Chapter 6

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The focus of this research has been on the interactions between large carnivores, their wild ungulate-prey, livestock and people, with the aim of understanding the central question: why do carnivores kill livestock? Here, I synthesize my findings in an attempt to address this broader question.

The ultimate answer is simple — Large carnivores, being adapted to a protein-rich diet, specialize on ungulate predation. Some individuals therefore kill domesticated ungulates when the opportunity arises (Treves & Karanth 2003). However, there is considerable variation in this pattern, and understanding the mechanisms leading to variation in livestock predation is a lot more complex.

Patterns of livestock depredation by snow leopard and wolf

I first examined the factors that predispose an area within a landscape to livestock depredation by snow leopards *Panthera uncia* and wolves *Canis lupus*, the two main carnivores of Central Asia and the Himalayan high altitudes (Chapter 2). We monitored 25 villages in the Trans-Himalayan Spiti Valley for two years to assess the total number of livestock lost to various causes including damage by snow leopards and wolves. We then identified the correlates of these livestock losses. Snow leopards primarily killed large-bodied, free ranging stock (yak and horse). This was consistent with the previous studies reporting disproportionate killing of horses by the snow leopard (Oli 1994; Mishra 1997; Jackson & Wangchuk 2004). Wolves mainly killed donkey and sheep. Our analyses revealed that habitat structure best explained livestock depredation by wolves. Being coursing predators, wolves are known to prefer relatively flat terrain where they can chase down their prey (Caro & Fitzgibbon 1992). Villages where people grazed their livestock in pastures that were structurally simpler experienced greater livestock damage by the wolf. The relative abundance of wolves, measured as encounter rate of wolf signs, did not show any relation with the extent of their livestock damage. This suggests that habitat structure could probably mediate the availability (access) of livestock and other prey for the wolf. It also suggests that the presence of wolves by itself may be one of the key determinants of livestock depredation in large parts of Central Asia that are
characterized by relatively flat steppes and plateaus. In contrast, snow leopards are known to stalk and ambush their prey in rugged terrain (Ale & Brown 2009), and we expected an opposite pattern for them compared to the wolf. We expected livestock damage by snow leopards to be higher in villages with complex habitat structure in their rangelands. However, we did not find any evidence to support this hypothesis. Livestock damage by snow leopards, instead, was higher in areas with higher abundance of wild-herbivore prey and higher encounter rate of snow leopard sign. This suggested that an increase in wild prey – a highly desirable conservation outcome considering their own conservation status and functional role – would, in fact, lead to an increase in livestock depredation by snow leopards, presumably by supporting a greater abundance of the cat.

The relationship between livestock depredation by snow leopards and the relative abundance of wild prey suggests that human–snow leopard conflicts are likely to get more intense if successful conservation programmes lead to increases in wild prey abundance from the low densities typical of multiple use, livestock-grazed landscapes (Mishra et al. 2004). In contrast, our own earlier work had indicated that livestock depredation by snow leopards declines with an increase in wild-prey abundance (Bagchi & Mishra 2006). This apparent contradiction led us to posit a non-linear relationship where livestock depredation by snow leopards would increase as wild prey populations increase or decline beyond certain thresholds. We explored this issue in chapter four. Our results suggested that extent of livestock depredation by wolves may not be similarly affected by changes in wild prey abundance (Chapter 2). The wolf is likely to face even more intense persecution in the future, considering the on-going socio-economic changes in Central Asia where the global demand for cashmere is leading to an increase in livestock population, and replacement of larger bodied livestock with smaller bodied, cashmere-producing goats (Schaller 1998; Namgail et al. 2007; Berger et al. 2013). Increasing populations of goats, especially in relatively flatter parts of Central Asia such as the Tibetan Plateau and the northern steppes will likely intensify human conflicts with wolves much more compared to snow leopards. Apart from measures to better protect livestock and finding ways of sustainable fibre production, sustained education and
awareness programmes to increase the social carrying capacity for these carnivores will be needed, especially for the wolf.

**Figure 6.1:** Relationship between snow leopard and wild prey density across seven sites in Central Asia. Linear relationship between snow leopard and wild-prey density is significant (Slope = 1.01; \( R^2 = 0.76; P = 0.01 \)). Error bars represent 95% CI. Wild-prey density was estimated using the double-observer survey (Chapter 3). Figure reproduced from chapter four.

We have also shown that human perceptions can be at considerable odds with actual patterns of livestock depredation by snow leopards and wolves (Chapter 2). This suggests that while interviews of local people, which have been commonly employed to study livestock depredation conflicts, could yield accurate information on peoples’ perception of a conflict situation, the reality of livestock depredation must be measured additionally and independently.
Predator-prey relationship

Wild prey abundance is an important determinant of large carnivore abundance (Carbone & Gittleman 2002; Karanth et al. 2004). Estimating mountain ungulate abundance and density, however, has remained a challenge in most mountain regions of the world. Methods of robust population estimation of wild ungulates have been fairly well developed for non-mountainous landscapes, but they have been largely unsuitable for mountain areas. Most past studies involving abundance estimation of mountain ungulate prey of the snow leopard, therefore, have relied on total counts, which are not statistically robust and are not suitable for monitoring programmes. We modified and standardized the double observer survey method (Forsyth & Hickling 1997) for estimating the abundance of the main wild-prey species of the snow leopard (Chapter 3). We have refined the double-observer method to estimate mountain ungulate abundance with greater precision and accuracy. We tested the critical assumptions associated with the double-observer technique based on capture–recapture theory. The technique was adapted to estimate the populations of bharal *Pseudois nayaur* and ibex *Capra ibex*, the two most important prey species of the snow leopard, at five different sites along a gradient of their population density. We also conducted power simulation and found that a detection probability of 0.75 was sufficient to detect a change of 20% in populations of > 420 individuals. Our results show that the double-observer method is precise and statistically robust with sufficient power to detect changes in mountain ungulate populations. Our work presented in Chapter 3 makes a methodological contribution for the study and monitoring of mountain ungulates worldwide.

In chapter four, we tested the impact of wild prey availability on the extent of livestock depredation by the snow leopard. We used the double-observer survey method to estimate the population of wild-ungulates and censused the livestock population at seven study sites. We also used molecular genetics and camera-trapping to estimate the abundance of snow leopards in these sites. Micro-histology was used to examine the diet of the snow leopard. We found that snow leopard density increased linearly with wild-ungulate-prey density within the range of wild prey density that we examined (Figure
6.1. Snow leopard density did not show any discernible relationship with the availability of large-bodied free-ranging or herded livestock. The linear relationship with wild-prey suggested that snow leopard density was limited mainly by the availability of wild-prey and not due to other factors such as denning and resting sites. The relationships between snow leopard diet and the abundances of wild prey and livestock suggested that snow leopards had a type II functional response towards wild-prey but a type III (switching) functional response towards livestock. Using this information, we modeled the relationship between wild-prey availability and the rate of livestock depredation by the snow leopard (figure 6.2). The model predicted a non-linear hump-shaped relationship. We empirically examined the actual levels of livestock depredation by the snow leopard in 5 sites over three years. Snow leopard depredation of large-bodied free ranging livestock increased with increasing ratio of wild-prey to livestock abundance and reached a maxima when the density of large-stock was equal to wild-ungulate density. With a further increase in wild-ungulate prey, the proportion of large-stock predated by the snow leopard declined. A similar trend was seen with small-bodied herded livestock at a ratio of 1:7 wild-ungulate to herded-stock. Our results suggest that the interactions between wild ungulates, livestock and carnivores could be complex and non-linear.
Figure 6.2: Model prediction of total livestock killed along various ratios of wild-prey and livestock availability. The model is a product of snow leopard abundance \((P_r)\) as a function of wild-prey abundance and snow leopard functional response towards livestock \((F_l)\) as a ratio-dependant multi-species functional response. Figure reproduced from chapter four.

**Predator-people relationship**

The other important dimension of human-carnivore conflicts is the acceptability of a carnivore by local people. In parts of chapter two and chapter five, we examine and explain how human perception and attitudes shape our acceptability of carnivores. We
suggest that human tolerance of livestock depredation by large carnivores is an outcome of the interaction between human attitudes towards carnivores and human perception of the extent of damage. However, a key finding of chapter two was that human perceptions of the threat posed by a carnivore were at odds with the actual extent of damage caused by the carnivore. Indeed, human perceptions were influenced by socio-economic factors such as livestock holding, while the actual extent of damage by carnivores was influenced by ecological factors such as the relative abundances of predator and wild-prey and habitat structure. This suggests that human perception of interactions with carnivores is dynamic and likely to change with the socio-economic and cultural context.

Most studies aimed at understanding human attitudes towards carnivores have quantified individual level human attitudes and examined their socio-economic, demographic, and other correlates. In Chapter five, we explored how factors influencing human acceptance of carnivores change as one scales up from the level of an individual to a village. We quantified attitudes of local people towards the snow leopard and the wolf at six sites comprising 24 villages to identify. We used structured interview surveys to quantify attitudes. We posited that while certain personal traits such as age and gender could only influence attitudes at the level of the individual and factors such as culture, traditions and ecology could influence attitudes at the level of the community, the influence of socio-economic factors such as income, job, property and risks could span the entire range, from individual to larger social organizations such as the state. Such multi-scale examination of human attitudes towards large carnivores had not been attempted previously.

Our results revealed notable differences in the individual-level and community-level correlates of human attitudes towards carnivores in conflict. The significant factors at the individual-level were gender, education, and the age of the respondent (for both wolves and snow leopards), number of income sources in the family (wolves), agricultural production and large stock holdings (snow leopards). At the community-level, the significant factors included the number of herded-stock killed by wolves and the mean agricultural production (wolves), and village size and large stock holdings.
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(snow leopards). Presence of a community-based conservation program was influential in improving human attitudes at the scale of the study site. People consistently had significantly more positive attitudes towards the snow leopard than the wolf.

The role of the extent of livestock depredation in influencing attitudes towards the wolf at the level of the community implies that people weigh the risk of carnivore predation on their livestock based on cumulative livestock damage suffered by the larger community. Thus, while education and having multiple sources of income seem to help in improving the attitudes of individuals towards wolves, these effects may be overridden if the individual lives in a community that experiences relatively high levels of livestock losses.

These findings also suggest that, at the scale of the individual, access to formal and conservation education programs in areas where people are expected to co-exist with large carnivores is likely to be more effective in increasing the social carrying capacity for the carnivores. Women empowerment is generally not a conservation agenda but our results agreed with what appears to be a global pattern that women were less accepting of carnivores. Thus, we suggest that working with women to assist in improving their attitudes to wildlife may have far-reaching benefits for wildlife conservation.

Our work suggests that scaling-up from the individual to higher levels of social organization can highlight important factors – which would have been otherwise ignored – that influence attitudes of people towards wildlife in conflict, or formal conservation efforts in general. Such a distinction of factors based on scale should be helpful in targeting appropriate conservation measure at the appropriate scale. Our results reiterate the need for conflict management programs to be multi-pronged.

Limitations and future work

Our work on human perceptions (chapter 2) and attitudes (chapter 5) towards carnivores in conflict has shown some interesting patterns about the relationship between humans and carnivores. While we have demonstrated the correlates of attitudes towards carnivores change as we scale up from the level of an individual to the community, our
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work lacks a mechanistic explanation of how the importance of these factors changes with scale. A plausible avenue would be to explore the role of ownership of various resources and the different risks (environmental, market driven) in leading to scale-dependence in the correlates of human attitudes towards carnivores. For instance, a publicly owned resource such as access to pastureland which is susceptible to environmental risks is more likely to affect human attitudes to carnivores at the higher scale of the community. Furthermore, our work focuses mainly on the quantitative aspects of attitudes and may be lacking in some of the qualitative insights that people could have provided.

In chapter two we suggested that habitat structure could be mediating the availability (access) of livestock and other prey for the wolf. This result is consistent with studies on hunting habitat of wolves that have shown habitat structure to have a strong influence on kill sites (Kauffman et al. 2007; Kunkel & Pletscher 2000). However, the relative importance of habitat structure and wild prey availability on the livestock depredation behaviour of the wolf is little understood. The wolf is one of the most widely distributed carnivores and a robust understanding of its livestock depredation behaviour will have wide scale implications.

The results presented in chapter four throw light on the complex issue of the impact of wild-prey availability on the livestock depredation behaviour of large carnivores. However, in its current form, the model presented in the chapter can make only qualitative predictions about the trends in livestock predation along gradients of wild-prey to livestock ratios. Estimation of parameters such as attack rate could help make quantitative predictions about livestock damage by large carnivores. Such parameterization of livestock depredation models will also help discern patterns and identify general rules of livestock depredation along the scales of predator and prey body sizes.

I would like to point out that while we have attempted to evaluate and improve the double-observer technique as a robust field method for enumerating mountain ungulates (Chapter 3), we have not addressed the issue of spatial variation in wild ungulate
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distribution and associated stratified sampling. Depending on the expected pattern of
spatial variation and size of the study area, appropriate stratification is recommended to
identify the specific survey sites, which can then be sampled using the double-observer
technique (Yoccoz et al. 2001). The current abundance estimation based on the double
observer method is based on a canonical estimator. We suggest future investigators to
adapt likelihood estimation for this analysis. Finally, a key source of variation in the
double-observer estimate, that tends to make the confidence limits around the population
estimates wider, is the variance in group sizes of mountain ungulates. Modeling the
variation in the ungulate group size in order to reduce the uncertainty around the animal
abundance estimate would be useful.

A comment on 'Problem individuals' and the extent of livestock damage

Worldwide, a large extent of livestock damage by carnivores is managed with the
assumption that a few individuals (problem animals), representing a small fraction of the
carnivore population, are responsible for majority of livestock depredation events.
However, few studies have examined this empirically (Linnell et al. 1999). Our
understanding of ‘problem animals’ and their management is hampered by the difficulty
in studying individual carnivores and a lack theoretical framework.

Linnell et al. (1999) defined two types of problem animals. The first (type 1) is the
“animal in the wrong place”. These are individuals that have disproportionately higher
number of livestock in their home range compared to other individuals in neighboring
territories. Thus, as a direct consequence of greater livestock abundance, there is a higher
representation of livestock in their diet compared to neighboring individuals. For
example, a young individual dispersed to the edge of a protected area or an old animal
displaced from its territory to a human-dominated habitat. The second (type 2) is when
all individuals have similar abundances of wild-prey and livestock in their home ranges,
and a ‘problem individual’ is the one that kills disproportionately larger number of
livestock. Examples of type 2 problem animals are individuals with improved efficiency
for killing livestock, or reduced efficiency at killing wild-prey. It’s been long assumed that old and sick individuals resort to livestock depredation due to their reduced predation abilities. However, empirical evidence for these assumptions is rare (Linnell et al. 1999).

Our model (chapter 4) could provide a useful starting point to better understand and integrate these two hypotheses. Problem animals of type 1 appear to be a straightforward special case of this model. Using the average size of the home range of an individual cat as the sampling unit or area of interest, the model potentially allows one to predict the diet of the individual carnivore based on the ratio of wild-prey to livestock within its home range. Thus, our model presented in chapter four could be used as a framework to assess individual level variation in prey selection when spatial information on individual home ranges is available.

The development of type 2 problem individual can be influenced by the age, sex, health (Rabinowitz 1986), personality (Bekoff 1977) of the individual carnivore, the herding practices (Sukumar 1991), and livestock and wild prey populations within its home range. These factors could change the shape of the functional response for certain individuals in a population. A change in the individual level cost-benefits of hunting that leads to higher attack rate on livestock will lead to a change in the shape of the functional responses of the individual towards livestock and wild-herbivores. The extent of livestock damage by such an individual could then be examined by using the relevant shaped functional response in model similar to the one in chapter four.

While it is important to understand the individual level variation in livestock depredation behavior, it is widely recognized that most individuals of large-carnivore species will occasionally kill some of the livestock that they encounter (Linnell et al. 1999; Mishra et al. 2003; Treves & Karanth 2003; Woodroffe et al. 2005). Thus, a state of ‘absolute no livestock-loss’ may never be achieved for carnivore conservation in a multiple-use landscape. However, livestock depredation could be minimized and maintained low enough to be socially acceptable and economically feasible.
Finally

This thesis is a step towards developing more quantitative and predictive understanding of livestock depredation by large carnivores and associated conflicts with humans. While our work has given insights for better management of livestock and conservation of wildlife, I realize that it has generated more questions than answers. I hope that this effort and the future work it inspires will contribute towards more effective conservation, and enable better coexistence between humans and large carnivores that share our planet.

Reference


Kauffman MJ, Varley N, Smith DW, Stahler DR, MacNulty DR, & Boyce MS. (2007). Landscape heterogeneity shapes predation in a newly restored predator-prey...


