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Livestock depredations and attitudes of local pastoralists toward carnivores in the Qinghai Lake Region, China

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As human population increase, human-wildlife conflicts have reached unprecedented levels, often resulting in negative attitudes toward regional conservation initiatives, and thus are of concern for conservation communities. From April to May 2011, we carried out a survey to quantify carnivore-induced livestock losses perceived by local pastoralists in the Qinghai Lake region on the pastoral Qinghai–Tibetan Plateau and examined the ecological and socio-economic dimensions in the conflict. We finished 286 in-person interviews using a semi-structured questionnaire with mixed closed- and open-ended questions. Our results showed that 93.7% of the respondents reported livestock depredations by carnivores from March 2010 to March 2011. The perceived losses represented 3.7% of total standing value of livestock in the region. The losses were positively correlated with livestock number in each household and showed significant seasonal and diurnal difference. Adult sheep and goats were the mostly killed (54.9%), followed by lambs (21.0%), adult yaks and cattle (19.1%), calves (4.9%) and horses (0.1%). More than 80% of the respondents reported that they could not tolerate the contemporaneous depredations and nearly two thirds expected compensations for their losses. Wolf *Canis lupus* was blamed for most of the killings (76.0%) and was perceived most negative followed by brown bear *Ursus arctos*, Tibetan fox *Vulpes ferrilata*, red fox *Vulpes vulpes* and raptors. Attitudes toward the problem carnivores were positively correlated with livestock size but negatively with magnitudes of the depredations. The attitudes also varied among the three survey sites, which may be attributed to the different extent of openness and livelihood dependence on animal husbandry. In the light of our results, we suggested possible measures to mitigate the conflict and maintain coexistence between human and wild carnivores on the Qinghai–Tibetan Plateau.

Conflicts between human and wildlife are common and widespread (Richard et al. 2004, Woodroffe et al. 2005, Steele et al. 2013). Negative attitudes and responses of local communities toward these conflicts impede, to a large extent, the success of regional wildlife conservation initiatives (Mishra et al. 2003, Naghton-Treves et al. 2003). To better manage problem species, it is necessary to quantify the human–wildlife conflict, recognize the underlying ecological and socio-economic factors and involve human dimensions in conservation planning (White et al. 2005, Woodroffe et al. 2005).

Among various types of the human–wildlife conflicts, human–carnivore conflict (mainly livestock predations by carnivores) are widespread in the trans-Himalayan region (Bagchi and Mishra 2006, Worthy and Foggin 2008, Dar et al. 2009) and elsewhere (Palmeira et al. 2008, Rosas-Rosas et al. 2008, Hemson et al. 2009, Klare et al. 2014). Attitudes and responses of local communities toward problem carnivore species differ among regions. Positive attitudes, in favor of human coexistence with wildlife, are found to be correlated with less economic loss in the conflict (Dickman 2005, Kideghesho et al. 2007), benefits from ecological tourism (Lindsey et al. 2005, Hemson et al. 2009) and respondents' education level and personal wealth (Naghton-Treves et al. 2003, Zimmermann et al. 2005).

Wild animals, many in large numbers, coexist with people for centuries on the Qinghai–Tibetan Plateau, one of the world's largest alpine pastoral ecosystems (Miller 2002, Miehe et al. 2009). However, human population growth, economic development, global climatic changes and heavy poaching during the last century have led to deep changes in human–wildlife interactions on the plateau (Schaller 1998, Arthur et al. 2008, Harris 2010). The Qinghai Lake region, located on the plateau's more accessible northeastern edge, is one of the most fragile regions facing anthropogenic influences (Banks et al. 2003, Liu et al. 2004, Yang et al. 2011). Since the 1950s, human population has increased ten times and livestock four times in this region, aggravating rangeland degradation and intensifying human–wildlife conflict (Li et al. 2012). Local pastoralists alleged food competition of livestock with wild herbivores, e.g. Przewalski's gazelle *Procapra przewalskii*, Tibetan gazelle *P. picticaudata*, pika

Ochotona curzoniae and small rodents (Jiang and Xia 1985, Smith et al. 2006, Li et al. 2008, 2012, Hu et al. 2009). Besides conflicts with herbivores, livestock depredation by wild carnivores is another challenging issue to be seriously handled. However, current status of the conflict and locals' perceptions are poorly known in the region and across the plateau. Given the daunting challenge of the issue, it is necessary to understand the conflict before formulating any management plans.

In this study, we carried out a social survey, in the Qinghai Lake region, to quantify the current status of carnivore-induced livestock losses perceived by local pastoralists and their attitudes toward the problem carnivores, defined as their preferences or aversions toward the species formed through perception and evaluation of the human–carnivore conflict (Manfredo 2008). We further examined the underlying socio-economic factors influencing pastoralists' attitudes. Based on the results, we proposed measures that may mitigate the conflict and maintain coexistence between human and wild carnivores on the pastoral Qinghai–Tibetan Plateau.

Material and methods

Study area

We carried out our survey in the Qinghai Lake region in China (36°15′–38°20′N, 97°50′–101°20′E, Fig. 1). The region covers an area of ca 30 000 km^2 with elevation ranging from 3025 m to 5225 m. In the catchment, one nature reserve, the Qinghai Lake National Nature Reserve, was established in 1975 with an area of ca 5000 km^2 to protect the biodiversity in the region. The region has an inland semi-arid plateau climate with dry, cold and long winters, intense solar radiation and a short frost-free period. Mean annual temperature is 0.5°C and the extreme low temperature recorded is –31°C. Annual rainfall varies from 300 mm to 500 mm, mostly between June and September.

The region supports a human population of ca 100 000 of which 68% are Tibetans with Buddhist belief (Qinghai Statistical Bureau 2010). The mainstay of the rural economy is livestock farming with a history of more than 4500 years (Miller 2002). Livestock, totaling ca 3.5 million head, mainly consist of sheep, goats and yaks with fewer horses, cattle and donkeys. Livestock number per household varies from dozens to more than 1000 (Qinghai Statistical Bureau 2010). Dogs are raised in almost all households but their livestock herding function have been replaced by people riding modern vehicles (e.g. motor bicycle).

We selected Hudong, Ganzihe and Shengge as our survey sites, which encompass 13.3% of the entire catchment area. The three communities, indicating a gradient of openness to the outside and intensity of animal husbandry, are supposed to represent the pastoral system in the entire region. Hudong is the starting point of ecotourism in the region and local herdsmen earned some money from private ecotourism or employment in neighboring cities. Ganzihe is located to the north of the lake and its openness is less prevalent than Hudong. Located in remote mountains furthest west in the region, Shengge is the least contacted with the outside world. Livelihood of herdsmen at Ganzihe and Shengge almost entirely depended on animal husbandry. Densities of human population and livestock were the highest in Hudong followed by Ganzihe and Shengge. However, per capita livestock was of the reverse order (Qinghai Statistical Bureau 2010).

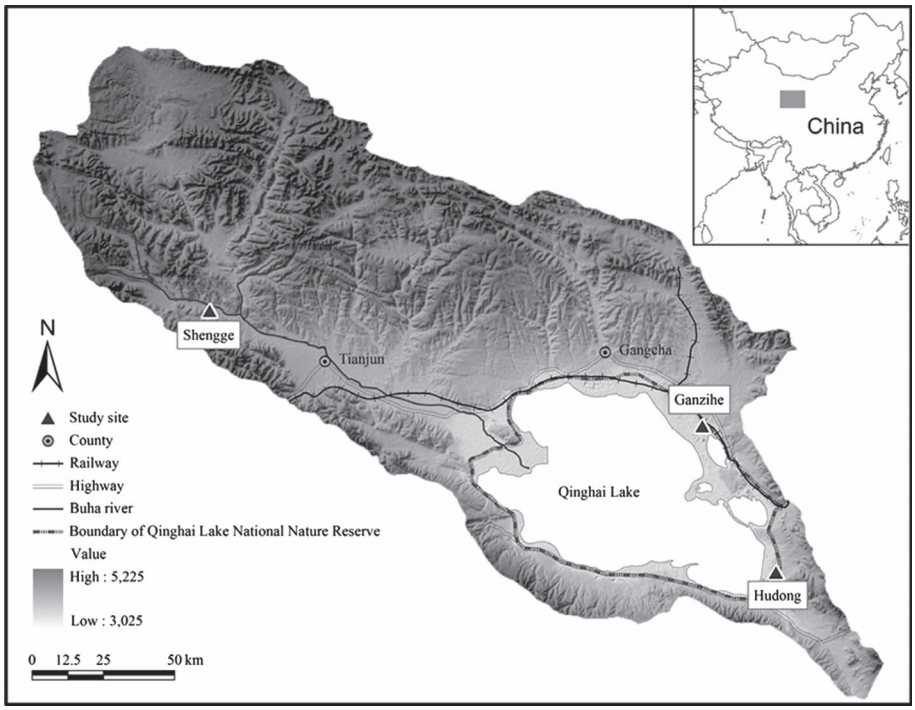

Figure 1. Survey sites. From April to May 2011, the social survey was carried out in Hudong, Ganzihe and Shengge (in Gonghe, Haiyan and Tianjun Counties, respectively) on the northeastern edge of the Qinghai–Tibetan Plateau, China.

Potential predators

Carnivores that may prey upon livestock in the study area include wolf *Canis lupus*, Tibetan fox *Vulpes ferrilata*, red fox *V. vulpes*, brown bear *Ursus arctos* and large raptors. Wolf, fox and raptors are widely distributed in the region while brown bear is restricted to high mountains in the west such as Shengge and neighboring villages (Liu and Jiang 2003, Xia et al. 2007). We grouped Tibetan fox and red fox together due to the fact that the two sympatric species have similar ecological characteristics and it is not easy for all herdsmen to distinguish livestock depredations by the two species (Larivière and Pasitschniak-Arts 1996, Clark Jr et al. 2008). We also assessed local attitudes toward snow leopard *Panthera uncia* that was once distributed in mountains around the lake (Schaller et al. 1988). Possibly due to habitat loss and illegal poaching, the cat is now rarely seen in the region (Ma et al. 2002). Local pastoralists may hear about rather than experience with the cat in the field in recent decades.

Survey method

From April to May 2011, we carried out the social survey using a semi-structured questionnaire with mixed closed- and open-ended questions. For each respondent, we recorded his/her gender, age, family composition and education background. For each family, livestock number of each class owned and perceived number of carnivore-induced depredations during March 2010 to March 2011 were recorded and attributed to different predators and seasons. Respondents were required to report the depredation trend and possible reasons they considered. We asked their tolerance with the different carnivore species, contemporaneous livestock losses and the maximum depredations they could tolerate. We defined 'tolerance' as pastoralists' willingness to accept the fact of depredation losses or the co-existence with problem species. We also asked their opinions about carnivore management measures (extent of support for conservation) and carnivore extinctions (extent of regret for the extinctions). We obtained contemporaneous market prices of livestock from two livestock traders and more than 10 herdsmen who were familiar with livestock trading.

The questionnaire was piloted with 10 local herdsmen to examine and revise possibly unclear, misleading and threatening questions. Heads of households were selected as respondents when we encountered their houses along our travel routes randomly selected on Google Earth map. At each site, 1 or 2 Tibetans in the same community provided translations for us. Due to the good communication skills of the translators who were familiar to the local respondents, response rates at the three communities were high, i.e. 98% in Hudong, 100% in Ganzihe and 97% in Shengge. Each person-to-person interview lasted from 30 min to 1 h. During the two decades of field studies in the region, we knew that most herdsmen were able to distinguish causes of deaths based on sightings of livestock killings, bite markings on carcasses as well as predators' pugmarks on the kill sites. In addition, local experienced elders always helped identification once livestock depredations occurred, resulting in more accuracy. As locals might have a tendency to exaggerate livestock depredations for the purpose of attracting attention, we informed respondents that their information would be treated anonymously as part of scientific research, rather than as a justification for any compensation. We further crosschecked the answers by separately asking family members or neighbors all the questions except those related to the respondents' attitudes. We discarded interviews that had more than 10% inconsistence with the crosscheck.

Data analysis

For the convenience of analysis, we translated different classes of livestock into adult sheep equivalent (ASE), according to the contemporaneous market price, i.e. 1 ASE = US$92.3 = 1 adult sheep or goat = 3 lambs = 1/4 adult yak or cattle = 2/3 calf = 1/10 adult horse = 1/5 colt.

Data were tested with one-sample Shapiro–Wilk test and transformed, if non-normal, to meet assumptions of normality and homogeneity of variances. A general linear model (PROC GLM) was fitted to test differences in per capita ASE owned, per capita ASE losses and proportion of depredations to livestock number among the three communities. χ^2 goodness-of-fit test (PROC FREQ) was used to examine the differences of livestock depredations (among sites, seasons and time) and the proportions of respondents tolerating different carnivore species.

We assigned integral scores (+ 2~–2) to the responses related to carnivore management measures and carnivore extinctions with higher scores indicating more support for carnivore conservation or more regret for carnivore extinction. We assessed respondents' attitudes toward the problem carnivores by adding the two scores (+ 4~–4). Scores above 1 were labeled as 'positive' attitudes while the remaining as 'negative'. We used logistic regression (PROC LOGISTIC) with stepwise selection to examine underlying factors influencing pastoralists' attitudes toward the problem carnivores. Potential explanatory variables included sites (three levels: Hudong, Ganzihe, Shengge), respondents' age, education, family size, ASE owned, per capita ASE, depredations and all the two-way interaction effects.

All analyses were conducted in SAS ver. 8.1 (SAS Inst.). Data below are shown as mean (± SE) and the statistical significance was set at $p < 0.05$.

Results

After discarding the seven interviews that were inconsistent with crosscheck and the nine involving female household heads, we obtained 286 questionnaires (94 in Hudong, 95 in Ganzihe and 97 in Shengge), representing 17.4% households at the three communities. The average age of the respondents was 39.9 ± 0.7 and the average family size was 4.9 ± 0.1. There were totally 1391 persons in the interviewed households which together had 497.13 km^2 pastures supporting 131 463 ASE. Of the livestock owned, sheep and goats accounted for over 60%, yaks and cattle about 30% and horses less than 10%.

Depredation

Across all the three communities, 93.7% of the interviewed households reported suffering livestock losses to carnivores. There were no significant differences in the proportion between communities ($\chi^2 = 0.47$, $p = 0.790$). The total reported depredations during the year were equal to 4215 ASE, representing 3.7% (± 0.2%) of the total livestock. The economic losses amounted to US$ 389 227 and the per capita loss averaged US$ 279.8, representing 7.0% of the per capita GDP in the region (US$ 4000 year^{-1}). Depredations were positively correlated with livestock number ($\beta = 0.02 \pm 0.002$, $t = 9.68$, $p < 0.001$, Fig. 2) and were more serious in Shengge than in Hudong or Ganzihe (Table 1). Wolf was reported as the main predator, contributing to 76.0% (72.1% in Hudong, 75.0% in Ganzihe and 77.5% in Shengge) of total depredations in the three communities, followed by fox (16.0%) (27.6% in Hudong, 22.9% in Ganzihe and 10.0% in Shengge) and raptors (1.7%) (0.3% in Hudong, 2.1% in Ganzihe and 2.0% in Shengge). Five cases occurred in Shengge that, in each killing event, more than 20 adult sheep were killed by wolf, known as the notorious 'surplus killing' (Odden et al. 2002, Sangay and Vernes 2008, Muhly and Musiani 2009). Brown bear was only distributed in Shengge and accounted for 10.6% of local depredations. Of the total losses, adult sheep and goats made up 54.9% (57.2% in Hudong, 46.2% in Ganzihe and 58.0% in Shengge), lambs 21.0% (28.9% in Hudong, 28.2% in Ganzihe and 15.8% in Shengge), adult yaks and cattle 19.1% (10.1% in Hudong, 19.8% in Ganzihe and 21.2% in Shengge), calves 4.9% (3.8% in Hudong, 5.3% in Ganzihe and 5.1% in Shengge) and horses 0.1% (1 colt in Ganzihe). Depredations of sheep and goats (17.9%) were more than, and yaks and cattle (19.4%) and horses (99.6%) less than would be expected based their proportions in the total livestock owned. Of the depredated lambs, 15.3% were killed by wolf, 76.3% by fox, 8.3% by raptors and 0.1% by brown bear. Depredations on adult sheep and goats occurred more often at night ($\chi^2 = 101.62$, $p < 0.001$, DF = 1), mostly from June to August ($\chi^2 = 910.24$, $p < 0.001$, DF = 11). Lambs were killed mostly during the daytime ($\chi^2 = 611.99$, $p < 0.001$, DF = 1) from December to February ($\chi^2 = 695.74$, $p < 0.001$, DF = 11). The peak for depredations on adult yaks and cattle was at night ($\chi^2 = 7.18$, $p = 0.007$, DF = 1) from October to November ($\chi^2 = 421.74$, $p < 0.001$,

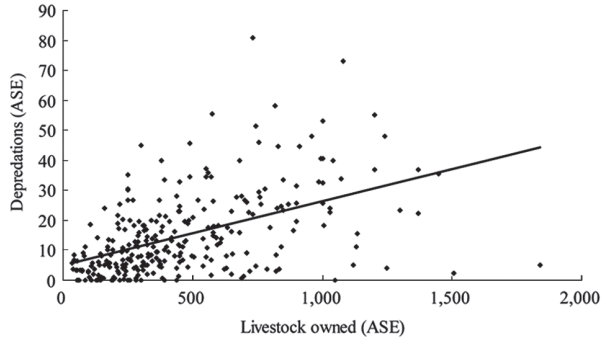

Figure 2. Relationship between livestock number and carnivore-induced livestock depredations in each family interviewed in the Qinghai Lake region, China.

Table 1. Status of livestock owned and carnivore-induced depredations in the three surveyed communities in the Qinghai Lake region, China.

					Differences between sites			
	Hudong	Ganzihe	Shengge	Overall	Hudong-Ganzihe (DF = 1)	Hudong-Shengge (DF = 1)	Ganzihe-Shengge (DF = 1)	Overall (DF = 2)
Total livestock owned (ASE)	29 555	38 007	63 901	131 463				
Per capita livestock owned (ASE)	59.5 (± 4.1)	95.1 (± 6.6)	150.3 (± 8.3)	101.1 (± 4.4)	$F = 20.61$, $p < 0.001$	$F = 94.79$, $p < 0.001$	$F = 27.05$, $p < 0.001$	$F = 48.13$, $p < 0.001$
Livestock density (ASE km^{-2})	1247.2	515.8	159.9					
Perceived depredations								
Total depredation losses (ASE)	671.5	1051.2	2492.7	4215.4				
Proportion of livestock killed	3.1% (± 0.3%)	3.5% (± 0.3%)	4.5% (± 0.3%)	3.7% (± 0.2%)	$F = 2.03$, $p = 0.156$	$F = 15.66$, $p < 0.001$	$F = 7.11$, $p = 0.008$	$F = 8.19$, $p < 0.001$
Per capita losses (ASE)	1.4 (± 0.1)	2.7 (± 0.2)	5.9 (± 0.4)	3.4 (± 0.2)	$F = 24.00$, $p < 0.001$	$F = 128.40$, $p < 0.001$	$F = 45.71$, $p < 0.001$	$F = 68.90$, $p < 0.001$

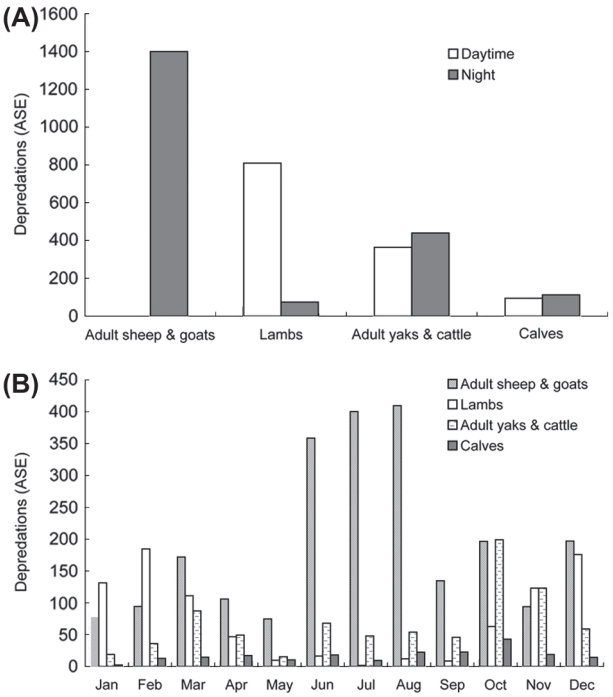

Figure 3. Temporal pattern of carnivore-induced livestock depredations in the Qinghai Lake region, China: (A) differences between daytime and night and (B) between months in different livestock classes.

DF = 11). Calves were mostly preyed upon from August to November ($\chi^2 = 62.87$, $p < 0.001$, DF = 11) with no significant difference between night and daytime ($\chi^2 = 1.57$, $p = 0.211$, DF = 1, Fig. 3).

Pastoralists' perceptions of the human–carnivore conflict

Across the region, more than 80% (85.1% in Hudong, 82.1% in Ganzihe and 87.6% in Shengge) of the respondents reported that they could not tolerate the contemporaneous carnivore-induced livestock losses. Over one quarter of them (35.1% in Hudong, 20.0% in Ganzihe and 23.7% in Shengge) could tolerate no depredations and over half of them (54.3% in Hudong, 55.8% in Ganzihe and 54.6% in Shengge) could only tolerate 1 or 2 ASE depredations each year. Over 60% believed that depredation in recent years was increasing and three quarters attributed the increase to carnivores' population growth. Nearly two thirds (63.8% in Hudong, 63.2% in Ganzihe and 68.0% in Shengge) of the respondents expected compensation for their losses. Over one third (36.2% in Hudong, 32.6% in Ganzihe and 32.0% in Shengge) stated that predators' population should be controlled while only a few (0% in Hudong, 4.2% in Ganzihe and 3.1% in Shengge) expected that carnivores should be eradicated.

Among the predator species, raptors were viewed most positively, followed by snow leopard and fox, while wolf and brown bear were viewed the most negatively (Table 2). Pastoralists complained the notorious 'surplus killing' by wolf and their lost fear of humans since the confiscation of hunting guns in mid 1990s. Several respondents in Shengge reported their close and dangerous encounters with brown bear, inflicting concerns of potential attacks on humans and camps among communities. They also complained that lamb depredations by fox could not be effectively prevented. No respondents reported encounters with snow leopard in recent years and their attitudes toward this cat were uncertain concerning their potential to inflict damages. Even though no respondents reported killing carnivores themselves, 4.2% alleged that they heard about 1 or 2 cases of trapping wolf for sale by others recently in their communities. More than three quarters of the respondents considered depredation magnitude as the main determinant of which carnivores they tolerated.

Factors influencing pastoralists' attitudes to problem carnivores

The final logistic model indicated that pastoralists' attitudes toward problem carnivores were significantly influenced by site ($\chi^2 = 8.69$, $p = 0.013$, DF = 2), ASE owned ($\chi^2 = 6.35$, $p = 0.012$, DF = 1), depredations ($\chi^2 = 20.82$, $p < 0.001$, DF = 1), and the two-way interaction between ASE owned and site ($\chi^2 = 7.41$, $p = 0.025$, DF = 2) and between depredations and site ($\chi^2 = 14.13$, $p = 0.001$, DF = 2). Pastoralists in Hudong (2.55) had more positive attitudes than those in Ganzihe (1.99) and Shengge (1.80), between which there was no significant differences. More livestock owned resulted

Table 2. Proportion of respondents tolerating different carnivore species in the 3 surveyed communities in the Qinghai Lake region, China.

					Differences between sites			
	Hudong	Ganzihe	Shengge	Overall	Hudong-Ganzihe (DF = 1)	Hudong-Shengge (DF = 1)	Ganzihe-Shengge (DF = 1)	Overall (DF = 2)
Wolf	8.5%	4.2%	7.2%	6.6%	$\chi^2 = 1.29$, $p = 0.255$	$\chi^2 = 0.09$, $p = 0.759$	$\chi^2 = 0.72$, $p = 0.397$	$\chi^2 = 1.31$, $p = 0.519$
Brown bear	16.0%	9.5%	26.8%	11.2%	$\chi^2 = 1.39$, $p = 0.239$	$\chi^2 = 2.16$, $p = 0.140$	$\chi^2 = 6.73$, $p = 0.010$	$\chi^2 = 7.09$, $p = 0.029$
Fox	34.0%	24.2%	11.3%	23.1%	$\chi^2 = 1.22$, $p = 0.270$	$\chi^2 = 8.97$, $p = 0.003$	$\chi^2 = 3.82$, $p = 0.051$	$\chi^2 = 8.90$, $p = 0.012$
Snow leopard	46.8%	40.0%	29.9%	38.8%	$\chi^2 = 0.35$, $p = 0.553$	$\chi^2 = 2.59$, $p = 0.108$	$\chi^2 = 1.04$, $p = 0.308$	$\chi^2 = 2.61$, $p = 0.271$
Raptor	67.0%	57.9%	42.3%	60.1%	$\chi^2 = 0.39$, $p = 0.533$	$\chi^2 = 3.49$, $p = 0.062$	$\chi^2 = 1.57$, $p = 0.211$	$\chi^2 = 3.56$, $p = 0.169$
None	3.2%	1.1%	13.4%	5.9%	$\chi^2 = 1.00$, $p = 0.317$	$\chi^2 = 5.50$, $p = 0.019$	$\chi^2 = 9.40$, $p = 0.002$	$\chi^2 = 12.95$, $p = 0.002$

in more positive attitudes ($\beta = 0.002 \pm 0.001$) while more carnivore-induced losses inflicted more negative attitudes ($\beta = -0.090 \pm 0.020$). Respondents' age, education, family size and per capita ASE were excluded in the final model because of no significant effects.

Discussion

Livestock depredations

The reported proportion of livestock depredated by carnivores in the Qinghai Lake region (3.7%) was higher than that in central Bhutan (2.3%) (Wang and Macdonald 2006), Nepal (2.6%) (Oli et al. 1994) and Kenya (2.6%) (Patterson et al. 2004), nearly the same as that in Botswana (3.5%) (Hemson et al. 2009) and northern Nepal (3.9%) (Wegge et al. 2012) but lower than that in Tanzania (4.5%) (Holmern et al. 2007) and the Indian trans-Himalaya (12%) (Jackson and Wangchuk 2004). Although we tried our best to collect true information provided by herdsmen, it is not easy to validate the perceived depredations (Sangay and Vernes 2008, Hemson et al. 2009). Some pastoralists may not be able to identify the species responsible for each predation event. Deaths due to diseases or other causes may also be, intentionally or not, attributed to carnivores' killing. However, these flaws of self-reporting do not invalidate the importance of our findings which reflected locals' perceptions toward the human–carnivore conflicts.

Richard et al. (2004) suggest that the main cause of intensifying human–carnivore conflict is the increase of human and livestock populations. During the last few decades, human population and livestock number have increased greatly in the Qinghai Lake region (Li et al. 2012). Larger size of livestock herd results in more losses to carnivores (Fig. 2), which is also found in other regions (Zimmermann et al. 2005, Hemson et al. 2009). Besides, increases in livestock may in theory contribute partly to the population growth of carnivores that in turn cause more livestock depredations. Carnivore-induced livestock losses in our study area may also be partly attributed to the unequal population growth between carnivores and wild prey. Populations of carnivores, especially wolf and fox, may have recovered since the government banned hunting in mid 1990s (Jiang et al. 2012, Li et al. 2012). However, populations of wild prey, especially ungulate species, do not increase in the same pace or even have continually declined due to habitat loss and fragmentation (Xia et al. 2007, Li et al. 2012). Declines in wild prey populations, to a large extent, force carnivores to hunt domestic livestock with poor ability to escape attacks (Mishra 1997, Liu and Jiang 2003, Bagchi and Mishra 2006). However, our respondents attributed the depredation increase mainly to population growth of carnivores and none cited the decrease of wild prey. The partial realization may not help mitigate the human–carnivore conflict.

The seasonal pattern of depredations in the Qinghai Lake region coincides with the regional rotational grazing regime (Banks et al. 2003). Traditional nomadic pastoralists have settled down since the 1980s when rangelands use rights were contracted to local pastoralists under the 'Household contract responsibility system' in what was essentially a privatization of livestock grazing on grasslands (Miller 1999, Breivik 2007). Nowadays, livestock graze in mountainous summer pastures in summer and early autumn but in winter pastures near their settlements in the other seasons. Unlike protected at night in pens in winter pastures, livestock in summer pastures are not penned. The less protection, combined with higher density of carnivores in summer pastures (Li et al. unpubl.), largely address the peak of depredations at nights from summer to autumn. In contrast, the peak of lamb killings occurred during the newborn boom period (from December to February) in winter pastures. They were protected in pens at nights but vulnerable to diurnal fox that often followed grazing herds during the daytime. The spatial pattern of depredations is in accordance with livestock size among the survey sites. Both livestock number and depredations per household were highest in Shengge. In addition, larger livestock size per household in remote mountains result in poorer anti-predator guarding practices, which may partially account for the extra depredations. However, this assumption remains to be proven.

We found variations of livestock depredations among livestock classes, which are also reported in other studies (Bagchi and Mishra 2006, Wang and Macdonald 2006, Sangay and Vernes 2008). In the Qinghai Lake region, reported depredations on sheep and goats were three times as many as on yaks and cattle. Relative abundance of the two classes accounted for a major part of the difference. The extra depredations on sheep and goats (17.9%) than would be expected based on availability should be attributed to their vulnerability to attacks. This stood in comparison to yaks and cattle which were less (19.4%) killed than expectation. Interestingly, Liu and Jiang (2003) reported that wolves consumed more yaks than sheep and goats according to scat analysis. This discrepancy could be partly explained by the different probabilities of finding carcasses of different livestock. Sheep and goats were herded by pastoralists every day and their carcasses were easily found and convenient to be taken home. However, yaks were often left in pastures without cares for several days, especially in summer pastures. Their carcasses were found later after returning predators consumed most of the flesh. Besides, wolves often kill more sheep and goats than they can consume, which is well known as 'surplus killing' (Odden et al. 2002, Sangay and Vernes 2008, Muhly and Musiani 2009). Comparatively, horses are fewer and taken good care of in each household and only one young horse was reported killed (in Ganzihe). In our study area, there is no large cat like those commonly prey horses in other regions (Polisar et al. 2003, Wang and Macdonald 2006).

Attitudes toward the problem carnivores

Factors influencing pastoralists' attitudes toward carnivores varied among species. Magnitude of livestock depredations, however, was considered as the main factor in determining which carnivores would be tolerated, e.g. negative attitudes toward wolf and fox. Religious belief may partly explain the relatively positive attitude toward raptors that were considered sacred in the Buddhist region. Concerns of potential attacks on humans and camps inflicted negative attitudes toward brown bear. Interestingly, fewer pastoralists at sites

where the bear was locally extirpated could tolerate the species, possibly due to horrible anecdotal stories about this predator. The bear is described more horrible and greedy there than where it is extant and thus fosters the fear of uncertainty.

As found in other studies, attitudes of our respondents were positively correlated with personal wealth (i.e. livestock owned) but negatively with carnivore-induced losses (Naghton-Treves et al. 2003, Kideghesho et al. 2007). We also found that the attitudes in Hudong were more positive than those in Ganzihe and Shengge. The spatial differences may be attributed to the facts that Hudong is more accessible to the outside and local pastoralists can earn some extra money from private ecotourism or employment in neighboring cities. Due to the large extent of livelihood dependence on animal husbandry, however, livestock depredations can easily inflict negative attitudes toward problem carnivores in pastoralists in Ganzihe and Shengge. High level of livestock losses, together with ban on hunting, may generate hostile attitudes toward the problem carnivores (Naghton-Treves et al. 2003, Bagchi and Mishra 2006). Pastoralists in the Qinghai Lake region argued that predators' population should be appropriately controlled rather than strictly protected with no consideration for economic losses of local communities. The attitudes of the local pastoralists may influence, to a large extent, the success of the regional wildlife conservation initiatives (Mishra et al. 2003, Naghton-Treves et al. 2003) and thus shoud be seriously recognized.

Management implications

The pressing issue for managing the human–carnivore conflict in the Qinghai Lake region is to reduce the impact of carnivore-induced livestock losses on livelihood of local communities. First, successful herding practices in other regions should be introduced and tried to improve the traditional labor-intensive animal farming (Bagchi et al. 2004, Bagchi and Mishra 2006). The abandoned livestock-guarding dogs should be reused and trained strategically at an early age (Rigg et al. 2011). Livestock enclosure should be improved and equipped with alarm system if possible. Guiding practice should be strengthened, particularly in lambing season and summer herding. Second, we suggested reducing livestock numbers and diversifying the local economy, such as encouraging herdsmen to work in towns or engagement in local ecotourism. This will not only reduce livelihood dependence on livestock herding but also mitigate the intensive livestock grazing. Third, the incentive for conservation programs should be stimulated. Monetary compensation for wildlife damage is widely used (Mishra et al. 2003, Schwerdtner and Gruber 2007) and is readily accepted by local communities in our study area. There is, however, argument that compensation for human–wildlife conflict does not necessarily do good, and that it may negatively impact the coexistence between local people and wildlife (Naghton-Treves et al. 2003, Bulte and Rondeau 2005). In remote western China, particularly, lack of special funds and assessment systems makes it hard to formulate and implement effective compensation plans (Cai and Jiang 2006, Cai et al. 2008). Community-based livestock insurance program may be an alternative. This has been successfully applied in other 'depredation hotspots' with ecological and socio-economic environment similar to the Qinghai Lake region (Mishra et al. 2003). Further, the philosophy of pure conservation should be changed to scientific management. It is necessary to keep in mind the ecological harmony and include human dimensions in local wildlife management plans. Environmental public education should be launched to raise awareness of wildlife conservation among communities (Lindsey et al. 2005, Jones et al. 2008, Liu et al. 2011).

The carnivore-induced conflicts in the Qinghai Lake region are challenging the co-existence between human and predators and even break the regional ecological relationship. Resolution of the issue will benefit the function of ecosystem and especially the coexistence between human and wildlife. In a general sense, our study provides important insights for the human–wildlife conflicts on the Qinghai–Tibetan Plateau.

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