) and buffalo (2%). The mean number of livestock heads kept per respondent was 21.3 ± 22.2 (SD). Most (70%) respondents kept one or two dogs that were used for guarding their livestock. The livestock attacks involved four predators, which killed a total of 363 livestock heads (from the estimated 37,233 heads available in the wider study area) and 34 dogs (Table 2).

Leopard was the main predator, responsible for the majority of livestock kills (90.6%), mainly of goats (57.3%) and sheep (27.8%) and greater than expected, given the availability of goats (31.0%) and sheep (18.0%) in the study area. The mean number of livestock killed per leopard attack was 1.7 individuals (±1.5, SD), with most attacks (53.4%) involving the death of a single livestock head attacked. The majority (64.2%) of leopard kills on livestock occurred during the night. The remaining (35.8%) kills occurred during the day, of which most (50.9%) were on livestock grazing near the village.

Table 2
Livestock and dogs killed in and around Machiara National Park, Pakistan.

Predator	Goat	Sheep	Cow	Donkey	Horse	Dogs	Total	% of total
Leopard	208	101	15	4	1	34	363	91.4
Himalayan black bear	5	6	13	0	0	0	24	6.0
Asiatic jackal	2	4	0	0	0	0	6	1.5
Golden eagle	1	3	0	0	0	0	4	1.0
Total	216	114	28	4	1	34	397	100

Please cite this article in press as: Dar, N.I., et al. Predicting the patterns, perceptions and causes of human–carnivore conflict in and around Machiara National Park, Pakistan. Biol. Conserv. (2009), doi:10.1016/j.biocon.2009.04.003

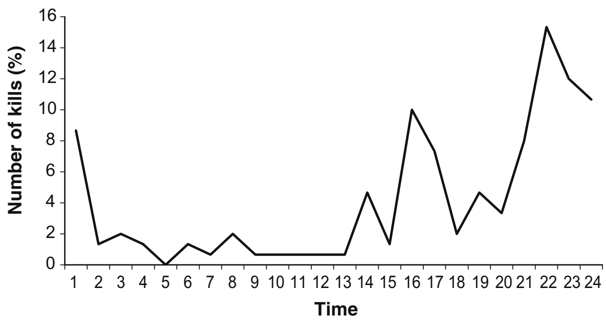

Fig. 1. Mean daily pattern of livestock killed in and around Machiara National Park, Pakistan.

For the main livestock predator, leopard kills were highest between 1600 and 1700 h and between 2100 and 0100 h (Fig. 1) most ($n = 82$, 55.4%) livestock kills by leopard occurred within the village at night, of which most (72.0%) livestock attacks took place within sheds rather than outside (28.0%). For those attacks occurring during the daytime ($n = 66$), most (48.5%) attacks occurred in grazing pastures near the village, then in forest areas (30.3%) and in pastures far from the villages (21.2%). The most (58.1%) common guarding strategy being used at the time of a leopard attack was people without dogs, then people with dogs (21.6%), neither (18.2%), or just dogs (2.0%). Comparing the total number of livestock heads killed by leopard inside and outside of the villages showed no significant difference ($n = 148$, $U = 2358.0$, $Z = -1.45$, $P = 0.147$).

Inside of the villages, most (89%) leopard kills occurred at night (2000–0600 h). An information-theoretic evaluation of a candidate set of regression models found that a greater number of livestock head kills were more likely to be experienced by respondents living in villages without electricity (Model 1.1; Table 3). This model explained 62.0% of the original observations and had an ROC value of 0.691. Herd size was identified as partially explaining the number of livestock killed, with larger herds being more vulnerable. There was no relationship between the number of livestock killed and livestock guarding technique, penning livestock in at night, elevation, distance to MNP or available leopard habitat cover.

Table 3
Best logistic regression models explaining the relationship between the number of livestock killed in villages around Machiara National Park, Pakistan, by leopard and several factors describing village infrastructure, livestock rearing, guarding techniques and environmental conditions ($n = 82$).

Model	K	2log likelihood	ΔAICc	w_i
1.1. Electricity	2	102.30	0.00	0.8584
1.2. Electricity + Log_{10} herd size	3	104.09	3.95	0.1194
1.3. Log_{10} herd size	2	109.61	7.31	0.0222

K is the number of parameters in the model, ΔAIC_c is the difference in AIC_c values between each model with the low AIC_c model, w_i is the AIC_c model weight.

Table 4
Best logistic regression models explaining the relationship between the number of livestock killed outside of villages in and around Machiara National Park, Pakistan, by leopard from several factors describing livestock rearing, guarding techniques and environmental conditions ($n = 66$).

Model	K	2log likelihood	ΔAICc	w_i
2.1 Log_{10} herd size + dist_MNP	3	82.78	0.00	0.8551
2.2 Log_{10} herd size	2	77.03	3.55	0.1449

K is the number of parameters in the model, ΔAIC_c is the difference in AIC_c values between each model with the low AIC_c model, w_i is the AIC_c model weight.

Outside of the villages, most (48.5%) leopard kills occurred while livestock were grazing near the village, which were mainly (84.4%) during the day. An information-theoretic evaluation of a candidate set of regression models found that respondents who were tending larger herds that were further from MNP were more likely to experience greater livestock losses (Model 2.1; Table 4). This model explained 63.6% of the original observations and had an ROC value of 0.758. There was no relationship between the number of livestock killed and livestock guarding technique, elevation, location or available leopard habitat cover.

Between January 2004 and May 2007, there were five recorded leopard attacks on humans: two were fatal and three resulted in serious injuries to the victims who survived. In retribution, two leopards were killed. There was one non-fatal black bear attack on a human, but it was not killed in retribution.

4.2. Seasonal patterns of attacks

The majority (56%) of livestock killed by leopard occurred during the summer months of May and July (Fig. 2). There was a significant and positive relationship between mean annual monthly temperature and annual monthly fatal leopard attacks on goats (Table 5), but not on sheep or other livestock types combined. No relationship was found between mean annual daily rainfall per month and mean annual daily fatal leopard attacks per month on goats, sheep or other livestock species combined (Table 5).

4.3. Financial valuation of livestock losses

The total financial loss arising from livestock deaths during the study period was estimated at US$137,183. The majority (72.7%) of these financial losses was attributed to disease, then leopard attacks (19.8%), other predators (4.0%) and accidents (3.5%), e.g. falling off cliffs or paths. While leopard was responsible for the greatest overall costs amongst wildlife-related attacks, livestock killed by black bear resulted in a much higher cost per livestock head (US$215) than livestock killed by leopard (US$83). This was because black bear mostly (54.2%) killed cows, a more expensive livestock type.

4.4. Local perception, attitude and tolerance towards human–carnivore conflict

The 148 respondents ranked leopard as the most problematic predators that affected them (87.9%), then black bear (10.1%) and fox (2.0%). The majority (93%) of respondents thought that the frequency of leopard attacks on livestock had increased since the establishment of MNP in 1996. Most (70%) respondents attributed this increase to the degradation and loss of forest habitat, while

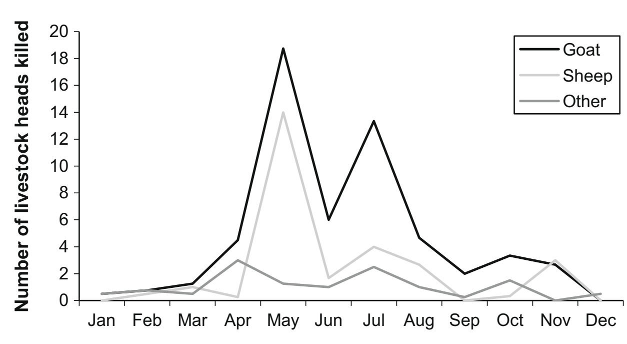

Fig. 2. Mean annual monthly patterns of leopard attacks on livestock in and around Machiara National Park, Pakistan.

Please cite this article in press as: Dar, N.I., et al. Predicting the patterns, perceptions and causes of human–carnivore conflict in and around Machiara National Park, Pakistan. Biol. Conserv. (2009), doi:10.1016/j.biocon.2009.04.003

Table 5
Patterns of monthly attacks by leopards in and around Machiara National Park, Pakistan with rainfall and temperature for the most attacked livestock types individually and for all other livestock types combined ($n = 12$), based on Spearman's rank correlation coefficient (r_s).

Livestock type	Average temperature/month			Average daily rainfall/month		
	r^2	r_s	P	r^2	r_s	P
Goat	0.399	0.832	0.001	0.085	0.140	0.665
Sheep	0.143	0.507	0.092	0.001	0.113	0.727
Other combined	0.166	0.465	0.128	0.169	0.268	0.400

some (24%) cited wild prey base decline. Most (81%) respondents correctly stated the national conservation status of the leopard and also correctly identified it as a species protected under national law. Most (91%) respondents correctly identified MNP administration and the Department of Wildlife and Fisheries as being responsible for the protection and conservation of leopards. Nearly half (49%) of the respondents thought that leopard was only present in the MNP area after its creation. All respondents agreed that the leopard was a major threat to their livestock, but a minority (35%) thought that leopard was dangerous to humans. Most (71%) respondents thought that the leopard should be protected, while 22% thought not.

There was no overall consensus amongst the respondents on the best way to mitigate livestock attacks by leopards. Only a minority (18%) cited improved animal husbandry, such as leopard-proof pens and increased guarding in the field. The most commonly cited management strategies were habitat restoration to increase the natural prey base of the leopard (36%), leopard translocation to more remote areas away from villages (27%), lethal control (18%) and do nothing (4%). Responses of leopard removal from the study area (45%) were not related to the number of livestock that a respondent had lost to leopard ($U = 2803.0$, $Z = -0.020$, $P = 0.984$). However, those respondents who had incurred greater financial loss from leopard conflicts were more likely to favour leopard removal ($U = 2230$, $Z = -2.179$, $P = 0.029$).

5. Discussion

This study highlights disease as the main agent responsible for livestock loss, which is not commonly reported in the human–wildlife conflict scientific literature, and dispels the notion that predators are always the main culprits in livestock loss. Nevertheless, leopard, the main livestock predator, still caused a relatively large amount of loss and, more importantly and regardless, was perceived by the pastoralists to be a major threat to their livelihood. With a 17–26% livestock increase in Azad Jammu and Kashmir over the past 20 years (Termizi and Rafique, 2001), conflicts between humans and carnivores are also expected to have increased, indicating that conflict mitigation is a priority conservation and development action for the region. From our study, goats and sheep were the livestock most vulnerable to attacks, especially during the warmer months. Although it might seem prudent to increase guarding effort during this period, we found that local strategies, such as using dogs or penning livestock in at night, were ineffective in reducing livestock losses. This probably explains why only a minority of respondents cited improved animal husbandry as a strategy for reducing leopard kills. Whether the future survival of leopard or other carnivores is dependent on alleviating their conflict costs to rural communities is debatable because only two leopards were known to have been killed in retribution during our study. However, the Department of Wildlife and Fisheries is responsible for wildlife, and local support for their broader conservation work is essential. So, for MNP and across the range of large carnivores in Pakistan, initiatives to improve local livelihoods, through vaccinating livestock, and tolerance towards wildlife, such as cost-effective guarding strategies, will need to be identified and then implemented in the field.

5.1. Livestock attacks by carnivores

From two human–carnivore conflict studies conducted in Bhutan and from our Pakistan study, leopard was recorded as the main livestock predator (Wang and Macdonald, 2006; Sangay and Vernes, 2008). From our study, the percentage of goats and sheep killed by leopard was greater than their availability. From the Bhutan study that recorded these data, leopard killed more sheep and horses than would be expected, although goats were not kept by the pastoralists in this area (Sangay and Vernes, 2008).

Goats and sheep are ideal leopard prey because these smaller animals (25–50 kg) can be quickly dragged to a secluded and safer place after being killed. In Sariska Tiger Reserve, India, goats, sheep and calves comprised 88% of leopard livestock kills (Sekhar, 1998). The mean wild and domestic prey body mass killed by leopard in Indian tropical forests was 23 kg (Karanth and Sunquist, 1995), while a synthesis of 33 published and unpublished leopard diet studies found that leopard preferentially preyed upon species within a weight range of 10–40 kg (Hayward et al., 2006). The amount of livestock loss to Himalayan black bear in our study (6%) was similar to that recorded from Bhutan (8%, Sangay and Vernes, 2008). However, in contrast to our study, black bear killed fewer cattle than expected given their availability. The MNP area also contained snow leopard, and although other studies have found this species to be a major livestock predator (Mishra, 1997; Jackson and Wangchuk, 2004), we recorded no such incidents, possibly because of its scarcity.

5.2. Patterns of human–leopard conflict

A lower availability of wild prey in Africa, which is often associated with rainfall patterns and seasonal movements of these prey, has been found to increase the risk of livestock attacks by carnivores (Patterson et al., 2004; Kolowski and Holekamp, 2006). In and around MNP, no relationship between rainfall patterns and livestock attacks was found, probably because water was not a limiting resource for wild prey due to the high levels of annual rainfall and permanent streams and springs. However, the availability of wild prey in our study area is more likely to be influenced by temperature.

During the winter months, the leopard's natural prey becomes more abundant in the study area as heavy snowfall at higher elevations forces the prey to descend, but only as far as the southern end of MNP that is bordered by villages which act as an artificial barrier to a further descent. In combination, these factors concentrate on wild prey inside MNP over winter, which coincides with significantly fewer livestock kills by leopard. During the summer months, when wild prey becomes less abundant in MNP, pastoralists also graze their livestock away from their village in meadows near the forest edge and often leave them unattended, thereby increasing their vulnerability to leopard attack.

Please cite this article in press as: Dar, N.I., et al. Predicting the patterns, perceptions and causes of human–carnivore conflict in and around Machiara National Park, Pakistan. Biol. Conserv. (2009), doi:10.1016/j.biocon.2009.04.003

Leopard tends to be a solitary and nocturnal hunter, relying on stealth and camouflage to stalk up close to their prey (Rabinowitz, 1989). It was therefore unsurprising that livestock in villages were particularly vulnerable at night, as they were often left unattended and in poorly constructed pens. Furthermore, villages without electricity supplies were more vulnerable to leopard attacks, presumably because the leopard had a greater chance of successfully approaching livestock undetected. We note that the presence of electricity may have acted as a proxy, possibly for increased wealth and the ability to fence livestock in securer night corrals; however, from our field observations, this seemed unlikely.

Leopard attacks exhibited a peak during the late afternoon (1600–1700 h), coinciding with livestock being left to graze unattended in fields nearby the village, while their owners were engaged in other work. While dogs might have alerted pastoralists to the presence of an approaching predator, our data indicate that dogs were ineffective in reducing leopard kills both inside and outside of villages. The death of 34 dogs to leopard attacks during our study might make dogs reluctant to alert leopard of their presence. From Kenya, dogs were also ineffective in deterring leopard attacks, as well as those by hyena (Kolowski and Holekamp, 2006).

Outside of villages, the risk of predator attack by day was greatest for larger herds (e.g. in Africa; Woodroffe et al., 2007), while attentive herding can lower predator attacks on livestock during the day (Ogada et al., 2003). Our study found no such effect, even though herders tend to herd in groups and not alone while watching over their flocks in the pastures. These grazing pastures, which tend to be further from MNP, are interspersed by forest that would provide adequate cover for leopards to stalk livestock prey. However, the greatest financial losses from livestock mortality were not due to conflicts with leopards or other wildlife, but due to disease. Disease is prevalent in the study area, mainly because there is no vaccination of livestock or treatment of sick individuals, which is a consequence of poor housing, the harsh environment and inadequate feed.

5.3. Local tolerance towards leopards

In our study area, the leopard was perceived as the major livestock predator and its attacks were thought to have increased since the creation of MNP, suggesting that the perceived threat of leopard attacks resulted in negative attitudes towards the protected area (Baral and Henien, 2007). Nevertheless, a benign situation exists for conserving leopard and also other carnivores in and around MNP. First, the number of carnivore attacks on people was low. Secondly, most respondents thought that the leopard was not dangerous to humans, should not be removed from MNP, should be protected, and they correctly recognized its protection under the Department of Wildlife and Fisheries. Thirdly, most people, although owning a firearm, tended to avoid shooting leopard or other carnivores in retribution for a livestock kill. Those who were less tolerant towards leopard tended to have suffered a greater financial loss, as has been found from human–snow leopard conflict studies in India (Mishra et al., 2003; Oli et al., 1994), which further emphasizes the need to mitigate conflict. Compensation schemes for livestock losses to wild carnivores, which currently do not exist in Pakistan, can also improve local tolerance towards wildlife (Bagchi and Mishra, 2006), but this is not always the case (Naughton-Treves et al., 2003), especially if payments are considered to be inadequate or delayed (Madhusan, 2003).

6. Conclusions

Being highly adaptable, the leopard has the widest geographic range of any wild felid. Yet, in Pakistan, this nationally protected species has been heavily persecuted because of conflicts with rural communities and poached for its fur and has consequently declined or disappeared over vast areas of its former range (Roberts, 1997; Nowell and Jackson, 1996). Our study found that leopard was not heavily persecuted. Instead, it highlights the complexity of human–leopard conflicts in and around MNP; it also reveals the spatiotemporal conflict patterns, which should be used to reduce the risk of carnivore attacks. The livestock guarding strategies used around MNP were shown to be ineffective, but improving livestock pens, increasing vigilance at night and in the grazing fields during the warmer months should reduce livestock losses. Thus, we recommend a dual strategy through rural development schemes to resolve these carnivore conflicts: installing electricity supplies within villages, such as solar lights or small hydro electric supplies, and vaccinating livestock populations against diseases, which is ideally linked to a wildlife conservation education programme. This should provide the greatest local livelihood benefits and generate stronger and wider local support for the recovery of large carnivores across their former Pakistan range.

Acknowledgements

We would like to thank the Department of Wildlife and Fisheries, Azad Jammu & Kashmir, the GEF/World Bank, DICE, Mohammad Yousaf Qureshi and the MNP staff and surrounding communities for supporting this study either through finance, logistics or participation. We are grateful to WWF-Pakistan for providing us with GIS data layers, in particular Mr. Hassan Ali. We thank Sanjay Gubbi for thoughtful inputs on an earlier manuscript.

References

Bagchi, S., Mishra, C., 2006. Living with large carnivores: predation on livestock by the snow leopard (*Uncia uncia*). Journal of Zoology 268, 217–224.
Baral, N., Henien, J.T., 2007. Resources use, conservation attitudes, management intervention and park-people relations in the Western Terai landscape of Nepal. Environmental Conservation 34, 64–72.
BirdLife International, 2007. BirdLife on line world bird database: the site for bird conservation. http://www.birdlife.org (accessed 23.8.2007).
Burnham, K.P., Anderson, D.R., 2002. Model selection and multimodel inference. A practical information-theoretic approach, second ed. Springer-Verlag, New York, USA.
Gurung, B., Smith, J.L.D., McDougal, C., Karki, J.B., Barlow, A., 2008. Factors associated with human-killing tigers in Chitwan National Park, Nepal. Biological Conservation 141, 3069–3078.
Hayward, M.W., Henschel, P., Brien, J.O., Hofmeyr, M., Balme, G., Kerley, G.H.I., 2006. Prey preferences of leopard (*Panthera pardus*). Journal of Zoology 270, 298–313.
Jackson, R.M., Wangchuk, R., 2004. A community-based approach to mitigating livestock depredation by snow leopards. Human Dimensions of Wildlife 9, 307–315.
Karanth, K.U., Sunquist, M.E., 1995. Prey selection by tiger, leopard, and dhole in tropical forests. Journal of Animal Ecology 64, 439–450.
Kolowski, J.M., Holekamp, K.E., 2006. Spatial, temporal and physical characteristics of livestock depredation by large carnivores along a Kenyan reserve border. Biological Conservation 128, 529–541.
Linkie, M., Dinata, Y., Nofrianto, A., Leader-Williams, N., 2007. Patterns and perceptions of wildlife crop raiding in and around Kerinci Seblat National Park, Sumatra. Animal Conservation 10, 127–135.
Linnell, J.D.C., Swenson, J.E., Andersen, R., 2001. Predators and people: conservation of large carnivores is possible at high human densities if management policy is favourable. Animal Conservation 4, 345–349.
Macdonald, D.W., Sillero-Zubiri, C., 2002. Large carnivores and conflict: lion conservation in context. In: Lynam, A.J., Macdonald, T., Loveridge, D.W. (Eds.). Wildlife Conservation Research Unit, Oxford University, pp. 1–8.
Madhusan, 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.
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., Madhusudhan, M.D., Bayarjagal, A., Prins, H.H.T., 2003. The role of incentive programs in conserving the snow leopard. Conservation Biology 17, 1512–1520.
Myers, N., Mittermeier, R.A., Mittermeier, C.G., Fonseca, G.A.B., Kent, J., 2000. Biodiversity hotspots for conservation priorities. Nature 403, 853–858.
Naughton-Treves, L., 1998. Predicting patterns of crop damage by wildlife around Kibale National Park, Uganda. Conservation Biology 12, 156–168.

Naughton-Treves, L., Grossberg, R., Treves, A., 2003. Paying for tolerance? The impact of livestock depredation and compensation payments on rural citizens' attitudes toward wolves. Conservation Biology 17, 1500–1511.

Nowell, K., Jackson, P. (compilers and editors), 1996. Wild Cats. Status Survey and Conservation Action Plan. IUCN/SSC Cat Specialist Group. IUCN, Gland, Switzerland.

Ogada, M.O., Woodroffe, R., Oguge, N.O., Frank, L.G., 2003. Limiting predation by African carnivores: The role of livestock husbandry. Conservation Biology 17, 1521–1530.

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.

Osborne, P.E., Alonso, J.C., Bryant, R.G., 2001. Modelling landscape-scale habitat use using GIS and remote sensing: a case study with great bustards. Journal of Applied Ecology 38, 458–471.

Pakistan Meteorological Department, 1990. Temperature and Rainfall Records in Muzaffarabad from 1961–1990. Islamabad, Pakistan.

Patterson, B.D., Kasiki, S.M., Slempo, E., Kays, R.W., 2004. Livestock predation by lions (*Panthera leo*) and other carnivores on ranches neighbouring Tsavo National Park, Kenya. Biological Conservation 119, 507–516.

Rabinowitz, A., 1989. The density and behaviour of large cats in a dry tropical forest mosaic in Huai Kha Khaeng Wildlife Sanctuary, Thailand. Natural History Bulletin of the Siam Society 37, 235–251.

Roberts, T.J., 1997. The Mammals of Pakistan. Oxford University Press, Karachi.

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.

Sekhar, N.U., 1998. Crop and livestock depredation caused by wild animals in protected areas: the case of Sariska Tiger reserve Rajasthan, India. Environmental Conservation 25, 160–171.

Termizi, S.S.H., Rafique, C.M., 2001. Forestry Statistics of Azad Kashmir. Forest Department, Azad Jammu and Kashmir, Muzaffarabad.

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

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

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