

REVIEW

Human–carnivore conflict in China: a review of current approaches with recommendations for improved management

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Abstract

Human–wildlife conflict (HWC) is a conservation concern that increasingly threatens the continued existence of some of the world's most endangered species. With an increase in human population, urban sprawl and subsequent encroachment on wild land, human and wildlife interaction has become inevitable. In the majority of cases, this interaction results in a negative outcome for humans, wildlife or both. In China, these key elements, along with a decrease in wild prey species, have resulted in the expansion of HWC encounters, and the need for alleviating this conflict has become a conservation priority. Loss of human life, livestock and/or crops is most often the catalysts that fuel HWC. Techniques to alleviate conflict around the world have included preventative measures and mitigation techniques, such as financial compensation and other incentive programs. Both types of measures have had variable success. We review the current status of human–carnivore conflict management in China, and, drawing lessons from around the globe, we make recommendations for improving conservation management in China. For example, an increase in law enforcement in nature reserves is vital to reducing human disturbance in prime carnivore habitat, thereby reducing conflict encounters. Also, modifications to current wildlife compensation programs, so that they are linked with preventative measures, will ensure that moral hazards are avoided. Furthermore, investigating the potential for a community self-financed insurance scheme to fund compensation and increasing efforts to restore wild prey populations will improve the outcome for wildlife conservation. Ultimately, HWC management in China will greatly benefit from an integrative approach.

Key words: China, human–wildlife conflict, wildlife compensation

INTRODUCTION

Human–wildlife conflict (HWC) can be defined as any direct or indirect interaction between humans and wildlife that results in negative impacts on humans and/or wildlife involved. However, in practice, HWC is most often considered as depredations by wild-

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life on humans, domestic animals and crops. HWC is a worldwide problem that occurs when and where humans and wildlife overlap spatially or in their resource use. It has existed for as long as humans and wildlife have coexisted (Lamarque *et al.* 2008). Shrinking natural habitats with human encroachment on wild lands, expanding human and livestock populations, increased disease transmission between wildlife and domestic animals, increased tourism and decreased food resources for wildlife are factors contributing to the persistence and escalation of HWC today (Treves & Karanth 2003; Lamarque *et al.* 2008; Madden 2008; Goodrich *et al.* 2011). Alleviating this conflict has become a conservation priority around the globe (Fourli 1999; Hussain 2000; Hill *et al.* 2002; Karanth & Madhusudan 2002; Mishra *et al.* 2003; Nyhus & Tilson 2004b; Gurung *et al.* 2008; Lamarque *et al.* 2008; Sangay & Vernes 2008; Aust *et al.* 2009; Inskip & Zimmermann 2009; Nugraha & Sugardjito 2009; Goodrich 2010; Kloskowski 2011; Liu *et al.* 2011). In many cases, HWC is exacerbated by the real or perceived threat that wildlife populations pose to human life or livelihood, which results in retaliation against individuals or populations of the animal in question, or reduced cooperation with conservation organizations (Miquelle *et al.* 2005; Treves *et al.* 2006; Goodrich 2010). The latter may occur if people feel that their needs are considered irrelevant or ranked second to those of wildlife.

Addressing HWC is undoubtedly complex and involves effective management of human actions as well as wildlife populations. Frequently, HWC results in financial loss (e.g. loss of livestock, property or crop land). This financial loss, particularly in developing countries and in poor rural communities, can be substantial and result in little tolerance for and poor attitudes toward wildlife conservation (Dickman *et al.* 2011).

In China, a large human population and intensifying encroachment on wild lands, as well as reduction of wild prey density, has contributed to an escalation in HWC. Additionally, with depredation events focused on humans, domestic livestock and crops amounting to significant financial losses (Cai *et al.* 2011). Conflicts occur mainly in or near nature reserves and poor and remote mountainous areas. Li (2011) reports that there were over 6000 compensation cases for wildlife damage from the late 1990s until the end of 2010. Since 2000, HWCs in China have mainly occurred in Shaanxi and Yunnan, as well as Guangxi, Tibet and Xinjiang Autonomous Regions (Zhou *et al.* 2010). The primary spe-

cies of concern are the tiger (*Panthera tigris* Linnaeus, 1758), the elephant (*Elephas maximus* Linnaeus, 1758), the wild boar (*Sus scrofa* Linnaeus, 1758), the takin (*Budorcas taxicolor* Hodgson, 1850), the brown bear (*Ursus arctos pruinosus* Linnaeus, 1758), the wolf (*Canis lupus* Linnaeus, 1758) and the snow leopard (*Panthera uncia uncia* Schreber, 1775). Although some of these species are associated with livestock depredation (tiger, wolf and snow leopard), others (elephant and wild boar) are associated with crop depredation. There is growing evidence that HWC is a serious conservation issue of great economic significance in China (Table 1) (Li *et al.* 2009; Cai *et al.* 2011).

The aim of this paper is to: (i) provide a brief, non-exhaustive review of the management approaches currently in use to mitigate HWC in China; (ii) review lessons learned globally on HWC prevention and mitigation measures; and (iii) generate recommendations for improved HWC mitigation in China. The recommendations will focus on HWC associated with carnivore depredation on livestock rather than crop depredation, recognizing that these are 2 related but very distinct problems requiring diverse solutions.

MANAGING HUMAN–CARNIVORE CONFLICT: A BRIEF REVIEW

Carnivore populations are especially susceptible to decline from HWC because carnivores require large areas, large prey populations and low rates of mortality to maintain viable populations (Woodroffe 2001; Macdonald & Sillero-Zubiri 2002; Chapron *et al.* 2008). They prey on livestock and compete with humans for wild prey. These depredations on people and their livestock elicit strong responses from local communities, resulting in retaliation killing and reduced support for conservation and protected areas (Miquelle *et al.* 2005; Maclellan *et al.* 2009).

Management measures used to reduce human–carnivore conflict include preventative measures taken to stop conflict before it occurs, mitigation attempts that reduce impacts of conflict after it occurs, and intervention, referring to efforts to stop specific conflict incidents as they occur (Goodrich 2010). In this review, we will focus largely on prevention and mitigation measures because mitigation is most widely used in China, but preventative measures are most effective for reducing conflict.

Table 1 Economic loss and corresponding compensation payment in China (adapted from Cai *et al.* 2011)

Location	Animal	Value of Loss (US\$)	Compensation payment
Yunnan	2009: Asian elephant was responsible for 38% of conflict cases, followed by wild boar (27%) and black bear (9%). Other animals included guar, brown bear, cloud leopard, macaque, dhole, wolf and black necked crane.	2000–2004: \$5.59 million (per year). 2005–2009: \$8.21 million (per year). 2009: \$8.75 million.	2000–2004: Total payment was 13.79% of total loss. 2005–2009: Total payment was 23.45% of total loss. 2009: In a pilot study area (consisting of 116 villages), compensation value was 60% for crops and livestock and 80% for human injury.
Xishuangbanna Nature Reserve	Mainly elephant.	>\$3 million annually.	>90% of total damage amount.
Simao and Linchang of Pu'er Municipal City	Mainly elephant, but also many other species.	Approximately \$1.5 million annually.	> 90% of total damage for places with an insurance program.
Zhaotong, Nujiang, Diqing, Lijiang, Chuxiong, Qujing and Honghe	Asian elephant, black bear, guar, brown bear, cloud leopard, macaque, dhole, wolf, wild boar and black necked crane.	>\$3 million annually.	30% for loss due to elephant.
Jilin	2007–2009: Wild boar responsible for 89.78% of conflict cases, followed by Amur tiger (8.96%). Other animals included black bear and migrating birds.	2007: \$0.39 million. 2009: \$1.29 million.	2007 and 2009: Compensation output was 87% of total loss. 100% was given for loss of livestock by tigers, 30% for loss of livestock by other animals and 60% for crops.
Changbai	Mainly wild boar.	2009: \$380 841.	Refer to Jilin.
Wangqing	Mainly wild boar.	2009: \$203 750.	Refer to Jilin.
Antu	Mainly wild boar.	2009: \$152 794.	Refer to Jilin.
Hunchun	Mainly wild boar and tiger.	2009: \$48 044.	Refer to Jilin.
Shaanxi	Takin, black bear, Chinese serow, common leopard, crested ibis, rhesus macaque, wild boar, wild rabbit, Reeve's muntjac, hog badger and brown hawk owl.	2005: \$0.18 million. 2009: \$0.57 million.	50% of loss or 50% of market value for crops.
Tibet Autonomous Region	Brown bear, black bear, snow leopard, lynx, dhole, wolf, white-lipped deer, blue sheep, wild yak and red deer.	No available information.	2008: Compensation in 10 demonstration counties was \$1.28 million. 2009: Compensation in 10 demonstration counties was \$1.40 million.

The compensation program in Tibet Autonomous Region was conducted as a pilot study; therefore, compensation payment was 100% of market value, different from that of provincial compensation policies at the time. Sources: Zhang and Wang (2003), Zhou *et al.* (2010) and Cai *et al.* (2011).

PREVENTATIVE MEASURES

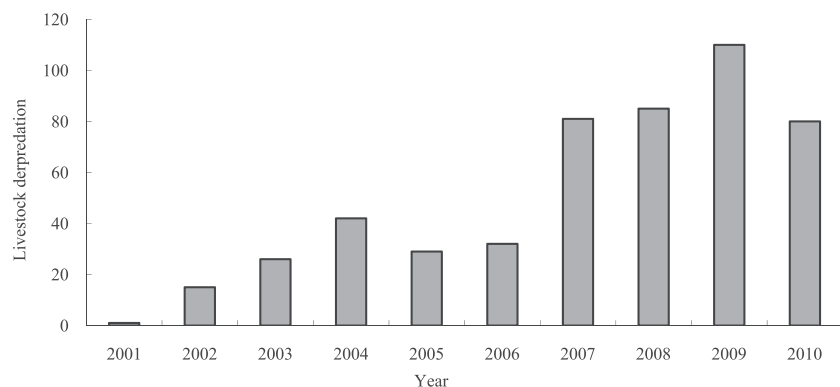
Prevention is widely recognized as being by far the most effective measure to reduce human–carnivore conflict (Treves & Karanth 2003; Goodrich 2010). Commonly used preventative approaches include improved livestock management, zoning of land use, increasing wild prey and reducing injuries to carnivores. In most cases, improving livestock management is the most significant action that can be taken to reduce the risk of carnivore depredation on livestock (Rabinowitz 1986; Charudutt 1997; Breitenmoser *et al.* 2005; Frank *et al.* 2005). Eliminating livestock grazing within carnivore habitat will eliminate depredation on livestock, except when carnivores wander into human-dominated landscapes. Tending of livestock by adult herders during the day and avoiding carnivore habitat (e.g. forested and brushy areas) and predator hotspots reduces depredation by large felines (Breitenmoser *et al.* 2005; Karanth & Gopal 2005; Miquelle *et al.* 2005). Land-use patterns influence human–carnivore conflict and zoning can minimize conflict through removal or better management of conflicting activities (e.g. livestock grazing) (Linnell *et al.* 2005). It is clear that the highest levels of conflict occur where carnivores and people geographically overlap (Karanth & Madhusudan 2002; Nyhus & Tilson 2004a; Gazzola *et al.* 2008; Smith *et al.* 2010), so the goal of zoning is to separate people and their livestock from critical carnivore habitats and movement corridors. Zoning requires human relocation programs that are transparent, incentive-driven (i.e. provide improved living conditions in a new area) and fair (Karanth & Madhusudan 2002). Removing people and livestock from tiger habitat can arrest human–tiger conflict, reduce habi-

tat fragmentation and facilitate prey population recovery (Karanth & Gopal 2005; Nyhus *et al.* 2010). Villages and their livestock have been voluntarily and successfully removed from parks in India (Karanth *et al.* 1999). The Viengkham District in Luang Prabang in Laos has successfully worked with farmers to remove several livestock grazing areas from the Nam Et – Phou Louey National Protected Area (NEPL) core zone, thereby reducing human–tiger conflict in the area (Wildlife Conservation Society [WCS] Laos Program, unpubl. data).

Analysis of preventative measures in China

To date, there have been several published studies on the implementation (including research and trials) of prevention measures to alleviate HWC in China (Zhang & Wang 2003; Tsering *et al.* 2007; Cai *et al.* 2008; Worthy & Foggin 2008). However, there has been mixed success in reducing conflict. In the relatively small Hunchun Nature Reserve (45 km²), livestock depredation by tigers has increased since 2006 (Fig. 1). In 2010 alone, the economic cost associated with the loss of 80 cattle due to tiger depredation was estimated to range between US\$48 400 and \$67 760 (WCS China Program, unpubl. data). Protective fences constructed in collective pastures to keep cattle confined at night were not successful in preventing conflict, primarily due to problems associated with location of fences. Fences were deemed too far from the cattle grazing zone and farmers would not bring their cattle into the fenced area; therefore, although the poorly designed preventative measures did not prevent conflict, it does not mean that preventative measures cannot be used in Hunchun and emphasizes the importance of well-designed and thoughtfully implemented preventative measures. In the Sanjiangyuan

Figure 1 Increase in livestock depredation by the Amur tiger (*Panthera tigris*) from 2001 to 2010 in Hunchun Nature Reserve, Jilin, China. (Note: due to a handover in compensation responsibility, data collected in 2006 is incomplete.)



National Nature Reserve, conflicts between brown bears and people have become increasingly common, with brown bears raiding critical food supplies and destroying homes. Complex factors, such as changing patterns of nomadism, eradication of the plateau pika (*Ochotona curzoniae* Hodgson, 1858; key component of the brown bear diet), increasing foraging areas for livestock, and privatization of land and livestock have been identified as key drivers of the escalating conflict (Worthy & Foggin 2008). Approaches to alleviate conflict have largely focused on preventative measures, such as strengthening doors and building fences, but, to date, these have been reported as not being entirely successful. However, in Changtang National Nature Reserve in Tibet Autonomous Region, protective pasture fences designed to keep away Tibetan brown bears designed and implemented in collaboration with herding households were found to help prevent depredation by brown bears. The rate of livestock loss decreased by over 90% compared with the annual average prior to the establishment of pastures enclosed by protective fences (Kang & Zhao 2011). Factors associated with effective prevention measures include good design, monitoring of relevant variables associated with the conflict, availability of technical and financial assistance to implement the prevention measures, the degree of willingness by local people and strict observance of management regimes by local people. With mixed success in the execution of preventative measures in China, future implementation of such measures requires consideration of all the above factors.

MITIGATION MEASURES

Compensation

Programs used to mitigate HWC include compensation, insurance programs and incentive programs. Compensation payments for losses of livestock to depredation, for medical expenses when people are wounded or for a family when a life is lost, are widely supported as tools to reduce HWC (Treves *et al.* 2009; Agarwala *et al.* 2010; Dickman *et al.* 2011). Conservation authorities use compensation mechanisms to address financial loss incurred as a consequence of HWC. The immediate objective of compensation is to increase tolerance toward wildlife by alleviating the financial losses associated with incidents of HWC. The ultimate long-term goal is to reduce losses of the (usually) endangered species involved and, simultaneously, mitigate loss of human life or livelihood. In this context, compensation may re-

duce losses through a reduction in retaliation killing and poaching (due to improved attitudes and a reduced financial need to kill wildlife). A key aspect of successful compensation schemes is linking them to land-use practices that are compatible with conservation, such as grazing in fenced zones and providing feed troughs for livestock rather than allowing 'free range' grazing. For example, compensation can help to improve livestock management (i.e. reduced depredation and higher stock productivity) and increase wild prey. However, without being appropriately linked to land-use practices, wildlife compensation might address only the economic aspect of the conflict. Therefore, the obvious question remains regarding whether this initiative alone addresses the social, political and conservation problems associated with land use, illegal poaching, declining prey densities, lack of education and habitat loss, all of which are also key drivers of HWC.

Wildlife compensation is widely used around the globe as a tool in mitigating conflict (Fourli 1999; Bulte & Rondeau 2007; Agarwala *et al.* 2010; Boitani *et al.* 2010). However, the implementation and conservation impacts of wildlife compensation have resulted in mixed outcomes (Naughton-Treves *et al.* 2003; Rondeau & Bulte 2007; Schwerdtner & Gruber 2007; Treves *et al.* 2009; Agarwala *et al.* 2010). Compensation programs have been widely criticized in the published literature for failing to meet the conservation goal of mitigating HWC. Failure is often linked to the struggle to meet one or more of the key concepts that are connected to the success of an effective program. Several key concepts are outlined by Nyhus *et al.* (2003) and are summarized in Table 2. Reasons for failure include unsustainable high payout costs, difficulty in verifying claims, high numbers of false claims, government corruption and the difficulty of making timely payments in rural areas (Karanth & Gopal 2005; Nyhus *et al.* 2005). Dickman *et al.* (2011) provide a review of operational issues associated with the failure of mitigation measures that involve financial mechanisms. They conclude that financial mechanisms may not be sufficient in themselves to solve the problem of conserving large carnivores on human-dominated land. Financial incentives may fail to facilitate coexistence in some areas associated with high costs imposed by carnivore presence. In such places, alternative strategies that spatially separate humans and wildlife might be necessary.

In many areas, there are multiple predator species that kill livestock and humans (MacLennan *et al.* 2009). Compensating only for damage caused by one species

(e.g. funds are sometimes available for tigers but not other animals) might not reduce retaliation killing because methods commonly used for retaliation killing (i.e. snaring, poisoning and explosive traps) are indiscriminate. Furthermore, compensation often does not improve attitudes toward offending wildlife (Naughton-Treves *et al.* 2003; Rondeau & Bulte 2007; Agarwala *et al.* 2010). Given that most compensation and insurance schemes pay only a portion of market value, livestock owners are rarely fully compensated for the economic cost of depredation. Furthermore, payments for verified depredation do not cover all of the associated costs incurred by guarding livestock from the risk of predation. Therefore, even if insurance or compensation schemes reduce the likelihood of retaliatory carnivore killing, incentives still remain for pre-emptive killing (Dickman *et al.* 2011). Nyhus *et al.* (2003) highlights that successful compensation programs include mechanisms for solving all of these problems, as well as monitoring of wildlife populations to demonstrate success.

If not linked closely to preventative measures, such as improved livestock management, compensation does little to encourage preventative measures and might even encourage the opposite; that is, pastoralists actually reduce their efforts to protect livestock because receiving compensation is easier than caring for and selling livestock (Nyhus *et al.* 2003; Bulte & Rondeau

2005; Rondeau & Bulte 2007). Indeed, compensation might provide incentive to increase numbers of stock, further exacerbating the problem.

For these reasons, compensation programs are not recommended as the only approach for livestock depredation, but, if they are used, compensation should be provided only in cases where, despite good livestock management practices, there is still depredation. That is, compensation must be used in conjunction with strong livestock management programs designed to reduce depredation. However, compensation for human injury, or loss of life, may have a more positive impact on conservation (Karanth & Gopal 2005; Nyhus *et al.* 2005) and such programs have fewer problems because attacks on humans are rare in most areas and claims are more easily identified.

Table 3 provides a brief review of compensation processes taken from global examples for livestock depredation associated with carnivores. Many compensation programs have established processes for evaluation of claims, but these vary in their comprehensiveness. Similarly, eligibility conditions for claims frequently do not exist, are unclearly defined where they do exist and, most importantly, are rarely linked to preventative measures.

Table 2 Key concepts for a successful compensation program as outlined by Nyhus *et al.* (2003)

Key concept	Application of the concept
Speed	Allow farmers to receive compensation payment quickly.
Transparency	The compensation process should be easily understandable, fair and all parties should be aware of and understand the process.
Funds	Ensure adequate funding is available (keeping in mind that wildlife damage can vary from year to year).
Separate responsibilities	Involve a separate entity that deals with the verification process of the loss and another entity that is responsible for the payment.
Involve experts or trained locals	Ensure verification of loss is conducted by impartial outside experts or trained locals. This aids trust and discourages fraudulent claims by giving farmers confidence that estimates of loss are accurate.
Clear guidelines	Ensure strong institutional support and link compensation to effective management practices.
Measure success	Be able to verify the success of the program. For example, survey farmers before and after implementation of a compensation program to investigate whether tolerance toward wildlife has increased. In addition, monitor wildlife to ensure the conservation outcome of protection is being met. For example: are numbers steadily increasing? Are fewer reports of retaliatory killings being made?

Table 3 A brief review of compensation processes in a non-exhaustive list of examples around the globe

Reference	Mitigation approach	Eligibility conditions	Compensation value
Fourli (1999); France	Direct compensation by the state for wolves, bears and lynx. Funding reliant on non-governmental organizations (NGOs), hunting associations and inter-communal groups.	None required or enforced.	Market value plus other costs associated with depredation.
Fourli (1999); Greece	Direct compensation by the Greek Agricultural Insurance Organization (ELGA).	In the case of repeated cases, proper prevention measures are required.	100% market value for bears and 80% for wolves.
Fourli (1999); Portugal	Direct compensation by state budget for damage caused by wolves.	Strict conditions based on protection measures.	Market value; all medical expenses resulting from an attack are compensated.
Fourli (1999); Austria	Direct compensation by regional authority through insurance mechanisms.	No conditions.	Compensation based on the actual claim, assumed to reflect market value.
Fourli (1999); Spain	Direct compensation by regional administration of autonomous communities.	Very structured and linked to protection measures.	100% or more of market value.
Treves <i>et al.</i> (2009); Wisconsin, USA	Direct compensation funded by annual state income tax, surcharges on specialty license plates (that depict a wolf) and from state revenues.	Conditions not linked to protection.	100% of market value.
Murphy (2010); Kenya	Direct compensation fund.	Conditions linked to protection measures; fines for poaching.	No available information.
Linnell & Broseth (2002); Norway	Direct compensation fund from the national and county level governments.	Conditions exist but not linked to protection.	Value is based on slaughter value of sheep.
Nemtsov (2003); Israel	Direct compensation funded by the federal government and a sponsor. (Note: only 1 year in operation.)	Strict conditions linked to protection.	Value based on level of protection.
Hotte & Bereznuik (2001); Russia	Direct compensation funded by the private Tigris Foundation.	Strict conditions linked to protection.	Not available.
MacLennan <i>et al.</i> (2009); Southern Kenya	Direct compensation funded by the Mbirikani Predator Compensation Fund and the 'group ranch'.	Livestock required to be kept in a boma (a predator-proof enclosure) every night.	100% of market value; however, deductions made for poor husbandry.
Lee (2011); Southwestern Alberta, Canada	Direct compensation financed through hunting and fishing licenses.	Currently, mitigation is not linked to the compensation program.	Compensation is based on average market value; does not cover loss of horses, donkeys or exotic animals, or cost of livestock loss or injured by coyotes.
Madhusudhan (2003); India	Direct state-funded compensation for livestock depredation.	Conditions not linked to protection but victims are required to provide proof of rights over land where loss has occurred.	Less than market value.

Type of conflict refers largely to livestock depredation by carnivores and 'eligibility conditions' refers to conditions that are required to be met to ensure that compensation payment can be received (i.e. eligibility conditions can include species responsible for the depredation, location of the conflict, landownership status of the claimants and linkages to preventative measures).

Insurance programs

Insurance programs are subject to similar difficulties to compensation programs, and also include the further problem of the lack of availability of private insurance companies willing to insure against livestock depredation for a reasonable price (Nyhus *et al.* 2005). Where private companies are willing to insure at reasonable rates, the system provides a sustainable mechanism for compensation due to depredation. However, in both Russia and Laos, people do not want to buy into insurance schemes because depredation rates are not high enough, people tend not to trust the scheme and incentives to reduce depredation are not there because of the opportunities provided by poaching tigers (Miquelle *et al.* 2005; Johnson *et al.* 2006). Alternatively, in China, survey results in Jilin indicate interest by communities to participate in a community self-financed insurance program, based on the condition of compensation at full market price within 2 months of the incident (J. Berger, unpubl. data). Community self-financed insurance schemes can assist compensation programs by reducing the financial burden often carried by government organizations that currently fund compensation programs. Preliminary results from insurance schemes as an alternative way to fund compensation for snow leopard depredation in Pakistan and India suggest some success (Hussain 2000; Mishra *et al.* 2003). However, local interest in insurance programs can be low, especially where the rate of depredation is low (Miquelle *et al.* 2005).

Incentive programs

Incentive programs attempt to offset costs of depredation by providing alternative sources of income based on ‘conservation-friendly’ practices, which often include improved livestock management practices. According to Dickman *et al.* (2011), one of the greatest challenges associated with carnivore conservation is the notion of ‘market failure’, where global resources drastically decline due to the lack of incentive at the local level to conserve it. Thus, the notion of providing incentives at the local level to protect a species has been adopted as a proactive, rather than a reactive, measure across many countries in order to improve conservation outcomes. In Mexico, payments of between \$50 and \$300 are given to local people, if evidence of jaguars on their property can be produced in the form of camera trap records. By providing such incentives, jaguars become more valu-

able alive than dead and, therefore, such a program can aid in their recovery (Nistler 2007). Incentive programs have been used successfully for snow leopard conservation in several countries, with a positive response from local communities, increased local incomes and increased density of wild prey (Mishra *et al.* 2003; Jackson *et al.* 2010). However, the value of incentive programs for tiger conservation is unclear because it has never been demonstrated that such programs have had a positive impact on tiger populations. Incentive programs are subsidized, at least at the outset, and may become self-sustaining. However, because the black-market value of a tiger is very high, it is difficult to develop incentive programs that offset the potential income gained by poaching tigers.

Revenue-sharing is an alternative incentive program aimed at promoting conservation. The concept is derived by sharing some of the revenue that can be generated through wildlife via things such as ecotourism and hunting activities. Profits are distributed back to the local community in order to offset the burden caused by the presence of the offending wildlife (Dickman *et al.* 2011). Evidence of success through revenue-sharing in promoting conservation of the target species can be seen in Uganda, where, between 1995 and 1998, local communities surrounding national parks used revenue generated through tourism to build 21 schools, 4 clinics, 1 road and 1 bridge. Furthermore, it has been demonstrated through interviews among local people that, after revenue-sharing, 72% of respondents improved their attitudes toward the protected areas (Archabald & Naughton-Treves 2001). However, similar to compensation programs, revenue-sharing ventures can also involve issues of an uneven distribution of funds, whereby villages in significantly remote locations, who likely suffer the heaviest burden from wildlife conservation, receive minimal revenue (Dickman *et al.* 2011). In addition, as outlined by Dickman *et al.* (2011), revenue-sharing may not always outweigh the cost of living with wildlife. For example, increasing the amount of protected land for ecotourism ventures can result in local communities suffering further cost by losing their right to use the land (i.e. for grazing, hunting and collecting non-timber forest products [NTFPs]).

Implementing incentive-based programs needs to be conducted in a manner that, first, considers the incentives for local people (which needs to include both financial and cultural incentives) so as to ensure that the benefits of living with wildlife outweigh the cost of their

presence. Second, revenue-sharing activities must be closely monitored and significantly improve the conservation status of the species in question.

Analysis of mitigation measures in China

In China, the main mitigation programs in place are compensation programs. Compensation programs for local communities suffering economic losses due to HWCs have been widely recommended and discussed as potentially essential to ensure community support for wildlife conservation in China (Zhang & Wang 2003; Cai *et al.* 2008; Worthy & Foggin 2008). However, there is a critical need to examine the effectiveness of compensation mechanisms in China, as well as globally, as a viable tool in improving public attitudes towards carnivores and reducing human–carnivore conflict. The following is a brief analysis of key issues influencing the effectiveness of compensation mechanisms for reducing livestock depredation caused by human–carnivore conflict in China (Table 4).

With reference to the synthesis of key elements associated with a successful compensation program (Nyhus *et al.* 2003), as in many other countries, China's compensation programs are plagued by numerous downfalls. These include: lack of financial sustainability and/or linkage with preventative measures, failure to provide timely payments, lack of clear guidelines and, to date, no conflict mitigation program in China has a follow-up method to measure success. Human–carnivore conflict has significant economic repercussions and sustainability is a key issue for financial compensation mechanisms that have been put in place to reduce conflict (Table 1). Since the first law for compensation was passed in Yunnan in 1998, expenditures for compensation by Chinese government agencies at all levels have increased. From 2000 to 2004, the direct compensation cost in Yunnan was US\$2 960 976, which accounted for only 14% of loss. At that time, compensation was still in its initial stages and many cases were only partly compensated or not compensated at all. From 2005 to 2009, compensation payments by the national government and the provincial government of Yunnan amounted to US\$7 776 923 (Cai *et al.* 2011). Despite such large expenditures, currently, national law in China has no stipulation for a unified compensation standard (Li 2011). Therefore, not all cases are compensated in the same way. As a result, compensation may have improved attitudes or reduced losses of wildlife in a small number of

cases, but, in others, it is likely that it has done little to alleviate this conflict.

Currently, in China, although there is a complex process involved in the reporting and verifying economic loss to wildlife, there are few clear guidelines and rigorous criteria associated with the disbursement of payments. Consequently, economic compensation mechanisms may relieve the burden of the loss but there is no accountability for or linkage to long-term conservation outcomes, as is evidenced by the compensation program for tiger depredation in northeastern China. In Jilin, compensation began in 2007 and amounted to US\$272 346; by 2008, it had reached US\$1 107 541 and, in 2009, US\$1 045 588 (Cai *et al.* 2011). Livestock depredations increased during this period (Fig. 1). Similar to work done by Agarwala *et al.* (2010), the compensation program succeeded in gaining community support and tolerance for tigers (local people to WCS staff, pers. comm.). However, the mechanism was a financial burden to the government agency. Currently, in China, funding for compensation is undertaken by national, provincial and local governments, with the responsibility of each level varying, depending on location. For example, in Jilin, 50% of funding comes from national and provincial levels, and the remaining 50% is financed by the local government. In Tibet, compensation is financed entirely by the central government. Alternatively, in Yunnan, some non-governmental organizations also contribute to funding compensation. Thus, there are no clear or uniform methods to fund compensation. In Jilin, livestock losses were compensated, regardless of location or livestock management practices (i.e. even a loss of livestock illegally grazing in the core area of Hunchun Nature Reserve was compensated). Therefore, there were no incentives for local people to improve livestock management to prevent losses and, subsequently, livestock depredations continued to increase (Fig. 1). Moreover, the program did not monitor tiger or prey population numbers, so ultimate success could not be evaluated.

Compensation programs have also been initiated at Changtang National Nature Reserve in the Tibet Autonomous Region. Originally announced in 2006, compensation was introduced to cover the cost of damage caused by wildlife. These measures have been warmly received by local residents since their implementation (Kang & Zhao 2011). However, the current compensation policy adopts a remedial approach with ineffective

Table 4 A brief overview of compensation approach in China

Location	Mitigation approach	Eligibility conditions	Analysis
Yunnan	Direct compensation.	In addition to ‘standard eligibility conditions’*, other cases are approved by forestry bureaus above the county level.	Yunnan was the first province to adopt wildlife compensation, passed as regulation in 1998.
Xishuangbanna Nature Reserve	November 2009, a pilot insurance program set up for the Asian elephant covers compensation payments.	Refer to Yunnan.	Utilizing an insurance program has made the process faster and more objective. Additionally, it has aided in obtaining community support and promoted tolerance toward wildlife. Prevention projects are separate from compensation and insurance projects. Therefore, the compensation project on its own is considered to be financially unsustainable.
Simao and Lincang of Pu’er Municipal City	Insurance program covers compensation payments.	Refer to Yunnan.	Program receives community support and promotes tolerance towards wildlife. No incentives are available for preventative measures, so it is financially unsustainable, as well as slow with payments.
Jilin Changbai, Wangqing and Antu	Direct compensation pilot project conducted; however, ‘tiger-proof fence’ unsuccessful.	In addition to ‘standard eligibility’*, other cases are considered under current laws and regulations. Moreover, the following clauses are included as actions that forego eligibility: (1) injury or death of a person who attacks or hurts a wild animal, and (2) damage incurred due to illegal behavior.	Jilin introduced wildlife compensation regulation in 2006. Direct compensation has been applied across the whole province. Payments can take up to 1 year. Program receives community support and promotes tolerance toward wildlife. County level government suffers from financial unsustainability. No incentives for preventative measures.
Hunchun	Direct compensation.	Refer to Jilin. An exception is tiger depredation which is compensated, regardless of the location of the kill.	Refer to Jilin.
Shaanxi	Direct compensation.	In addition to the ‘standard eligibility conditions’*, there are other cases approved by forestry bureaus above the county level. Changes of 2 clauses include: (1) a person who is injured or killed during legal activities (for livelihood and other income, such as farming), providing that the person took essential prevention measures or tried not to hurt the wild animal, and (2) injury or death of livestock in captive breeding or a pen. Furthermore, the following clauses are included as actions that forego eligibility: (1) injury or death of a person who attacks or hurts a wild animal, and (2) injury or death of a person who did not follow procedures for handling or transporting animals during business with permission from the government.	Shaanxi introduced wildlife compensation regulation in 2004. Direct compensation has been applied across the province.

Location	Mitigation approach	Eligibility conditions	Analysis
Tibet Autonomous Region	Direct compensation.	In addition to 'standard eligibility conditions'*, damage to houses, furniture and enclosures is included. The following clauses are included as actions that forego eligibility: (1) injury or death of a person who attacks or hurts a wild animal, and (2) damage due to illegal behavior.	Tibet Autonomous Region issued temporary wildlife compensation regulation in 2006, and updated it to formal regulation in 2010. Compensation cost is increasing. Lack of an operating budget and staff in the forestry system to conduct case investigations, due to a large area. Regulation has detailed descriptions how to conduct investigations and evaluate each case. Village and township level government authorities are requested to conduct investigations, so pressure on the forestry system can be reduced. Program receives community support but, to date, no survey has been conducted to measure tolerance. County-level governments are unable to meet required financial compensation.

*In this table, 'standard eligibility conditions' (Zhou *et al.* 2010) refers to those eligibility conditions that are common and shared by each province. 'Standard eligibility conditions' for receiving compensation include: (1) damage caused by species in the national protection list (class 1 and 2) or species in provincial protection lists; (2) people who are injured or killed during legal activities (for livelihood or other income, such as farming); (3) damage of legal crops or economic forests (e.g. forest plantation for future economic purposes, such as logging); and (4) injury or death of livestock in permitted herding area within nature reserves or in captive breeding areas or pens or under a person's care outside reserves. The following damage is not eligible: (1) injury or death of a person who is hunting; (2) injury or death of a person who provokes a wild animal; (3) injury or death of a person who enters a nature reserve without permission; (3) damage to crops or economic forests outside of permitted areas; and (4) livestock not under a person's watch or livestock entering reserves without permission. Currently, in China, there are no national 'standard eligibility conditions'. Sources: Zhang and Wang (2003); Zhou *et al.* (2010); Cai *et al.* (2011).

measures, which cannot abate the frequency of HWC, resulting in an increased cost in compensation payments. To address this issue, Kang and Zhao (2011) investigated the use of a 'bear-proof' fence as a preventative measure in Changtang National Nature Reserve. Monitoring data showed a 90% reduction in the loss of property and livestock due to bear depredation as a result of fencing and stronger doors to protect homes. This is compared to the livestock loss in 2006 and 2007, prior to the establishment of bear-proof fencing. In this case, a combination of compensation and prevention resulted in a more successful program. Reduction in depredation was due to improved preventative measures, while improved tolerance of bears and attitudes towards conservation was likely due to reduced depredation, increased education and compensation or a combination of all these factors. However, low government capacity

for implementation (i.e. to check and evaluate reported cases) and weak financial capacity at the prefecture and county levels to support compensation are key challenges to the success of these initiatives. Furthermore, success was not evaluated in terms of bear population numbers. The ultimate measure of success would be stable, or increasing, bear population densities.

Data on compensation projects in China are scarce. However, most available information indicates weak linkages to preventative measures and compensation levels, levels which are usually lower than the market value of the loss (Tables 1 and 4). A key observation is that most programs, while seemingly contribute to increased community support and tolerance of wildlife conservation, the lack of rigorous monitoring makes this hard to evaluate, and most programs were financially unsustainable.

RECOMMENDATIONS TO ADDRESS LIVESTOCK DEPREDAATION DUE TO HUMAN–WILDLIFE CONFLICT IN CHINA

Human–wildlife conflict is a complex problem requiring an integrated approach. The following recommendations are made on the basis of lessons derived from global examples and local experiences and represent components of a comprehensive plan to reduce HWC in China.

Increase law enforcement to secure nature reserves

There is already existing legislation that forbids human activity inside the core zone of nature reserves in China. According to Clause 18 of the Regulations of Nature Reserve Management, a nature reserve should be divided into core, buffer and experimental zones. Institutions and individuals are forbidden to enter into the core zone unless they are conducting limited scientific research, as permitted under Clause 27. The buffer zone is a defined space around the core zone, where some scientific research and observation activities are permitted. The area around the buffer zone is the experimental zone, where scientific surveys, public education, tourism and rare or endangered wild species breeding programs are permitted. We recommend that it would be beneficial to increase law enforcement of this legislation to ensure minimal disturbance, especially in the core zone. This should include removing all livestock from the core zone, thereby directly reducing HWC. In addition to increasing law enforcement, compensation policy should adapt to reflect the legislation, and no payments should be made for losses that occur inside reserve core zones. Ideally, there should be no livestock, and no compensation, within reserve boundaries, not just core zones. Otherwise, for example, there will be little chance of recovering tigers or leopards inside Hunchun Nature Reserve due to depredation-related issues, competition between livestock and wild prey and livestock-related habitat degradation.

Ensure preventative measures play a key role in alleviating conflict

Ultimately, preventative measures should play the primary role in alleviating livestock depredation, with

support from an improved compensation program. Guarding livestock, using herding dogs, bringing in livestock at night and providing fencing are just some examples of preventative measures which can be used as eligibility criteria for compensation payments (Fourli 1999). In Massailand, Kenya, HWC is largely a result of depredation of livestock by lions (*Panthera leo* Linnaeus, 1748). While compensation for wildlife loss is available, we recommend that certain measures be required to have been followed in order to receive full payment. These measures stipulate that livestock is required to be in a well-maintained enclosure at night (Murphy 2010). Livestock must be brought into barns or protected corrals at night. Fenced enclosures for holding livestock at night have been effective in preventing attacks by tigers and other carnivores (Breitenmoser *et al.* 2005; Frank *et al.* 2005), but increase the chances of multiple livestock deaths in the event that a predator gets inside the fence. This is particularly a problem with leopards, which can easily climb over fences (Breitenmoser *et al.* 2005). Thus, enclosures may need to be covered or built with fences that are difficult for carnivores to climb (e.g. with multiple strands of barbed wire). Vegetative cover around the enclosures may be reduced because many carnivores avoid open areas. Keeping buffalo together with cattle may also reduce predation because buffalo act defensively towards predators; however, this will not eliminate the problem completely because tigers are able to kill buffalo (Karanth & Gopal 2005; Hoogesteijn & Hoogesteijn 2008). Dogs are used to guard livestock against many different predator species (Green *et al.* 1984; Breitenmoser *et al.* 2005), but tigers readily prey on dogs, so the presence of dogs may attract tigers to livestock herds (Miquelle *et al.* 2005; Li *et al.* 2009; Nugraha & Sugardjito 2009; Goodrich *et al.* 2011). In Portugal, Fourli (1999) reports that strict preventative measures are associated with wildlife compensation. For example, every 50 free-ranging sheep or goats must be accompanied by at least 1 shepherd and 1 guard dog. For cattle and horses in groups fewer than 8, 1 person is required to guard them; groups larger than 8 must be checked at least once per week. Failure to comply with these requirements results in a forfeiture of eligibility for compensation. Unfortunately, many of these preventative measures are associated with significant cost to local people, so it is unlikely that they will be able to implement them without technical and/or financial assistance.

Compensation programs designed with rigorous eligibility criteria

Arguably one of the greatest flaws of standard compensation programs is that payments are made regardless of whether any measures have been taken to prevent HWC and also regardless of whether regulations or laws have been followed. We recommend that experienced personnel must be employed to investigate all conflicts and to ensure that these HWC were caused by the specific carnivore and that livestock had been cared for according to the strict guidelines of the particular compensation program (i.e. livestock is forbidden to graze in tiger habitat; livestock is attended to by a herder and kept in an enclosure at night). For example, in Hunchun Nature Reserve in Jilin, human disturbance, including cattle grazing in the core zone of the nature reserve is prohibited. However, despite the fact that a presence in the core zone is forbidden, current management practices in the region mean that cattle graze in the core zone, and also subsequent compensation payments are granted for losses inside the core zone. Therefore, it is evident that there is a need for those managing compensation policies to be more accountable for conservation outcomes.

Compensation payments in parts of Finland can be refused altogether, or substantially decreased, if the claimant is perceived to have been negligent in the care of their animals or if the animals are found to have been kept in a restricted area without prior authorization (de Klemm 1996). Similar restrictions on compensation payments are used in Namibia (Lamarque *et al.* 2008; Morrison *et al.* 2009). Livestock loss and crop damage in Namibia caused by crocodiles, elephants and large cats have resulted in retaliatory killings. A compensation payment program has been put in place in order to assist in alleviating this conflict. The program covers human life, livestock death and crop damage; however, no payments are made to farmers for livestock killed within protected areas. Placing restrictions on compensation payments helps ensure that people who are being negligent or violating rules are not being paid, and assist in protecting important areas, particularly those designated as disturbance-free zones. Important issues that ultimately determines the success of compensation mechanisms include a rigorous approach to verifying claims of wildlife damage, the difficulty in verifying species involved, challenges in getting investigators to the site in a timely manner and restricting compensation payments for damage by species of conservation relevance.

Initiate self-financed insurance schemes where local interest is demonstrated

Given the interest expressed by people in villages surrounding Hunchun Nature Reserve to participate in a self-financed community insurance scheme, a pilot project should be implemented and an investigation of interest in other locations and subsequent projects should be carried out. However, such a program should maintain the same close links to preventative measures and rigorous eligibility criteria described above in order for a person to receive compensation.

Increase depressed wild prey populations

Low density of wild prey may result in increased attacks on both livestock and people by carnivores, especially following sharp declines in prey density (Reza *et al.* 2002; Miquelle *et al.* 2005; Johnson *et al.* 2006; Li *et al.* 2009; Loveridge *et al.* 2010). Actions to increase prey populations need to be site-specific, but may include changes in legislation and improved law enforcement in order to reduce hunting or poaching and competition with livestock, and to increase habitat protection and restoration. For example, to increase prey populations and decrease tiger depredation on livestock, NEPL in Laos demarcated a core zone where no hunting or other human activity is allowed except for National Protected Area (NPA) research and management activities. Implementing strategies to increase wild prey populations concurrently with improving livestock management and, hence, reducing livestock availability to carnivore depredation are critical in areas such as Hunchun Nature Reserve, where carnivores depend largely on domestic prey.

CONCLUSION

Human–wildlife conflict is a conservation issue of enormous significance for both the affected human community and the (endangered) species associated with the conflict. Compensation is one of many initiatives aimed at alleviating HWC. Unfortunately, compensation initiatives can be financially draining, and the risk is that compensation will be dispensed among victims of HWC without adequate accountability. In addition, if compensation does not have clearly defined goals and restrictions, an outcome opposite to the intended one could be encouraged and pastoralists may actually reduce their efforts to protect their livestock or crops, simply receiving compensation payments instead (Nyhus *et al.* 2003; Bulte & Rondeau 2005; Rondeau & Bulte 2007). Hav-

ing no accountability for the safety of their livestock or their crops, and having the security of compensation, often provides a good incentive for livestock owners (in particular) to increase the number of their stock, possibly leading to greater disturbance on the land, a reduction in the number of native herbivores and, consequently, an increase in livestock depredation.

Human–wildlife conflict is a complex issue and there is no ‘one size fits all’ solution. Ideally, compensation should be used in combination with other approaches that include preventative measures and sound conservation planning. Goodrich (2010) outlines the need for a comprehensive plan to tackle HWC, including (but not limited to) education, community involvement, incentive programs and reactive measures. Reactive measures can include techniques like hazing (scaring away the animal), radio telemetry to monitor wildlife movement and even, in some extreme cases, translocation. Goodrich and Miquelle (2005) show in their study that in the case of ‘problem’ Amur tigers, translocation could, in fact, be considered a viable option.

Furthermore, the importance of public education in providing information on preventative measures, improved husbandry practices and how to co-exist with wildlife is essential in alleviating HWC. Based on current experience, an interdisciplinary approach to tackling HWC including a combination of conservation based programs, public education, incentive programs, along with an updated and improved compensation program reflecting conservation goals should be adopted. Reducing HWC depends on integrated programs, and successful HWC management programs focus on prevention, at the same time using other interventions, such as compensation, to support preventative measures. Just as the prevention of disease is the key to good health, prevention is also the key to successful HWC management.

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