Review

Human-felid conflict: a review of patterns and priorities worldwide

Chloe Inskip and Alexandra Zimmermann

Abstract Conflict between people and felids is one of the most urgent wild cat conservation issues worldwide, yet efforts to synthesize knowledge about these conflicts have been few. For management strategies to be effective a thorough understanding of the dynamics of human-felid conflicts is necessary. Here we present the results of a cross-species, systematic review of human-felid conflicts worldwide. Using a combination of literature review and geographical information system analyses, we provide a quantitative as well as qualitative assessment of patterns and determinants that are known to influence the severity of human-felid conflicts, and a geographical overview of the occurrence of conflict worldwide. We found evidence of conflict affecting over 75% of the world's felid species. The severity of conflict increases with felid body mass and is of greatest conservation significance to nine species: caracal, cheetah, Eurasian lynx, jaguar, leopard, lion, puma, snow leopard and tiger. We also reveal specific gaps in knowledge about human-felid conflicts, and required actions within this aspect of felid conservation. With only 31% of implemented management strategies having been evaluated scientifically, there is a need for greater and more rigorous evaluation and a wider dissemination of results. Also urgently required are standardized reporting techniques to reduce the current disparity in conflict reporting methods and facilitate resolution of patterns and trends in the scale of human-felid conflict worldwide. This review provides a basis both for further synthesis and for the coordination of human-felid conflict management among researchers, practitioners and organizations.

Keywords Conflict mitigation, felid, human-felid conflict, human-wildlife conflict, livestock depredation, persecution, wild cats.

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Introduction

The increasing human population and the associated increase in rates of resource use and habitat loss worldwide are, in many areas, forcing wildlife to live in increasing proximity to humans. In such circumstances competition arises between wildlife and people for space and food resources, often leading to human-wildlife conflict. Definitions of the term vary (c.f. Conover, 2002; IUCN, 2003; Madden, 2004). We define human-wildlife conflict as the situation that arises when behaviour of a non-pest, wild animal species poses a direct and recurring threat to the livelihood or safety of a person or a community and, in response, persecution of the species ensues. Human-wildlife conflicts most commonly involve damage to crops or killing of livestock or game, and occasionally involve attacks on people. They are of particular concern when the animal persecuted in retaliation for these events is a threatened species.

Carnivores are particularly predisposed to conflict with humans because of their large home ranges and dietary requirements (Linnell et al., 2001; Macdonald & Sillero-Zubiri, 2002). Human-carnivore conflict appears to be increasing in frequency in many areas (Treves & Karanth, 2003), presenting a significant threat to many carnivore species, including many threatened species of wild felids. Human-felid conflict typically occurs when wild cats prey on livestock or game, or even attack people, and the people affected respond by killing or harming felids, either in retaliation or as a preventative measure.

Effective human-felid conflict management is essential given the precarious conservation status of many felid species, yet also highly complex as it must reconcile human needs with those of felid populations. Despite the urgency and importance of resolving these conflicts, there does not yet appear to have been a review of such conflict on a global scale or the success of management techniques worldwide. Our aim was therefore to provide a systematic, cross-taxonomic, review of the state of knowledge and practice of human-felid conflict globally. Specifically, our research questions were: (1) Which cat species are affected by conflict and to what extent? (2) What are the spatial, taxonomic and socio-economic patterns of these conflicts? (3) What are the factors that determine the scale of conflict? (4) What is the scope of the available human-felid conflict literature and what information needs are apparent? (5) To what extent have conflict management strategies been implemented and evaluated?

Methods

Sourcing information and data collation

A comprehensive and systematic review of scientific, secondary and internet-based literature on human-felid conflict was carried out. Information regarding such conflict was sought for the 37 extant felid species (Nowell & Jackson, 1996, with the addition of the more recently described Bornean clouded leopard *Neofelis diardi*; Kitchener et al., 2006).

A literature search was carried out using a pre-defined search protocol, involving a number of filters based around a set of keywords, selected to balance search sensitivity (finding all relevant information) with specificity (the proportion of hits returned that are relevant; Pullin & Stewart, 2006). All of the keywords used in our searches were English. Although this will have precluded a number of non-English language literature sources from our review this restriction was necessary to limit the sources obtained to a manageable number. To be selected, a literature source had to include a felid name (common or scientific), and one or more of the following keywords: attacks, attitudes, cattle husbandry or management, coexistence, conflict, depredation, diet, ecology, feeding ecology, human, livestock, mitigation, mortality, perceptions, persecution, prey, retaliatory killing. Scientific literature was sourced from scientific databases such as ISI Web of Science (2007), the IUCN/SSC Cat Specialist Group (2007), and Google Scholar (Google, 2007b), and searches for secondary and internet-based literature were carried out using web-based search engines. A 'snowball' reference technique was then used, which resulted in the opportunistic inclusion of some non-English literature. In some cases, particularly for the smaller felid species, no (or no relevant) scientific or secondary literature was available; so information from the most reliable internet sources available was used or expert opinions sought.

Felid body mass data were obtained from Nowell & Jackson (1996), Macdonald (2006), Hutchins et al. (2003) and the Cat Survival Trust (2007). The average weight for each species was calculated from the minimum and maximum mean weight provided by at least two of these sources. Species were categorized by (1) body mass ($\leq$ 10 kg, 11–49 kg, $\geq$ 50 kg), (2) the extent of information available, and (3) the scale of conflict (see Table 1 for definitions of the categories used).

Where the data allowed, the average annual attack or persecution rate was calculated. Time scales of reports were calculated from the beginning of the first year to the end of the last year documented, unless the article specified otherwise. For example, a report between 2000 and 2002 was calculated as a time period of 3 years. Statistical analyses were carried out using *SPSS v. 9* (SPSS, Chicago, USA).

Details of all conflict management techniques mentioned in the literature reviewed were recorded and coded by whether they were implemented or proposed techniques, by whether they had or had not been evaluated scientifically (see Table 1 for definition), and by the felid species involved. The location of each implemented technique was recorded and any anecdotal evidence of a technique's success rate was noted. The implemented conflict management techniques were then categorized by type into 12 groups: financial, livestock husbandry, livestock guarding, education and community development, deterrents, barriers, aversive conditioning, translocation, lethal control, zoning, land use, and attack verification.

Mapping conflict locations

Maps of felid species' ranges were sourced (Appendix 1). Some were available in the required geographical information system (GIS) format, others were converted to JPEG images, imported into the geographical system *ArcView v. 9.2* (ESRI, Redlands, USA), georeferenced and digitized to provide species range layers. Where possible, coordinates for conflict presence/absence were obtained from the literature, or acquired from *ArcView* (using the World Database on Protected Areas, see Appendix 1), Google Earth (Google, 2007a) or Wikipedia (2007). The coordinates obtained varied in accuracy depending on the geographical scale of the report and the resolution of the resource used. Where the coordinates provided by a reference demarked an area, for example a national park, the central point coordinates were calculated. Coordinates were standardized by converting them to decimal degrees using a coordinate converter (COSports, 2007). GIS-compatible global livestock density data were obtained, as was the World Database on Protected Areas (sources detailed in Appendix 1).

Results

Literature quantity and quality

In total 349 literature sources (189 scientific articles, 74 secondary and 86 web pages) were reviewed. The primary and secondary literature was published over 1979–2007, and the number of sources per publication year increased significantly over this period (Spearman's Rank Correlation, $r_s = 0.763$, $P < 0.001$; Fig. 1). The conflict literature was biased toward large-bodied species (Spearman's Rank Correlation, $r_s = 0.536$, $P = 0.001$): 67% of sources contained information about large ($\geq$ 50kg) felid species (Fig. 2) and

TABLE 1 Definitions of the categories used to sort the data collated from the literature review.

Category	Definition
Extent of knowledge	
Conflict well documented (CWD)	Conflict between people & felid species documented in > 5 primary literature sources and detailed information available from secondary literature & websites
Conflict poorly documented (CPD)	Evidence in < 5 primary literature sources that a species is involved in conflict & only general information available from secondary literature (if at all) or from websites. More research needed to clarify the extent of conflict.
No conflict (NC)	Evidence in literature that the species is not involved in conflict in a particular location (this includes studies that directly confirm conflict does not occur at a location and reports that indirectly imply there is no conflict; for example, when no livestock remains have been found in a felid species' scats at that location)
Expert opinion (EX)	Categorization based on expert opinion due to paucity of information in the literature (primary, secondary or internet); in some cases therefore, research is required to clarify whether a species is or is not involved in conflict
Research required (RES)	A paucity of information in the literature & no species expert identified, therefore research is required to clarify whether species is involved in conflict &, if so, the extent of the problem. For many species there is a need for more general research to improve our knowledge of behaviour & ecology.
Scale of conflict	
Severe	High frequency of (perceived) livestock depredation, attacks on people, retaliatory killing
High	High frequency of (perceived) livestock depredation, low frequency of attacks on people (if any), high levels of retaliatory killing
Moderate	Some livestock depredation, no attacks on people, retaliatory killing frequent
Low	Infrequent livestock depredation, no risk to humans, some retaliatory killing
None	No evidence of species exhibiting conflict behaviours or being a perceived threat to humans or livestock, or of retaliatory killing
Data deficient	Very little reliable (especially scientific) information available regarding the species
Applied and evaluated mitigation	
Evaluated	Mitigation strategy scientifically evaluated and results reported in primary literature. Success may be conditional, i.e. a strategy may only work in certain conditions.
Not evaluated	No scientifically-based evaluation of strategy. There may, however, be an indication of success and failure in the literature.

conflict, or a lack thereof, was therefore better documented for these species (Fig. 3 & Table 2).

Felid conflict species

Felid species were assigned to conflict categories based on the evidence in the literature reviewed (Fig. 4 & Table 2): there was no evidence of conflict for seven species, evidence of a low level of conflict for 20 species, and evidence of a moderate or higher level of conflict for nine species. We categorized the Bornean bay cat *Catopuma badia* as data deficient because of insufficient information (Table 1). The severity of conflict differed significantly between felid weight groups (Kruskal Wallis, $\chi^2 = 21.021$, $P < 0.001$). Conflict is more severe with large cats than with either medium (Mann-Whitney U, $Z = -3.268$, $P = 0.001$) or small cats

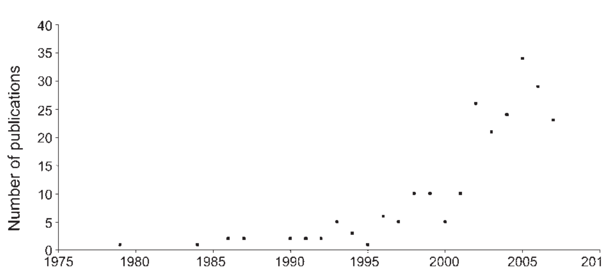

FIG. 1 Publication dates of primary and secondary literature sources reviewed.

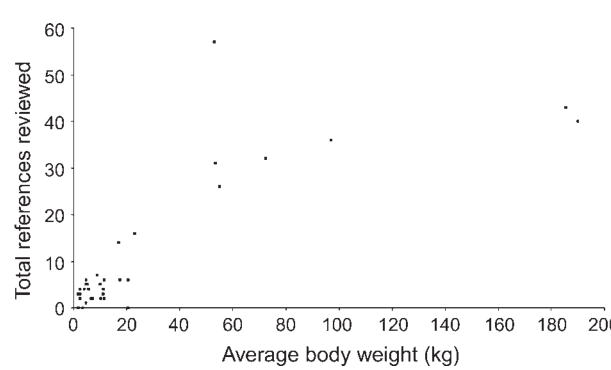

FIG. 2 Total number of information sources (white and grey literature and website resources) reviewed for each of the 39 felid species; 67% of literature sources reviewed concerned species with an average body mass ≥ 50kg.

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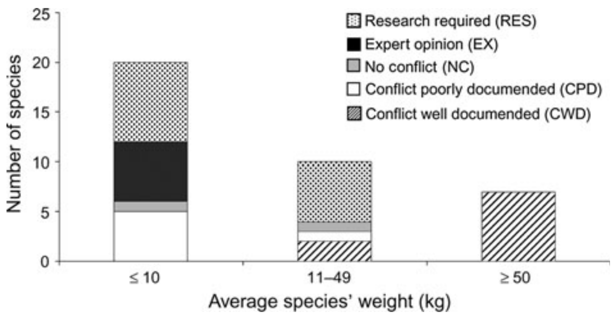

FIG. 3 Extent of felid conflict knowledge determined by the number and type of literature sources accessible for each species. See Table 1 for full category definitions.

(Mann-Whitney *U*, $Z = -4.143$, $P < 0.001$), and conflict with medium and small cats is of a similar intensity (Mann-Whitney *U*, $Z = -1.894$, $P = 0.126$). With the exception of the caracal *Caracal caracal* (17 kg) and Eurasian lynx *Lynx lynx* (23 kg) all of the species with which conflict is of a moderate or higher level have an average body mass > 50 kg. For the remainder of the analyses and synthesis we focus on the nine species for which conflict is of a moderate or higher level: caracal, cheetah *Acinonyx jubatus*, Eurasian lynx, jaguar *Panthera onca*, leopard *Panthera pardus*, lion *Panthera leo*, puma *Puma concolor*, snow leopard *Uncia uncia* and tiger *Panthera tigris*.

Scale of conflict

Livestock depredation Both livestock depredation and attacks on people may incite human-felid conflict but, of the two, livestock depredation occurs more frequently, with cattle, sheep and goats being most commonly attacked (Table 3). Although well documented, livestock depredation data in the literature are quantified in incomparable ways, for example: the total number of livestock lost, the percentage of livestock holdings lost, the quantity of livestock remains in felid scats, or the percentage of the total number of livestock lost to all predators. Of the total primary and secondary literature sources, 225 concerned the nine conflict felids and of these only 10% contained information on the economic loss resulting from livestock depredation. The data are reported in different currencies as absolute values, percentages of income, or percentage of all monetary loss to predators or wildlife (Appendix 2) making them incomparable. No data were available on the economic loss resulting from depredation by caracals or cheetahs. Appendix 2 summarizes the livestock depredation and economic data available in the literature.

Attacks on people Of the nine conflict felids only those with an average body mass > 50 kg show a propensity to attack humans. The three species responsible for most attacks are leopard, lion and tiger; attacks by puma and jaguar are comparatively rare (Beier, 1991; Perovic & Herrán, 1998; Quigley & Herrero, 2005; Altrichter, 2006), and there are no reports of snow leopards or cheetahs attacking humans. Calculation of an average annual attack rate was possible for most locations and indicated that attack rates are not evenly distributed across species' ranges (Appendix 3). The differing geographical scales of reports make further comparisons difficult but reports suggest that attacks have generally declined over time (Thirgood et al., 2005), a trend possibly linked with declining felid populations (Nowell & Jackson, 1996; Treves & Naughton Treves, 1999). However, in some Asian and African locations attacks are still common (Thirgood et al., 2005). For example, attacks by lions increased significantly in Tanzania over 1990–2005 (Packer et al., 2005). An increase in attacks by pumas has also been reported in the USA and Canada in recent decades (Beier, 1991).

Retaliation against felids Appendix 4 summarizes the reports of the numbers of felids killed in retaliation for livestock depredation and/or attacks on humans. Generally, the data presented in the literature allowed the calculation of the average annual persecution rate for each location but, as with the data for attacks on humans, reports are at differing spatial scales. The extent of retaliation was quantified in various ways, including as a percentage of felid mortality. For example, 47% of cheetah (Marker et al., 2003a), 46% of Eurasian lynx (Andrén et al., 2006), and up to 50% of tiger (Miquelle et al., 2005) mortality has been attributed to retaliatory killing in certain regions. Responses from surveys indicate that 39% of respondents in Belize have hunted cats in retaliation for livestock depredation (Brechin, 2003), 88% of ranchers interviewed in the Brazilian Pantanal believe that jaguars are shot by ranchers to prevent cattle losses (Zimmermann et al., 2005), and 14% of herders interviewed in four Mongolian regions have hunted snow leopards (Allen et al., 2002).

Geographical distribution of conflict Locations at which the presence (n = 176) or absence (n = 9) of conflict with at least one felid species has been reported were identified from the literature and mapped. They are presented for each felid species (Fig. 5) and globally (Fig. 6). Fig. 6 highlights a degree of clustering in the location of research efforts and also provides an illustration of the distribution of felid species and conflict in relation to livestock density and the number and distribution of protected areas.

Determinants of conflict

A multitude of factors influence the occurrence and scale of conflict. Because of the extent and complexity of these factors a comprehensive review is beyond the scope of this article, although we present the key findings and conclusions from the literature reviewed.

TABLE 2 Felid conflict categories, average body mass, extent of conflict knowledge, and threat status.

Species	Conflict category	Extent of knowledge[1]	Average body mass (kg)[2]	Red List status[3]
Bornean bay cat *Catopuma badia*	DD	RES	3.5	EN
Sand cat *Felis margarita*	No conflict	EX	2.4	NT (*F. m. scheffeli*, LR/nt)
Black-footed cat *Felis nigripes*	No conflict	EX	1.78	VU
Canadian lynx *Lynx canadensis*	No conflict	NC	11.5	LC
Chinese mountain cat *Felis bieti*	No conflict	EX	7.25	VU
Flat-headed cat *Prionailurus planiceps*	No conflict	EX	4.75	VU
Iberian lynx *Lynx pardinus*	No conflict	NC	9	CR
Manul/Pallas's cat *Otocolobus manul*	No conflict	EX	3.5	NT (*O. m. ferrugineus*, LR/nt)
African golden cat *Profelis aurata*	Low	RES	11.65	VU
Andean mountain cat *Oreailurus jacobitus*	Low	CPD	5.25	EN
Asiatic golden cat *Catopuma temmincki*	Low	RES	11	VU
Bobcat *Lynx rufus*	Low	CPD	17.5	LC
Clouded leopard *Neofelis nebulosa*	Low	RES	20.5	VU
Bornean clouded leopard *Neofelis diardi*[4]	Low	RES	20.5	Not yet classified
Fishing cat *Prionailurus vierrinus*	Low	RES	10.25	VU
Geoffroy's cat *Oncifelis geoffroyi*	Low	RES	4	NT
Jaguarundi *Herpailurus yagouaroundi*	Low	RES	6.5	LC (*H. y. cacomitli*, EN)
Jungle cat *Felis chaus*	Low	CPD	10	LC
Kodkod/guigna *Oncifelis guigna*	Low	CPD	2.5	VU
Leopard cat *Prionailurus bengalensis*	Low	RES	4.75	LC (*P. b. iriomotensis*, EN)
Marbled cat *Pardofelis marmorata*	Low	RES	4	VU
Oncilla *Leopardus tigrinus*	Low	EX	2.5	NT
Margay *Leopardus weidi*	Low	RES	5.75	LC
Ocelot *Leopardus pardalis*	Low	RES	11.5	LC (*L. p. albescens*, EN)
Pampas cat *Oncifelis colocolo*	Low	CPD	4.8	NT
Rusty-spotted cat *Prionailurus rubiginosus*	Low	RES	1.5	VU
Serval *Leptailurus serval*	Low	RES	11.25	LC (*L. s. constantinus*, EN)
Wild cat *Felis silvestris*	Low	CPD	4.5	LC (*F. s. grampia*, VU)
Caracal *Caracal caracal*	Moderate	CWD	17	LC
Cheetah *Acinonyx jubatus*	Moderate	CWD	53.5	VU (*A. j. hecki*, EN; *A. j. venaticus*, CR)
Eurasian lynx *Lynx lynx*	High	CWD	23	NT
Jaguar *Panthera onca*	High	CWD	97	NT
Puma *Puma concolor*	High	CWD	72.5	NT (*P. c. coyri, P. c. couguar*, CR)
Snow leopard *Uncia uncia*	High	CWD	55	EN
Leopard *Panthera pardus*	Severe	CWD	53	LC (*P. p. ciscaucasia, P. p. japonensis, P. p. jarvisi, P. p. kotiya, P. p. melas, P. p. saxicolor*, EN; *P. p. nimr, P. p. panthera, P. p. tulliana*, CR)
Lion *Panthera leo*	Severe	CWD	190	VU (*P. l. persica*, CR)
Tiger *Panthera tigris*	Severe	CWD	185.5	EN (*P. t. altaica, P. t. amoyensis, P. t. sumatrae,* CR)

[1]RES, research required; EX, expert opinion; NC, no conflict; CPD, conflict poorly documented; CWD, conflict well documented (see Table 1 for full descriptions of categories)
[2]From Nowell & Jackson (1996), Macdonald (2006), Hutchins et al. (2003), Cat Survival Trust (2007)
[3]CR, Critically Endangered; EN, Endangered; VU, Vulnerable; LR/nt, Lower Risk/Near Threatened; LC, Least Concern (IUCN, 1994, 2001)
[4]Clouded leopard categorization has been used here as there is no information specifically for Bornean clouded leopard.

Habitat availability Increasing competition for space between humans and felids is the core factor underlying the occurrence of conflict. Habitat degradation is currently one of the greatest threats to the survival of large felid species worldwide (Mazzolli et al., 2002) and certain felids, such as lions, are increasingly restricted to protected areas (Loveridge, 2002). However, few protected areas are of a size sufficient to host viable large carnivore populations (Breitenmoser et al., 2005). Large carnivores, including large felids, have extensive home-ranges that frequently extend beyond reserve borders into human-dominated areas. Consequently, conflict can become particularly acute in reserve border areas and may result in such areas becoming population sinks (Woodroffe & Ginsberg, 1998).

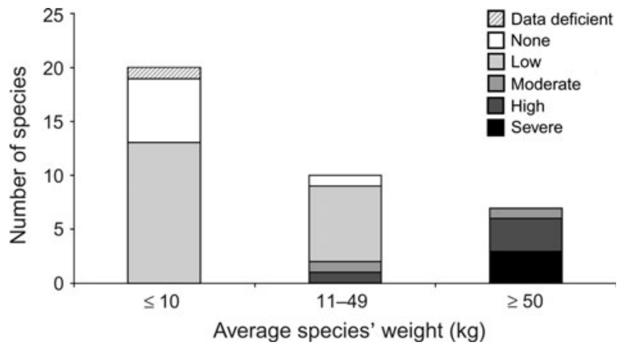

FIG. 4 Scale of human-felid conflict determined by the frequency of livestock depredation, attacks on humans and retaliatory killing of felids reported in the reviewed literature. See Table 1 for full category definitions.

Conflict also affects species such as cheetah and Eurasian lynx that, across all or parts of their ranges, are found predominantly outside protected areas (Marker et al., 2003b; Andrén et al., 2006). In certain locations, for example the Russian Far East, a lack of protected areas is of particular concern for the survival of felids (Miquelle et al., 2005) yet, paradoxically, the establishment of protected areas can increase conflict (Johnson et al., 2005; Wang & Macdonald, 2006).

Wild prey availability Availability of wild prey affects the potential for conflict with each of the conflict felids. Depredation rates tend to be higher in areas where, or at a time of year when, wild prey is less abundant (Saberwal, 1990; Nowell & Jackson, 1996; Pedersen et al., 1999; Polisar et al., 2003; Athreya et al., 2004; Bagchi & Mishra, 2006; Johnson et al., 2006; Melville & Bothma, 2006). However, in Norway and the French Jura, high depredation rates by Eurasian lynx on domestic sheep have been linked with an abundance of wild prey (Stahl et al., 2001a; Herfindal et al., 2005). The frequency of attacks on people by lions and tigers has also been linked with low prey availability (Jackson, 1991; Reza et al., 2002; Packer et al., 2005).

Livestock husbandry and management In many locations poor husbandry and management practices are in part responsible for high levels of livestock depredation (Mishra et al., 2003; Thirgood et al., 2005). Poor guarding or herding practices, the location of grazing pastures, often in close proximity to, or within, felid habitat (Weber & Rabinowitz, 1996; Rao et al., 2002; Herfindal et al., 2005; Rabinowitz, 2005; Kolowski & Holekamp, 2006) and inadequate, or a lack of, pens in which to keep livestock at night (Jackson, 1999; Wang & Macdonald, 2006) are the primary reasons for this.

Human behaviour and activity patterns The majority of attacks on people occur when they venture into felid habitat (Sanyal, 1987; Weiler, 1998; McDougal, 1999; Reza et al., 2002; Mukherjee, 2003) or when they are tending domestic animals or crops (Vijayan & Pati, 2002; Nyhus & Tilson, 2004a). Hunting of felids (Maddox, 2003) and sleeping outside or in makeshift huts during summer months (Vijayan & Pati, 2002; Packer et al., 2005) have been linked with increased risk of attack, and clustering of attacks around Gir Forest, India, has been linked to sites previously used for the baiting of lions for the tourism industry (Saberwal et al., 1990).

Socio-economic determinants A complex, varied and dynamic combination of socio-cultural factors affect the human dimension of human-felid conflict. Attitudes (Athreya et al., 2004; Rabinowitz, 2005; Zimmermann et al., 2005; Ramoñach et al., 2007), perceptions (Macdonald & Sillero-Zubiri, 2002; Marker et al., 2003b; Madden, 2004), belief systems (Hussain, 2002; Nugraha, 2005), educational and value systems (Shivik et al., 2003), religion (Ale et al., 2007), and the economic importance of livestock to a community (Bagchi & Mishra, 2006) can determine tolerance levels and govern the type and severity of human response to felids. Attitudes and perceptions in particular may distort the scale of conflict (Conforti & Azevezo, 2003; Marker et al., 2003a; Silva-Rodríguez et al., 2007) causing people to take

TABLE 3 Livestock species attacked by the nine species of felid involved in conflict, as reported in the literature.

	Poultry	Dog	Goat	Domestic sika deer	Sheep	Pig	Semi-domestic reindeer	Donkey	Horse	Camel	Cattle[1]	Yak	Buffalo[2]
Caracal			X		X								
Cheetah			X		X						X[3]		
Eurasian lynx			X		X[3]		X						
Jaguar		X				X					X		
Leopard	X	X	X	X	X					X[3]	X		
Lion			X		X	X		X		X	X		X
Puma			X		X	X					X[3]		
Snow leopard			X		X				X		X	X	
Tiger	X		X	X					X		X	X	X

[1]Includes oxen
[2]Domestic buffalo in India
[3]Indicates a preference for subadult individuals

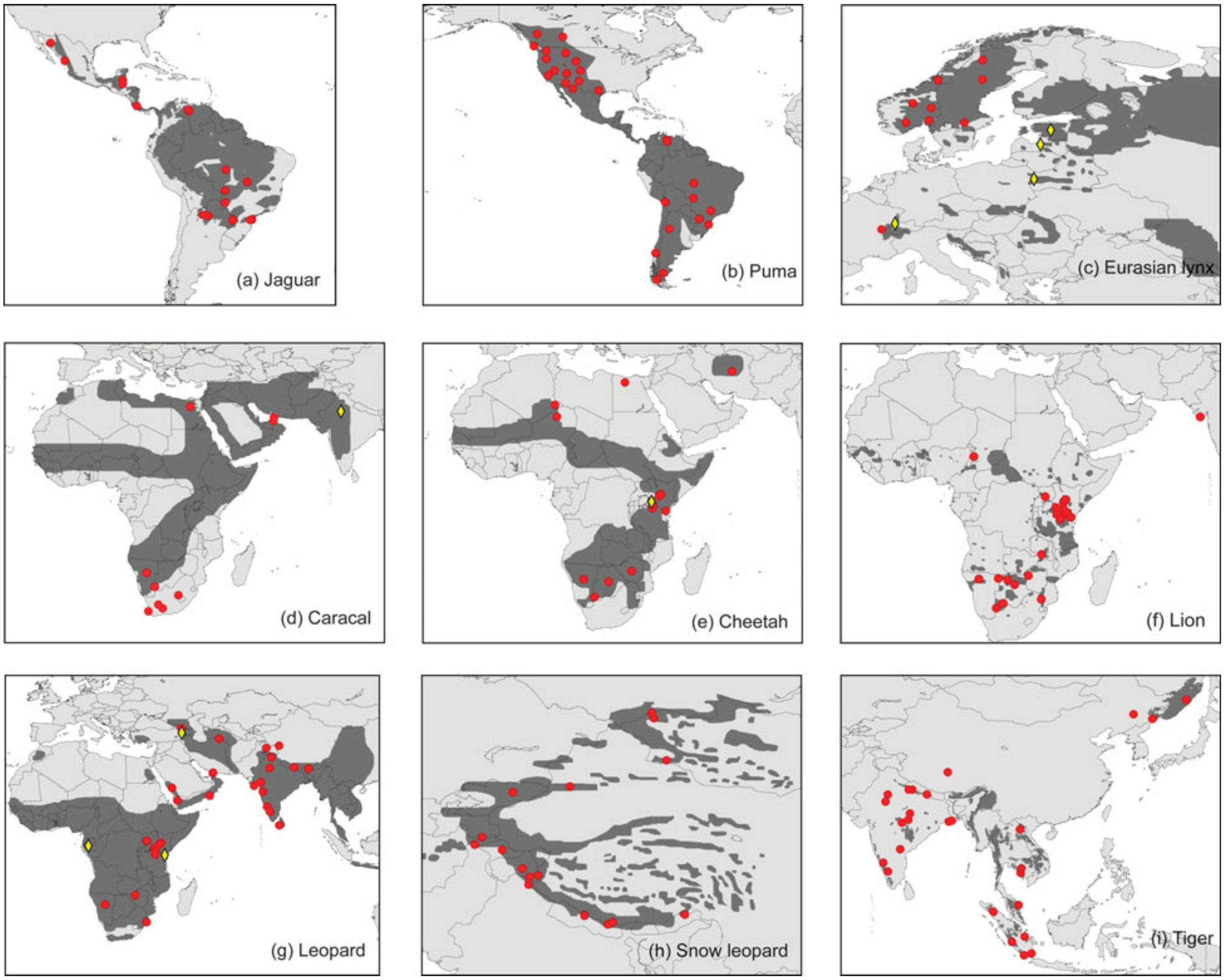

FIG. 5 Locations for which there is evidence of conflict or no conflict in the literature reviewed for each of the nine felid conflict species. Red circles denote conflict locations; yellow diamonds denote locations with no conflict. For details of felid range data sources see Appendix 1.

retributive action that is disproportionate to the actual scale of the problem. Little information is available regarding the human aspect of conflict in many locations but a number of studies (Oli et al., 1994; Saberwal et al., 1994; Weiler, 1998; Sekhar, 1998; Hussain, 2000; Reza et al., 2002; Maddox, 2003; Casey et al., 2005; Rabinowitz, 2005; Altrichter et al., 2006; Silva-Rodrigez et al., 2007) indicate significant geographical variation in attitudes towards felid species and their habitats. Wealth may also in part determine the number of livestock lost and consequently how losses are distributed throughout a community. For example, Saberwal et al. (1994) found that poorer villagers around the Gir Forest, India, lost substantially more livestock to depredation than wealthier villagers who could afford better husbandry and protective measures for their animals.

Spatial determinants Landscape characteristics that influence the occurrence or scale of conflict have been documented for eight of the conflict species (all except caracal). There is a general consensus that depredation increases with increasing proximity to natural habitat types that provide suitable cover for felids (Mizutani, 1995; Rao et al., 2002; Stahl et al., 2002; Vijayan & Pati, 2002; Athreya et al., 2004; Madhusudan, 2003; Nugraha, 2005; Michalski et al., 2006; Woodroffe et al., 2007). Depredation rates also tend to decrease with increasing proximity to human habitation (Sunde et al., 1998; Mazzoli et al., 2002; Rao et al., 2002; Stahl et al., 2002; Kolowski & Holekamp, 2006; Michalski et al., 2006). The effect of other landscape characteristics, for example crop type (Vijayan & Pati, 2002) or features for which a felid species may have a particular affinity such as play trees (Marker et al., 2003b), water bodies (Johnson et al., 2006; Michalski et al., 2006), steep rocky slopes (Stahl et al., 2002) or cliffs (Jackson et al., 1996), on rates of depredation, attacks on humans or retaliatory killing, receive less attention in the literature, making the identification of further trends difficult. However, reports indicate a degree of inter-specific variation in the influence of landscape characteristics, as would be expected from species' differing ecological habits.

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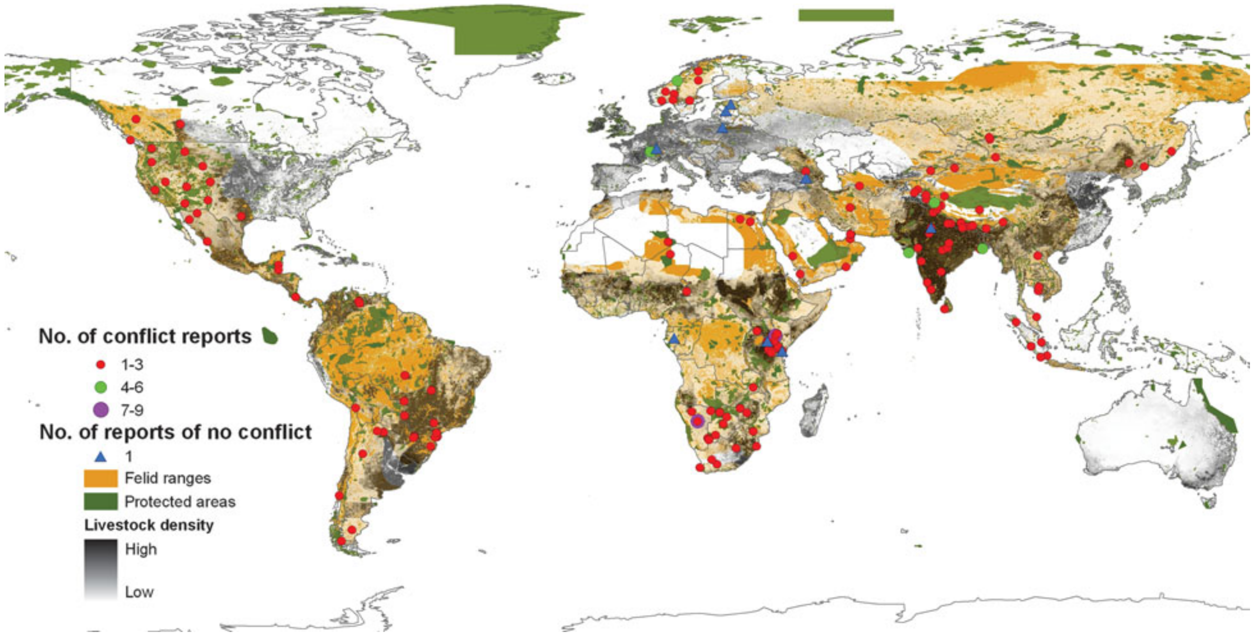

FIG. 6 Global overview of locations for which conflict (circles) or no conflict (triangles) have been reported in the literature reviewed. At each location mapped there may be conflict with more than one felid species and there may be reports of both conflict and no conflict at a given location as these will be for different species. The number of reports per location is detailed to provide an indication of the clustering of research efforts to date. Livestock density data represent the density of cattle and small ruminants globally as these are the most commonly attacked species. For data sources see Appendix 1.

Other determinants of conflict Many species- or location-specific factors influence the scale of conflict but consistent patterns could not be identified. Temporal patterns of conflict, predominantly in livestock depredation, have been described for all of the conflict felids (Oli et al., 1993, 1994; Jackson, 1999; Bauer & Kari, 2001; Nybakk et al., 2002; Madhusudan, 2003; Polisar et al., 2003; Melville et al., 2004; Mohd-Azlan & Sharma, 2006) but they are extremely varied and even differ between populations of the same species. For example, leopard attacks on livestock occur at night around Kenya's Maasai Mara National Park (Kolowski & Holekamp, 2006) yet in Laikipia they also occur during the day (Woodroffe et al., 2007). Other highly specific conflict determinants include: particular felid behaviours and adaptations (Jobin et al., 2000), poor anti-predatory behaviour of livestock (Srivastaav, 1997), environmental phenomena such as drought and floods (Frank & Woodroffe, 2002; Hoogesteijn & Hoogesteijn, 2007), and a lack of wildlife knowledge in communities with whom there is conflict (Hunter et al., 2007). Unsuccessful mitigation techniques have also been known to exacerbate conflict levels (Athreya et al., 2004).

Human-felid conflict management

A detailed review of conflict management strategies is beyond the scope of this article. However, we observed that 110 conflict management attempts were documented in 74 literature sources; of which 31% had been evaluated and the results documented in the primary literature (Table 4).

Discussion

Species affected & the extent of conflict

According to our review and classification, conflict affects 29 of the 37 felid species worldwide. The severity of conflict increases with felid species' body mass and is therefore of greatest significance for the conservation of the larger species. The only anomaly in this pattern is the caracal: despite having an average body mass of 17 kg we found human-caracal conflict to be of a moderate level, yet the slightly heavier bobcat (17.5 kg) is only affected by low levels of conflict. This may be explained by their prey preferences; the *Lynx* species are thought to have evolved to prey on lagomorphs (Jobin et al., 2000) and bobcats specialize on cottontails (*Sylvilagus* spp.) and snowshoe hares (*Lepus americanus*; Sunquist & Sunquist, 2002) and rarely attack livestock (Nowell & Jackson, 1996; Neale et al., 1998; Luna-Soria & López-González, 2005). Caracals, while also preferring small mammal prey, have broader diets than bobcat and are capable of killing larger prey such as springbok *Antidorcas marsupialis* or young kudu *Tragelaphus imberbis* and *T. strepsiceros* (Nowell & Jackson, 1996). We also classed conflict with both clouded leopard species (21 kg) as being of a low level as we could find few reports on

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Table 4 Implemented and evaluated human-felid management strategies as documented in the literature reviewed. Each technique employed at a location is classed as an attempt. A literature source may evaluate the success of more than one technique. Seventy-four literature sources included details of implemented mitigation techniques; 21 (28%) provided an evaluation of techniques. Overall, 31% of all implemented techniques were evaluated and the results published in the primary literature.

Management type	Attempts	Examples of implemented strategies	No. of attempts evaluated (% total attempts)	Conclusion from evaluations (no. of attempts: no. evaluated)
Financial	34 attempts; 15 countries; 7 species	Compensation, insurance, economic development or incentive schemes, ecotourism, trophy hunting	5 (15)	Compensation schemes (20:2) generally unsuccessful (e.g. Madhusudan, 2003) but occasionally experience success under certain conditions (Hermann, 2003); economic incentive schemes (11:2) are proving successful (Mishra et al., 2003); preliminary results indicate insurance schemes (3:1) are a promising technique (Mishra et al., 2003) but less successful attempts have been documented (Miquelle et al., 2005)
Livestock husbandry	17 attempts; 10 countries; 8 species	Improved productivity & protection, e.g. synchronization of calving seasons, immunization, community livestock dip programme, bomas/corrals	6 (35)	Generally effective; success of techniques varies between species (Ogada et al., 2003; Woodroffe et al., 2007)
Livestock guarding	16 attempts; 6 countries; 6 species	People or dogs (either livestock herding or guarding dogs) protecting livestock	11 (69)	Successful (Vandel et al., 2001; Ogada et al., 2003; Marker et al., 2005a,b,c; Woodroffe et al., 2007)
Education & community development	5 attempts; 5 countries; 3 species	Community outreach & education initiatives; provision of grants for community development in exchange for community-wide agreements to safeguard livestock & protect wildlife	1 (20)	Education initiatives in Namibia significantly reduced numbers of cheetahs removed by farmers per year (Marker et al., 2003a)
Deterrents	5 attempts; 4 countries; 5 species	Scarecrows; lights & loud noises; pyrotechnics; face masks	2 (40)	Scarecrows associated with increased risk of attack on livestock (Woodroffe et al., 2007)
Barriers	8 attempts; 7 countries; 7 species	Specialized electric fencing; fences preventing cattle entering forests; wire mesh, wooden pole or nylon netting barriers around villages	2 (25)	Varied success depending on barrier structure and felid species (Schiaffino et al., 2002; Scognamillo et al., 2002)

Table 4 (Continued)

Management type	Attempts	Examples of implemented strategies	No. of attempts evaluated (% total attempts)	Conclusion from evaluations (no. of attempts: no. evaluated)
Aversive conditioning	4 attempts; 4 countries; 3 species	Electrified human dummies or stuffed animals; recently killed livestock injected with nauseating substances, e.g. lithium chloride	0	
Translocation	6 attempts; 6 countries; 4 species	Translocation of problem animals to protected areas/ areas a distance from human habitation	4 (67)	Unsuccessful (Rabinowitz, 1986; Athreya et al., 2004; Athreya & Belsare, 2007) or mixed success (Ruth et al., 1998; Goodrich & Miquelle, 2005)
Lethal control	5 attempts; 5 countries; 3 species	Selective removal or regulated harvest of felids	2 (40)	Selective removal not ideal (Stahl et al., 2001a), non-selective removal unsuccessful (Sunde et al., 1998; Herfindal et al., 2005)
Zoning	5 attempts; 3 countries; 4 species	Harvest Management Units; separating livestock grazing from felid habitat	0	
Land-use	1 attempt; 1 country; 1 species	Proactive agriculture extension, livestock grazing-free areas, resettlement	0	
Attack verification	1 attempt; 1 country; 1 species	Tiger Response Units	0	
Total	107 attempts		33 (31)	

depredation; however, the lack of information about these species makes this a tentative conclusion.

Spatial, taxonomic & socio-economic patterns of conflict

Reviewing conflicts between humans and mammalian and avian predators, Graham et al. (2005) found that resolution of trends was limited by inconsistent and sparse data, and highlighted the need for a consistent framework for assessing and managing human-predator conflicts that involve game and livestock species. Even at the more specific taxonomic level of our review, meta-analysis was not possible because of inconsistent reporting methods and disparity in the spatial scale of reports, making data generally incomparable either within or between felid species. A lack of comparable data particularly hampered our attempts to identify patterns and trends in livestock depredation. It appears, however, that while for some species, such as Eurasian lynx, there is variation in the number of livestock killed across their range, for others such as jaguars or snow leopards, the numbers killed are more consistent. No further trends were identified. Similarly, the varied economic reporting methods meant that comparing economic loss across locations, to identify those communities most greatly affected financially by conflict, was not possible.

The consistency in reporting technique was greater for data concerning attacks on humans and retaliatory killing than for livestock depredation, and again indicates geographical and inter-specific variation in attack and persecution rate. Although it has not been possible to identify further trends in retaliatory killings worldwide, it is apparent that persecution remains a significant threat to the nine conflict felids. For example, conflict is a principal threat to cheetahs in nine range countries in Africa and Asia (Marker, 1998), the lion population in Laikipia, Kenya, is regulated by lethal control in response to livestock depredation, rather than natural mortality rates (Woodroffe & Frank, 2005), and the retaliatory killing of snow leopards by farmers in Baltistan, Pakistan, poses a significant threat to the species' survival in the region (Hussain, 2000). In most parts of species' ranges however, the extent of retaliatory killing is unknown (Hussain, 2003; Breitenmoser et al., 2007).

Factors that determine the scale of conflict

The factors that determine the nature of a conflict are diverse. As many of these are location- or species-specific, a unique combination of factors determines the nature of a given conflict. The socio-economic factors fundamental to the human dimension of conflict, and that ultimately determine the scale of a given conflict, can be particularly varied, and identification of these factors is difficult. For example, in Scandinavia, although economic loss provides a proximate reason for killing felids, it is apparent that retaliation results from a general antipathy for the Eurasian lynx (Andrén et al., 2006), and other cultural or economic influences such as traditional lion hunts, or *Olamayio*, in Kenya (Frank et al., 2006), or the potential to derive income from the sale of tiger body parts (Karanth & Gopal, 2005; Nugraha, 2005), must also be taken into consideration.

The scope of human-felid conflict literature

The amount and quality of human-felid conflict-related literature per species increased with felid body weight and therefore information about the smaller felid species with which conflicts are also likely is scarce. For example, ocelot *Leopardus pardalis*, margay *L. weidi*, jaguarundi *Herpailurus yagouaroundi* and Geoffroy's cat *Oncifelis geoffroyi* have a propensity to kill poultry but there is no published research to clarify the occurrence, extent or scale of the conflict (T. de Oliveira, pers. comm.).

Research has focused more on livestock depredation than attacks on people, persecution or game depredation, yet the economic impact of livestock depredation is rarely quantified. When it is, only the direct financial costs of livestock depredation are considered. However, it is recognized that economic losses can be catastrophic, particularly as they are often not evenly distributed throughout a community (Thirgood et al., 2005). There are also few instances in which the impacts of conflict are placed in a wider context through comparison with, for example, other factors that may limit livestock production (Hoogesteijn et al., 1993; Schiess-Meier et al., 2007), human deaths caused by other wildlife or domestic dogs (Beier, 1991), or natural or accidental (e.g. collisions with cars) causes of felid mortality (Marker et al., 2003a; Marker & Dickman, 2004; Miquelle et al., 2005).

A geographical analysis of human-felid conflict research efforts shows that there are vast areas of felid ranges for which no information on conflict is available and also that accurate distribution data for many species are not readily available (e.g. there are discrepancies between the caracal range data we were able to access, and the reported conflict locations for the species; Fig. 5d), which may hinder efforts to target future human-felid conflict research effectively. Additionally, obtaining accurate conflict data can be challenging as people may not be willing or able to report an accurate offtake by felids (A. Zimmermann, unpubl. data) or readily divulge whether they kill felids (Allen et al., 2002), and it can be difficult to determine the cause of livestock deaths (Madhusudan, 2003).

Conflict management: implementation & evaluation

We grouped the large and diverse number of conflict management techniques into 12 categories depending on the type of technique involved. The effectiveness of techniques varies and, over time, shifts in the types of techniques have occurred. Historically, lethal control was the dominant type of conflict management. It is still used in the USA and Europe to control puma and Eurasian lynx populations respectively, despite questions about the effectiveness of such measures (Sunde et al., 1998; Stahl et al., 2001b; Hoogesteijn, 2003; Herfindal et al., 2005). More recently, compensation schemes have been the most commonly implemented strategy but have largely been unsuccessful. Other financial techniques such as insurance and economic incentive or development schemes are now being more heavily relied upon (Hussain, 2000; Jackson & Wangchuk, 2004), and preliminary results indicate that economic incentive schemes in particular are achieving success (Mishra et al., 2003). The use of guarding or herding dogs is one of the most consistently successful livestock husbandry-related techniques (Vandel et al., 2001; Ogada et al., 2003; Marker et al., 2005a,b,c). Conversely, translocations are generally ineffective (c.f. Linnell et al., 1997) and may even aggravate conflict levels (Athreya et al., 2004).

It is also apparent that little rigorous scientific information about the success and failings of the techniques is available. Thorough monitoring and evaluation of implemented management techniques is essential if practitioners are to identify the most successful and efficient methods of managing conflict, yet by our calculation only 31% of implemented techniques have been thoroughly evaluated and the results made available to the conservation community through publication. This number may in reality be even lower as it is likely that conflict mitigation techniques are being employed in more places than documented in the literature.

Conclusion

Human-felid conflict is a complex and multifaceted issue, the management of which is a key conservation priority for at least nine felid species. Many different conflict management strategies have been implemented worldwide, with varying degrees of success. To address conflict more effectively, practitioners must develop culturally acceptable, sustainable solutions, developed using not only sound scientific research but the practical field experience of other practitioners. Such solutions must aim to accommodate the requirements of both felids and people and reduce the costs incurred by both as a result of conflict.

We have highlighted three needs that are fundamental to the development of successful management strategies. Firstly, the development of standardized reporting techniques to allow comparison of the scale of conflict between locations and between species. This is particularly required for livestock depredation, which is the most commonly reported aspect of conflict but for which there is the greatest disparity in reporting methods. The reporting of livestock losses to a particular predator as a proportion of total holdings, for example, would facilitate comparisons between livestock owners at all economic scales, and would also indicate where losses have the greatest financial impact.

Secondly, although general principles can be applied to conflict management strategies worldwide, variation in the determinants of conflict at each location dictates that strategies must be situation-specific. For example, while the effects of certain conflict determinants, such as habitat availability, appear uniform across species, and other determinants such as wild prey availability are a common influence on conflict severity, variation in the spatial, temporal and socio-economic determinants of conflict is evident, making each conflict situation unique. A thorough exploration of the conflict determinants at each location is therefore essential, and must result in a management strategy tailored to the situation to achieve maximum impact.

Thirdly, implemented management techniques should be evaluated rigorously and the results, even if they are negative, made available through publication. Communication between conflict practitioners is also essential for the transfer of knowledge regarding the successes and failures of applied techniques.

We have also highlighted a number of gaps in knowledge that must also be addressed if conflict management techniques are to become more efficient and effective. We propose that future research efforts should therefore:

- Seek to clarify the extent of conflict with the smaller felid species, and the species for which we currently have little information, such as the clouded leopards.
- Target range areas for which we currently have no information, to provide a range-wide overview of conflict for each species. Such efforts will be aided by accurate distribution data for felid species and, where not already available, efforts should be made to determine current species' distributions and the data made widely available.
- Focus more on understanding the patterns, trends and extent of attacks on people by felids worldwide.
- Investigate the extent to which game depredation by felids incites conflict, and the locations and felid species for which it is of greatest significance.
- Aim to understand better the human dimensions of conflict, and particularly the socio-economics, through greater collaboration with the social sciences.
- Quantify the extent of persecution of felids and assess its impact on felid population dynamics in those areas for which there is currently no information.

If the needs and knowledge gaps identified by this review are addressed, the knowledge gathered will increase our understanding of the scale, occurrence and determinants of conflict worldwide. It will enable the more effective allocation of resources to target those species for which conflict is of greatest threat and/or the particular locations where conflict is having the greatest impact on both humans and felid species. Ultimately, the impact of implemented conflict management techniques will be increased, strengthening conservation efforts for members of the Felidae.

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Appendices 1-4

The appendices for this article are available online at http://journals.cambridge.org

Biographical sketches

Chloe Inskip is carrying out research on human-carnivore conflicts in tropical forest habitats. At the time of writing she was based at Chester Zoo, UK, assisting with the development and coordination of the Zoo's felid conservation programmes. She is interested in wild cat conservation, and in particular, human-felid conflict. Alexandra Zimmermann specializes in human-wildlife conflicts, both in theory and practice. Having worked on jaguar conflict in Brazil and developed a successful long-term human-elephant conflict mitigation programme in India, her current research focuses on conflict dynamics, and conceptual models for best practice in conflict mitigation, in particular for large cats and elephants. For the past decade she has developed conservation programmes for Chester Zoo in the UK and is now based at the Wildlife Conservation Research Unit, Oxford University, UK.