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<https://doi.org/10.1007/s10344-019-1270-x>

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European Journal of Wildlife Research

Managing human-tiger conflict: lessons from Bardia and Chitwan National Parks, Nepal

--Manuscript Draft--

Manuscript Number:		
Full Title:	Managing human-tiger conflict: lessons from Bardia and Chitwan National Parks, Nepal	
Article Type:	Review	
Keywords:	Human-tiger conflict; predators; compensation; prey; problem-tiger; human-attack.	
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	Zoological Society of London	Mr. Babu Ram Bhattarai
	Federation Univeristy	Mr. Babu Ram Bhattarai
Abstract:	<p>Successful conservation outcomes for the tiger (<i>Panthera tigris</i>) have been achieved in Nepalese protected areas. However, an unwelcome consequence of greater tiger numbers is the increased prevalence of human-tiger conflict (HTC), particularly in buffer zone areas adjacent to the tiger reserves, which are heavily utilised by farming communities. HTC events may manifest as attacks by tigers on livestock or people; or as people harming tigers. Since 1994, 12 and 99 fatal tiger attacks on people were reported in and near Bardia and Chitwan National Parks respectively; and 34 tigers from these Parks were killed due to HTC since 1979. HTC presents major threats to local people and to the ongoing success of tiger conservation programs. Conservation authorities in Nepal are implementing innovative solutions to prevent and mitigate HTC. These include financial compensation for damage caused by tigers; and locally based community projects and programs focussed on, changing livestock husbandry practices, raising awareness of tiger ecology among local residents and supporting families to reduce their reliance on park resources. While these approaches have been successful in mitigating HTC and its effects in Nepal, further development and refinement is required. This paper provides a synthesis of published and unpublished reports of HTC, in order to demonstrate the magnitude of the problem faced in Nepal. A critical summary of current management practices adopted in two of Nepal's key tiger reserves is intended to provide a tool for managers to target their efforts towards methods likely to achieve success.</p>	

Title: **Managing human-tiger conflict: lessons from Bardia and Chitwan National Parks, Nepal**

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1 Managing human-tiger conflict: lessons from Bardia and Chitwan National Parks, Nepal

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5 Abstract

6 Successful conservation outcomes for the tiger (*Panthera tigris*) have been achieved in Nepalese
7 protected areas. However, an unwelcome consequence of greater tiger numbers is the increased prevalence of
8 human-tiger conflict (HTC), particularly in buffer zone areas adjacent to the tiger reserves, which are heavily
9 utilised by farming communities. HTC events may manifest as attacks by tigers on livestock or people; or as
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19 Nepal. A critical summary of current management practices adopted in two of Nepal's key tiger reserves is
20 intended to provide a tool for managers to target their efforts towards methods likely to achieve success.

21 Key words: Human-tiger conflict; predators; compensation; prey; problem-wildlife; human-attack.

Background

Tigers (*Panthera tigris*) are universally recognised to have high intrinsic value and, as top order predators, are considered to play a significant role in their ecosystems (Wang and Macdonald 2006; Damania et al. 2008; Linkie and Christie 2007). In addition, the presence of wild tiger populations provides developing countries with significant potential to attract tourism revenue through eco-tours and associated services. The current vulnerability of existing tiger populations threatens both the species' long term existence and the sustainability of tourism-based income streams (Buckley 2013).

HTC has played a significant role in declining tiger populations globally, along with habitat loss and fragmentation, prey depletion due to over hunting, and poaching for tiger body parts, which are sold in illegal markets (Chapron et al. 2008; Damania et al. 2008; Karanth and Stith 1999). Sadly, three tiger subspecies, namely the Javan (*P. t. sondaica*), Balinese (*P. t. balica*) and Caspian (*P. t. virgata*) tigers are now extinct, while the South China tiger (*P. t. amoyensis*) is considered likely extinct in the wild (Barlow et al. 2013). Historical conflict with humans has played an important part in these extinctions (Nowell and Jackson 1996; Nyhus and Tilson 2010).

Tiger range countries are characterised by dense human populations and a high dependence of people on forest resources (Dinerstein et al. 2007). Livestock are grazed in forests; and fodder, firewood and various herbs are gathered from the forest and provide important supplements to subsistence livelihoods (McLean and Stræde 2003; Thapa and Hubacek 2011). Tigers also source their food (prey), water and cover from the forest (Karanth et al. 2017; Sunquist et al. 1999). Due to this spatial overlap, there is potential for tigers, humans and their livestock to encounter one another (Nyhus and Tilson 2004). Recent successful conservation outcomes, resulting in larger tiger numbers in key reserves, have exacerbated the problem (Aryal et al. 2015; Duangchantrasiri et al. 2016). In 2010, a target to double the world's tiger numbers by 2022 was endorsed in the St Petersburg Declaration on Tiger Conservation, as part of The Global Tiger Recovery Plan (Wikramanayake et al. 2011).

Tigers are large predators that require extensive home ranges and large numbers of ungulate prey species (Karanth et al. 2017). Increasing tiger populations within reserves which remain at a constant size results in more frequent contact between tigers, humans and livestock as the big cats search for food and territories, including in buffer zone areas (Karanth and Gopal 2005; Woodroffe and Ginsberg 1998).

1 In Nepal, several populations of Bengal tiger (*P.t. tigris*), are located mostly within key national parks.
2 Doubling the Nepalese tiger population equates to an aspirational target of 250 breeding tigers by 2022. Since
3 the target was set in 2010, a 63% increase has already been achieved (GoN 2014). Continued increases in tiger
4 numbers are likely to increase pressure on park resources and will affect human populations living in buffer
5 zone areas surrounding the reserves. These communities depend on natural resources both within the parks and
6 in buffer zone areas (Aryal et al. 2015; GoN 2014; Thapa et al. 2016).

7 Dense human populations occur within the buffer zone areas associated with Bardia and Chitwan
8 National Parks (figure 1). These areas include community forests, which are used extensively by both tigers and
9 humans. As tigers are specialized predators of large ungulates, they readily kill livestock and often attack
10 humans (Karanth and Gopal 2005; Nyhus and Tilson 2010; Smith et al. 2010). In response, tigers may be killed,
11 either by park management authorities or by angry victims or their families (Gurung et al. 2008; Lamichhane et
12 al. 2017). Increasing incidents of livestock loss and attacks on humans can also result in negative attitudes
13 towards tigers and tiger conservation among local communities. Such attitudes, together with revenge killings,
14 can seriously undermine conservation efforts (Carter et al. 2014; Singh et al. 2015).

15 Figure 1. Location of Bardia and Chitwan National Parks and their buffer zones in surroundings

16 To explore this complex issue, this review considers characteristics and consequences of HTC, with a
17 particular focus on Nepal. Current HTC countermeasures are identified. The efficacy of these measures are then
18 considered and discussed comparing the research findings in other tiger range countries, with recommendations
19 for further evaluation and assessment through dedicated research.

20 **Summary of documented incidents of HTC in Nepal**

21 Although research is sporadic, and more work is required for a full understanding, several studies
22 enumerating livestock loss, human casualties and loss of tigers have been carried out in Chitwan National Park
23 and other Nepalese protected areas. This section summarises published and unpublished reports of human
24 casualties, livestock loss and loss of tigers as a direct result of HTC in CNP and BNP, along with accounts of
25 indirect conflict, in the form of estimates of crop damage attributed to tiger prey species.

26 **Human casualties**

27 Evidence of human casualties due to tigers is found at both CNP and BNP, with fewer incidents
28 reported at BNP. Using data held by park authorities, Bhattarai and Fischer (2014) reported approximately one

human death per year due to tigers occurring in BNP and its buffer zone areas between 1994 and 2007. There are no records of fatalities from communities around BNP after 2007; however there were three records of non-fatal attacks (one in 2013 and two in 2016) in BNP (BNP unpublished data). Similarly in CNP an average of 3.2 fatal attacks per year occurred due to tigers between 1979 and 2006 (Gurung et al. 2008).

Humans have long been preyed on by tigers (Nyhus and Tilson 2010). Seidensticker and McDougal (1993) argue that humans are not the preferred prey of tigers, pointing out that we must seem very different to ungulate prey. When humans are standing or walking on two feet, the neck - the usual target of the lethal bite for the tiger - is located differently and is usually positioned much higher than that of many ungulate prey. Individual tigers which kill humans do so either because the cat senses a threat or because they are hungry as a result of being unable to find or hunt their usual prey (Gurung et al. 2008; Karanth and Gopal 2005). In general, tigers avoid human contact (Karanth et al. 2017).

When humans intrude into tiger habitat, either for tourism experiences or to gather forest resources, they may inadvertently present a perceived threat to a resident tiger (Boomgaard 2010). In both BNP and CNP, local people depend on park resources for their livelihoods. Wood, grasses and many herbs are collected, either legally or illegally. In CNP, approximately 50% of the 88 people killed by tiger attacks in the period 1979-2006 were collecting grass. Similar results were found elsewhere. In the Sunderban Tiger Reserve (which extends across the border of Bangladesh and India), humans are killed when they enter the tiger habitat to collect various resources such as honey, fish or wood (Barlow et al. 2013; Neumann-Denzau and Denzau 2010). Likewise, in Ranthambhore Tiger Reserve in India, people collecting fuelwood in the forest are at the highest risk of tiger attack (Singh et al. 2015).

Tigers may have difficulty in finding or hunting their usual prey if they are physically impaired (wounded, broken teeth, very old). In such circumstances, humans and their livestock might be perceived by an impaired cat as an easier or alternative target (Goodrich et al. 2011; Gurung et al. 2008). This suggestion is certainly supported by the available data. Gurung et al. (2008) documented nearly 60% tigers involved in human killing in CNP, Nepal were impaired. A female tiger whose claws were broken killed 19 people in CNP between 2008 and 2016 (Lamichhane et al. 2017).

In Nepal, tigers may encounter humans more frequently in buffer zone areas adjacent to the park boundary. Before the establishment of the buffer zones (1979-1997), the average annual frequency of human deaths due to tigers was 1.2 per year. This rate increased to 7.2 persons per year following the establishment of

1 buffer zones and the restoration of buffer zone forests (1998-2006) (Gurung et al. 2008). A later study by
2 Dhungana et al. (2017) documents four human deaths per year at CNP from 2007 to 2014. Most incidents
3 (75.9%) occurred in the buffer zones (the remaining 24.1% occurred within the park).

4 Several other authors have documented increased casualties in the buffer zones surrounding CNP
5 following forest restoration and the related increase in the utilisation of these areas by tigers (Gurung et al. 2008;
6 Smith et al. 2010). Prior to 1996, forests adjacent to the park boundary were heavily exploited (over-grazing and
7 resource extraction) as common resources. After the introduction of regulations for buffer zone management in
8 1996, free grazing of livestock was banned and resource collection was strictly regulated (Gurung et al. 2009).
9 The buffer zone forests recovered well and were again utilised by tiger prey species; followed by their predators
10 (Gurung et al. 2008; Smith et al. 2010). Since people still utilise the resources of the buffer zone forest, albeit in
11 a regulated way, the buffer zones are therefore shared areas for both tigers and humans.

12 The data relating to human casualties indicate that CNP has higher rate of human casualties than in BNP
13 (figure 2). This may be associated with the higher density either of tigers, or of humans, at this location. According
14 to 2013 census data, the density of tigers at CNP is 2.5 times higher than at BNP and the number of people living
15 in areas surrounding CNP is twice as high as around BNP (GoN 2014; GoN 2015a; GoN 2015b). There are some
16 indications that the higher number of human deaths due to tigers in CNP is associated with cultural and
17 geopolitical factors. In CNP, *Bote* and *Darai* communities have funeral practises that include burying the dead in
18 shallow graves along the *Narayani* River. Tigers often excavate the corpses (Pers com. Yadav, R. 2017 October).
19 In addition, passenger busses sometimes veer off into the river (in road accident). The bodies are sometimes
20 carried away by the river current. Tigers have been observed to consume these corpses (Dhungana et al. 2017).
21 These factors may mean that tigers are more familiar with humans as prey and may increase the likelihood of
22 attacks on living people.

23 (Figure 2 here)

24 **Livestock loss**

25 Communities surrounding both CNP and BNP regularly experience the loss of livestock due to
26 predation by tigers and leopards. Unlike attacks on humans, where the predator is often clearly identified,
27 reports of livestock losses do not necessarily distinguish between these two large cats. Reporting is further
28 complicated because, although there are different words for tiger (*Bagh*) and leopard (*Chituwa*) in the Nepali
29 language, the word *Bagh* is commonly used locally to refer to both species (BRB, pers obs.).

Bhattarai and Fischer (2014) collated livestock losses reported by 272 householders across six buffer zone communities surrounding Bardia National Park. In the three year period 2007-2009, 28% of the surveyed householders reported livestock losses and, after being shown images of both tigers and leopards, attributed these losses to tigers. These authors documented that in surveyed buffer zone communities, each household lost, on average, 0.25 domestic animals per year to tigers. A comparable study was conducted by Tamang and Baral (2008) in BNP. There, 66.5% of 322 households surveyed across seven buffer zone communities lost one or more types of livestock to predators in six a year period (1993 to 1998). Interview data from this study led the authors to conclude that tigers were responsible for 68% of the total livestock losses. They attributed a further 20% of the losses to leopards and the remainder to other predators. All but one incident involving large domestic animals (cattle, buffalo) were associated with tigers.

Various authors have suggested explanations for the tendency of tigers to prey on domestic stock. These explanations include a reduced abundance of wild prey, and the increased availability of domestic animals. The latter occurs particularly when stock are grazed inside tiger habitat areas; or when tigers expand their territories into human dominated areas. Treves and Karanth (2003) suggest that tigers may be forced to prey on livestock when abundances of natural prey species are depleted, due to either to overhunting by humans or other ecological reasons. Although occasional illegal hunting of tiger prey species by the human population still occurs in both BNP and CNP (Bhattarai et al. 2016), both parks claim to support sufficient numbers of prey species to support current tiger populations. Data collected in 2008/2009 describe the density of tiger prey species in BNP and CNP as 92.60 and 72.63 animals per km² respectively and the breeding tiger densities in BNP and CNP are 3 and 7 per 100 km² respectively (GoN 2014). According to Karanth and Stith (1999) prey density of 25-50 ungulates/km² can sustain 72 breeding females in 1000 km² reserve. Therefore, we argue, that at least for now, depleted abundances of prey species are not driving tigers to predate on livestock in BNP and CNP.

An alternative explanation is that livestock are easier to hunt and kill compared to wild prey animals, since the former have lost anti-predatory behaviours. Tigers will therefore take livestock that they encounter opportunistically; and the availability of domestic animals to tigers drives the numbers of stock lost (Madhusudan 2003; Polisar et al. 2003). Encounters between tigers and livestock are more likely to occur when domestic animals are grazed inside tiger habitat. There is evidence of illegal grazing activities within the park boundaries at both BNP and CNP (Bhattarai et al. 2017; Carter et al. 2012). Rivers form the boundary of both

1 parks and grazing of livestock on the floodplain (technically legal, since one side of the river is not located
2 inside the park) is common. Also limited grazing (in prescribed zones and at prescribed times) is permitted in
3 some buffer zone forests. Tigers have ready access to river floodplains and to buffer zone areas.

4 Karanth and Gopal (2005) and Smith (1993) have argued that juvenile and sub adult tigers may
5 disperse from core forest habitat and make their territories at forest fringes which border on agricultural areas.
6 Here, at the edge of forests and agricultural areas, livestock are readily available. The concentrated efforts of
7 Nepal's conservation agencies have resulted in growing tiger numbers at both CNP and BNP. Transient sub
8 adult populations are increasing at both locations (GoN 2016). Many agricultural areas used for livestock
9 grazing are located within metres of the forest edge at both reserves (BRB, pers.obs.). Night corrals are not
10 always used for livestock, or may not be sufficiently sturdy to protect domestic animals from large predators.
11 Several events of livestock depredation from night corrals have been observed in areas surrounding of both
12 national parks (Tamang and Baral 2008; BRB, pers.obs.). Nepal's international commitment to double the tiger
13 population by 2022 is likely to exacerbate the number of livestock depredation events in the future.

14 **Loss of tigers associated with HTC**

15 Park authorities may remove tigers from the breeding population as a result of HTC. "Problem tigers",
16 once identified, are often killed or placed in captivity by park authorities. These measures also compromise
17 conservation outcomes. Combined data from studies conducted in 1979-2006 (Gurung et al. 2008) and 2007 –
18 2016 (Lamichhane et al. 2017) indicates that 58 animals were deemed to be problem tigers in CNP and the
19 surrounding buffer zone forests. Between 1979 and 2016, 28 of these 58 problem tigers identified in and around
20 CNP were removed from this protected habitat. Additionally nine tigers were killed by local communities in
21 retaliation for the killing of livestock (Table 1).

22 Although BNP and CNP are comparable in area, BNP has fewer tigers (GoN 2014) and fewer incidents
23 of attacks on humans by tigers. Thus fewer problem tigers have historically been identified at BNP; and
24 management interventions are also less frequent. From 1989 to 2009, six animals were identified as problem
25 tigers in and around BNP. All were either killed or removed from the protected area (Bhattarai 2009). Between
26 2010 and 2016 there were no tigers removed from BNP (Pers. com. Dahal, B. February 15, 2017). The 2013
27 tiger census recorded 120 and 50 tigers respectively at CNP and BNP (GoN 2014). The removal of 34 tigers
28 from the two parks represents a significant cost to conservation (Table 1).

(Table 1 here)

Lethal control of problem tigers has been practiced as a tool for the management of HTC in several other countries (Goodrich et al. 2011; Karanth and Gopal 2005; Nugraha and Sugardjito 2009; Nyhus and Tilson 2010). Nugraha and Sugardjito (2009) reported removal of an average of 3.2 tigers per year from Kerinchi Seablat National Park, Indonesia between 2000 and 2004. Barlow et al. (2013) documented that an average of 2.5 tigers were killed annually in Sunderban Tiger Reserve, Bangladesh between 1984 and 2006. Neither of these studies clarifies how many of these animals were killed by poachers, park authorities and local people.

Killing problem tigers in order to reduce HTC is a strongly debated management approach. In CNP of Nepal though problem tigers are removed the conflict incidents are not reduced (Dhungana et al. 2017; Lamichhane et al. 2017). Treves and Karanth (2003) conclude that killing of carnivores does not reduce human carnivore conflict, and (Wang and Macdonald 2006) argue that declines in carnivore populations may lead to explosions of herbivore populations which will destroy farmers' crops. Those who focus on animal rights may oppose the idea of lethal control of problem tigers on principle (Karanth and Gopal 2005); however, local community members who bear the costs of HTC may understandably support the killing of problem animals (Lamichhane et al. 2017; Nugraha and Sugardjito 2009). Based on such arguments, Karanth and Gopal (2005) and Karanth and Madhusudan (2002) prescribed the killing of only the individual tigers which have killed and eaten humans. In Nepal, where the dominant religions are Hinduism and Buddhism, the killing of tigers is not generally favoured. Hindus consider tigers as a symbol and the vehicle of the goddess *Durga*, and thus killing any tiger is considered a sin (Bhattarai and Fischer 2014). Further, since tiger numbers are critically low throughout their historical range, conservation of this iconic species has become important, both ecologically and politically (at an international level). Lethal control of problem tigers in Nepal has therefore also been controversial (Gurung et al. 2008).

The lethal control of HTC increases tiger mortality and reduces the size of the breeding population. The challenges of maintaining viable tiger populations are exacerbated by a host of other factors including habitat loss, prey depletion and poaching for international trade of body parts (Chapron et al. 2008; Dinerstein et al. 2007; Karanth and Stith 1999). These factors, combined with HTC, have reduced tiger numbers in several countries and decreased the species' worldwide range (Damania et al. 2008; Goodrich et al. 2011; Nyhus and Tilson 2010). Therefore, while adopting lethal control, along with socio-political factors, demography of the tiger populations should be considered.

Economic losses associated with HTC

HTC causes direct and indirect economic losses for communities living adjacent to Nepal's tiger reserves. Tamang and Baral (2008) estimated direct losses as a result of livestock depredation implicating tigers or leopards in seven buffer zone communities around BNP. These authors calculated that each household lost on average US\$24.19 over a six-year period (1993-1998). These economic losses represent significant sums for subsistence farmers given that the annual average income per capita in Nepal in 1995 was less than US \$ 1400 (Trading Economics 2017). Farming communities in the buffer zones of CNP and BNP are likely to earn less than the average income. Livestock play a vital role in subsistence farming communities of Nepal; they provide power for tilling the soil or pulling a cart, manure for compost and a source of protein. A very important factor to consider is that the people living in such areas are mostly poor, subsistence farmers and so any small losses, such as loss of a single head of livestock, can have a profound effect on livelihoods (Bhattarai and Fischer 2014). Therefore, the impact of livestock losses on the livelihoods of subsistence farming communities is severe.

As noted earlier, tigers are a charismatic species and tiger tourism plays a significant role in earning revenue from international tourism (Bhattarai 2009; Buckley 2013). In particular, financial opportunities in top-end tourism provide flow on benefits in employment and education for local communities (Baucher 2014). Loss of tigers resulting from HTC may threaten the economy of local communities surrounding the tiger habitat and subsequently Nepal's developing tourism industry and the associated economic benefits that this may bring to the nation.

Critical review of existing strategies for minimizing HTC in Nepal

Various efforts have been deployed to reduce the frequency and severity of HTC incidents and to mitigate the financial costs of HTC in BNP and CNP. These include preventive and mitigative measures which are described in following paragraphs.

PREVENTIVE MEASURES

Four different preventive measures are currently in place in Nepal to prevent human wildlife conflict including that involving tigers. These are: are resettlement of human communities and bans on resource use, removal of problem tigers, use of predation proof night corrals for stock and conservation education. These measures are described briefly below.

I) Resettlement of human communities and bans on resource use

During the establishment of Nepal's parks and reserves in the 1970s, the Government of Nepal relocated human settlements from core areas of the reserves to locations outside of the reserve boundaries (Bhattarai et al. 2017; Smith 1993; Sunkist 1981). This forced relocation occurred at both BNP and CNP, as well as at other locations. Further, voluntary, relocation also occurred in CNP in the 1990s. Park regulations introduced in 1973 (National Parks and Wildlife Conservation Act) and 1976 (National Parks and Wildlife Conservation Regulation) banned the grazing of livestock and harvesting of natural resources from the park (Bhattarai et al. 2017). The dual intention of both resettlement programs and the bans on access to park resources was to reduce the frequency with which humans encountered dangerous wildlife including tigers, while also protecting areas of true wilderness within the nature reserves from anthropogenic disturbances (Sunkist 1981). This policy was successful in re-establishing depleted wildlife populations however, the intended reduction in levels of conflict between humans and wild predators was only partially achieved, largely because more than 300, 000 people (and an approximately equal number of livestock) now live in communities adjacent to the park boundaries. These people remain dependent upon park resources for their livelihoods (Mishra 1982; Thapa and Chapman 2010).

In contrast to the exclusion policy, which operates inside the park boundaries, a co-existence policy which encourages local people to live harmoniously alongside wild animals applies to multiple use areas surrounding the national parks. These areas include areas within buffer zones used for community forestry and agricultural activities; and forested wildlife corridors. Co-existence with tigers is tacitly encouraged (GoN 1999).

Various authors support the use of exclusion policies in tiger conservation. Karanth and Madhusudan (2002) note that spatial coexistence with large carnivores costs human casualties, affects livelihoods when livestock are predated and increases mortality of the wildlife. Therefore, physical separation by transparent policy of volunteer relocation of human settlements would prevent conflict and benefit wildlife too (Karanth and Gopal 2005). Harihar et al. (2014) suggest that resettlement of human communities should be prioritized in areas of high tiger occupancy to reduce conflict and to keep the tiger habitat inviolate. In BNP and CNP, original human settlements were relocated to areas outside of the parks; however the subsequent formation of buffer zones and the restoration of buffer zone forests mean that densely populated human settlements are now adjoined with tiger habitat. Human casualties have increased after the establishment of the buffer zone areas.

Further resettlement programs may not be feasible due to the lack of land required to resettle the very large populations currently located in the buffer zone areas; the extensive financial costs involved; and concern regarding the potential disruption of place-based social and cultural community values and identities (Ghimire and Pimbert 1997; McLean 1999). Predation on livestock and human attack are related with the behaviour of tigers therefore it is believed to be unavoidable (Treves and Karanth 2003). Co-existence strategies are suitable only in low tiger density and low human population (Karanth 2005). Therefore, a coexistence strategy in Nepalese protected areas where both human and tiger densities are high, may not be suitable.

II) Removal of problem tigers

As practiced in other countries, Nepal is moving towards removal of problem tigers to prevent repeated incidents of HTC. It is usual practice for park authorities to distinguish between animals which have killed only once and those which have killed repeatedly when considering the removal of a tiger from a protected area (Gurung et al. 2008; Lamichhane et al. 2017). In general, tiger removal is limited to those animals defined as ‘man eaters’. These are tigers which have: a/ killed humans on multiple occasions inside the park, b/ killed once only, outside the park (e.g. in a field or village) or c/ where injury, old-age or disease impedes the animal’s ability to hunt and kill its natural prey. Tigers which have killed a human on one occasion only inside the park are not usually considered ‘man-eaters’, unless the tiger consumed its victim (Dhungana et al. 2017). Although provisions exist for killing ‘man eater’ tigers in section 10 of the National Parks and Wildlife Conservation Act (NPWCA), 1973¹, there are no clear guidelines regarding the appropriate methods for killing, sedating, relocating or keeping tigers in captivity. Further, the provisions offer no formal advice or guidelines regarding how to choose the most appropriate approaches for any given circumstance (GoN 1973). Therefore, decision-making regarding approaches and actions for management of problem tigers tends to be subjective.

The subjective approach to the management of problem tigers is illustrated by the following description

¹ Section 10 (a) of this act allows for the killing of protected species under certain conditions and by prescribed officers. The conditions allow for the destruction of “*a rogue wild elephant, man-eater tiger and wildlife that suffer from disease or have become disabled and may not survive*” (NPWCA 1973 section 10a). Section 10 (b) of the same act allows for the killing of wildlife “*which come out of the forested area and cause considerable loss to human beings or to domestic birds and animals, they may be killed, captured or chased by order of the prescribed officer*” (NPWCA 1973 section 10b).

of different treatments applied in similar scenarios. In CNP between 1979 and 2006, 19 tigers killed two or more people. Eleven of these 19 tigers were killed or sent to zoos by authorities. No action was taken for the other eight problem tigers. Since 2007 a different approach has been applied in CNP. For three tigers which had no history of attacking humans, but which were considered to pose a threat because of their observed proximity to village locales, two were captured and re-released into core park area. A third and fourth tiger, where the latter had killed livestock, were caught and placed in an enclosure within the park. No action was taken by the authorities against several other tigers which killed humans during the same period (Lamichhane et al. 2017).

Sending the animals to a zoo or keeping them confined in enclosures within the National Parks are alternative options provided that animal welfare conditions are appropriate. Given the resources required to meet such expectations, the capacity for this type of approach is quickly exhausted in developing countries such as Nepal. Relocation of problem animals to other areas also raises concerns since such transfers can be perceived as simply relocating the problem from one place to another (Fonturbel and Simonetti 2011). Experts also argue that relocation of problem individuals may create competition with resident tigers (Smith 1993; Treves and Karanth 2003), or other predators (Harihar et al. 2011; Odden et al. 2010). The behavioural response of either the original resident animal, or of the new arrival, may be to seek new territory in fringe habitats; so increasing the probability of further conflict with humans (Smith 1993). Another concern associated with tiger relocation is that, while establishing a territory, newly translocated tigers may kill the cubs of resident tigers (Barlow et al. 2009). This is clearly an adverse conservation outcome; and has been documented elsewhere (Smith 1993). In Nepal, the history of problem tiger relocation has been mixed. Of four relocated animals, two were relocated to BNP from CNP (350 km away). One of these was poisoned by poacher(s) after three months and one lost satellite signal after two weeks and is assumed to have also been killed. The two remaining problem tigers were relocated within CNP. They survived well inside core habitat without evidence of further HTC (Lamichhane et al. 2017). Similar outcomes are reported by Goodrich and Miquelle (2005) for tigers in Far East Russia; of four translocated problem tigers, two were considered successful and survived in their new locations without further conflict with humans.

Responding to an incident of HTC is a complex task for authorities. Where there are human casualties, immediate capture and translocation, including euthanizing the tiger or sending the animal to a zoo is often considered necessary. Capturing a live tiger demands skilled personnel, equipment and resources (Goodrich et al. 2011), and therefore a well-trained and fully equipped rapid response team is normally required. Identifying

the individual tiger involved in killing humans or livestock, then locating and capturing the animal responsible for the damage (alive), can take several days (Goodrich et al. 2011; Karanth and Gopal 2005) at a time when people in the affected community are deeply distressed. Many biologists recommend regular monitoring of problem tigers and the provision of real-time information to local residents about where the animals are located (Barlow et al. 2013; Bhattarai and Fischer 2014; Dhungana et al. 2017; Gurung et al. 2008). Such information enables local people to avoid animals which are perceived to present a risk. However, such monitoring is costly, (Karanth and Gopal 2005) requiring expensive equipment and technology and ongoing access to significant expertise to identify, locate and sedate the animal, then to fit a satellite collar and collect, interpret and communicate location data to community members. According to Lamichhane et al. (2017), in 2009, 2010 and 2013, a total of 131 individual tigers were captured by camera trap; out of these 131 individuals, 15 tigers were involved in conflict (livestock and human attack and threats to humans). It is likely that increasing tiger populations will eventually saturate or exceed the carrying capacity of the habitat and lead to greater numbers of problem tigers (Karanth and Gopal 2005).

III) Provision of predator proof night corrals to protect stock

The night corrals traditionally used to house livestock in the buffer zone communities surrounding BNP and CNP are not safe against wild predators. Together with national and international conservation agencies and organisations, Nepalese authorities are supporting local communities to build predator proof night corrals for smaller domestic animals such as goats, sheep and pigs. Such corrals for large cattle and buffaloes have not been made. However the efficacy of such corrals are yet to be examined.

IV) Conservation education

Since the early 1990s, conservation education programs, awareness activities and stakeholder meetings focused on the ecology and behaviour of species involved in human-wildlife conflict, including tigers, have been held. Participants have included livestock herders, farmers and nature guides living and working adjacent to Nepal's tiger reserves. It is believed that conservation education can prevent HTC (Bhattarai and Fischer 2014; Mukhacheva et al. 2015) however, the effectiveness in Nepal has not been tested yet.

MITIGATIVE MEASURES

Despite the implementation of four preventive measures described above, HTC still occurs. The policy of coexistence inevitably causes some level of conflicting events and the communities surrounding the tiger habitat

suffer. To overcome this, Nepal has implemented some mitigative measures. Two important measures are discussed in the following paragraphs.

I) Participatory community development programme

In 1996, the fourth amendment of Nepal's National Parks and Wildlife Conservation Act 1973 introduced provisions to allocate up to 50% of revenue earned by the parks and reserves to support development activities in communities living within specified buffer zones. In the fiscal year 2014/2015 BNP and CNP together allocated ~ US\$1,345,000 for community development activities according to provisions made in the Act. The main source of this revenue is via the park entrance fees paid by international visitors (DNPWC 2016). Various community development activities such as school maintenance, rural road improvement, irrigation, grassland management etc. were conducted (Bhattarai et al. 2017). Importantly, involvement of local communities in the planning stages of the buffer zone development program has created a sense of ownership among local people (Paudel et al. 2007). The primary aim of these community development projects is to change mindsets and values so that local people value the role that tigers and other wildlife play in the generation of better living conditions. Outcomes have included increased tolerance to damage caused by wildlife, since communities are more resilient and better able to absorb the economic losses associated with HTC. Such programs have resulted in reduced levels of retaliatory actions following human wildlife conflict events (Acharya et al. 2016). Additional benefits also include, improved livelihoods and further reductions in local people's reliance on forest resources (Budhathoki 2004).

A clear and visible link between park revenue and improved living conditions and livelihoods has assisted in developing mutually supportive relationships between park authorities and local people. The tangible financial benefits of wildlife conservation, in the form of the tourist dollar, are now becoming apparent and more accessible to local community members as they engage in visitor services. The community-led buffer zone programme itself has brought about a positive attitude towards conservation among local community members (Bhattarai et al. 2017). Communities benefit from these programs through additional income derived from the conservation of wild animals. Such schemes encourage locals to view wildlife as valuable community assets.

II) Compensation payments

Financial compensation for damage caused by wildlife was formally initiated in Nepal in 2009 after promulgation of the 'Wildlife Damage Guideline' by the Ministry of Forests and Soil Conservation. According to this guideline, compensation can be claimed against various damages including loss of livestock and human

injuries or death as a result of tiger attack. Assistance provided to poachers and revenge killing of wildlife were both reduced after the formal compensation scheme began in Nepal (Acharya et al. 2016). Compensation payments can reduce the economic effects of HTC for local people. Prior to the introduction of compensation schemes, local people sometimes supported commercial poachers in order to achieve the removal of animals that they perceived as problematic, while also receiving financial benefits in the form of payments from poachers in return for the provision of assistance, information or a 'blind eye' (Johnson et al. 2006). During the late 1980s, at least 12 tigers were poisoned by poachers in CNP. Local people were involved in poaching activities, including selling their buffaloes to poachers, who baited the carcasses in order to kill tigers and then sell body parts (Martin 1992). The local peoples' support of poachers may have been encouraged by the losses that they were sustaining with little or no compensation (Harihar et al. 2014). Their willing assistance provided perceived benefits in the form of reduced risk of livestock losses (Martin 1992).

Compensation for damage caused by wildlife is a strategy widely used to manage human wildlife conflict. It has been effective in restoring carnivore populations such as wolves in North America (Fisher, 2003). There are, however, some drawbacks associated with financial compensation. Firstly, sufficient funds may not be available from government or other sources to adequately compensate people (Ogra and Badola 2008). Secondly, as HTC events are relatively frequent, the administration of a compensation scheme is costly (collecting the required documents and evidence, verifying and assessing losses, contacting involved parties and so on). During a five year period between 2010 and 2014 inclusive, authorities at Chitwan National Park distributed US\$94,000 in compensation for livestock losses and human casualties associated with HTC (Dhungana et al. 2016). The administrative costs associated with these payments are not reported but are likely to have been substantial. As a third drawback, people may exaggerate losses in order to attract higher compensation payments (Goodrich 2010). Rigorous administration and documentation is therefore required. Fourthly, in the knowledge that losses will be compensated, people may reduce or abandon efforts to guard their livestock while grazing or neglect to make strong predator-proof corrals (Nyhus et al. 2005). Finally, with regard to compensation for human casualties, placing a monetary value on human lives raises moral questions (Nyhus et al. 2003).

The practice of compensation according to the current official guidelines of Nepal has attracted criticisms from several authors. Dhungana et al. (2016) claim that victims do not receive compensation equivalent to their loss. The process of applying for compensation is described by Acharya et al. (2016) and

Bhattarai and Fischer (2014). Wildlife victims are required to collect several documents from several institutions and the release of funds to the claimant may take as long as six months. In fact, Dhungana et al. (2016) remarked that it may take up to a year for claimants to receive compensation payments. In addition, compensation budgets are released and managed by each Regional Forest Directorate, rather than by a local protected area office. This approach entails high transaction costs, long processing times and difficulties for victims in accessing the scheme (Bhattarai 2009).

Nepal has implemented an integrated approach to the management of human-tiger conflict. Initially, while wildlife reserves were being established, the resettlement of human communities to areas outside of the parks and reserves, and the banning resource of collection within park boundaries, served both to protect core areas and to reduce HTC. However, after the establishment of buffer zone areas, and the successful restoration of forest ecosystems within the buffer zones, levels of HTC increased. To manage this, a coexistence approach in buffer zones and other multiple use areas was promulgated. Measures intended to mitigate the effects of HTC, such as compensation payments and community development activities, have been effective in increasing tolerance to damage caused by tigers and other wildlife. However, proactive conservation efforts to double the tiger numbers may escalate the HTC events in future. This may pose threats to the coexistence approach.

Recommendations for further reduction in HTC in Nepal

Despite the positive steps made to date, there is much work remaining in order to resolve HTC. Few studies which document the loss of stock due to tigers have examined the potential for confusion between animals killed by leopards and those killed by tigers. Real-time documentation of HTC events which clearly identify predators at the time of, or soon after, an attack is needed. Expert assessment of tracks, scats and other signs at the site of an incident could be used to ascertain which of the two large cats was responsible for the incident, building our understanding of the extent of the HTC problem; and better informing efforts to address conflict between humans and each of the large cat species. Along with strict enforcement of bans on grazing of livestock inside park boundaries, livestock depredation events can be minimized by replacing large numbers of stock of less productive breeds with lower numbers of more productive animals, allowing closer supervision or cost-effective protection (Gurung et al. 2009).

Illegal hunting of tiger prey species (Bhattarai et al. 2016), should be addressed and active management of grassland areas within tiger reserves should be undertaken in order to maximise populations of prey species. For instance, in the eastern part of BNP (Babai valley and the surrounding areas), there is an opportunity to

1 create and maintain a grassland habitat, along with the construction of artificial water holes, to increase the
2 abundance of natural prey species (Bhattarai and Fischer 2014; GoN 2016). In the western section, regular
3 management intervention is necessary to maintain the grassland and prevent invasion by tree species. In CNP
4 Mikenia an exotic invasive climber has extensively covered the grassland posing threats to the prey population
5 (Dhungana et al. 2017) which likely increases livestock predation by predators. Therefore, management of
6 invasive species and maintaining grassland are crucial to minimize HTC.

7 Clear guidelines or recommendations for the consistent management of problem tigers must be established,
8 including the location of a rapid incident response team in all protected areas supporting tiger conservation.
9 Though the concept of rapid response teams is envisioned in the current tiger conservation action plan (GoN
10 2016), these are yet to be established. A failure to take a consistent approach to the management of problem
11 tigers may erode the hard-won support for tigers and tiger conservation among communities adjacent to the
12 major conservation reserves, and so lead to adverse conservation outcomes (Carter et al. 2014). Experiences in
13 the Russian Far East indicated that regular removal of old, diseased and wounded tigers could reduce the
14 frequency of conflict events (Goodrich et al. 2011). Pre-emptive removal could be considered for Nepal's tiger
15 zones. Such an approach however may not be favoured since lethal control, particularly, is often controversial
16 when managing species which are listed as internationally endangered or critically endangered (Goodrich et al.
17 2015); and which are protected by national (GoN 1973) and international laws and treaties (Convention on
18 International Trade in Endangered Species of Wild Fauna and Flora).

19 Further improvements in farming practices can also assist to reduce HTC. On-farm fodder production
20 reduces the dependency of local farmers on park resources thereby minimizing the frequency of encounters
21 between humans and tigers, while also improving living conditions for local people. Such improvements should
22 be continued and promoted on a larger scale.

23 Awareness of the ecology and behaviour of tigers among local community members can help to minimize
24 HTC cases. Such knowledge can inform preventive measures. For example, minimizing peoples' use of forest
25 areas during times when tigers are most active (dawn and dusk) will reduce HTC events (Bhattarai and Fischer
26 2014; Carter et al. 2012; Gurung et al. 2008).

27 Transparent, fair and equitable sharing of benefits from wildlife tourism can help in reducing HTC. Aside
28 from the funds directed towards community development programs, which are derived from park revenue, most
29 of the financial benefits of tiger conservation go to tourism entrepreneurs. These people, often from outside the

1 local region, have established profitable hotels, restaurants or wildlife guiding services all due to the tiger's
2 existence while local farmers bear almost all of the financial losses associated with HTC. This balance needs to
3 be readdressed and more of the revenue earned by the parks should be directed towards resolving human
4 wildlife conflict.

5 The national compensation scheme dictated by the Wildlife Damage Relief Guidelines remains unwieldy.
6 The guidelines require amendment in order to facilitate access to funds for claimants within reasonable
7 timeframes. Local distribution of funds by the relevant protected area authorities, or the local District Forest
8 Office, rather than by the Regional Forest Directorate, would assist in reducing processing times and transaction
9 costs as they are closer to the problem. This approach also requires field verification of the predator responsible
10 (considered above) and calculation or evaluation of the loss based on a standard and consistent scientific
11 approach.

12 Payment for ecosystem services (Bhagabati et al. 2014; Wunder and Wertz-Kanounnikoff 2009) may
13 provide an alternative or additional approach to compensation. For example, tourism entrepreneurs who benefit
14 from the presence of iconic wildlife species in the reserve areas could pay a levy towards a local relief fund
15 designed to pay for human-wildlife conflict mitigation (including financial compensation for farmers who lose
16 stock and to the families of victims killed or injured by wildlife). Likewise, community forests in buffer zones
17 yield income from the sale of forest products to the users. Community forest user groups could therefore
18 contribute some of their derived income to a local relief fund.

19 Finally, local governments are not currently involved effectively in HTC prevention and mitigation. Co-
20 ordinated and collective efforts of all concerned stakeholders, specifically including local governments, are
21 required to effectively minimize HTC (Inskip et al. 2013).

22 Conclusion

23 Continued focus on the reduction and mitigation of HTC events in Nepal and across the other tiger
24 range countries is crucial for ongoing conservation success, especially given the international commitment to
25 double tiger numbers by 2022. Key strategies to reduce HTC and mitigate the costs of HTC events involve the
26 separation (in time or space) of human and tiger activities, including reducing the dependence of human
27 communities on park resources, appropriate and consistent responses to the identification of problem tigers,
28 prompt and suitable compensation for the economic costs of HTC along with equitable sharing of the financial
29 benefits from the conservation based tourism for all local stakeholders. These measures will increase the
30 likelihood of human and tiger coexistence. However, due to efforts to double the tiger numbers to fulfil the
31 international commitment it is likely that the increased tiger numbers may increase the HTC events in future and
32 the current coexistence policy may be counterproductive.

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Acknowledgements

This review paper forms part of the literature review for BB’s PhD project which is jointly funded by Federation University Australia, the Rufford Foundation and the Zoological Society of London’s Nepal program.

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Figure 2 Human deaths caused by tigers in and around Chitwan (CNP) and Bardia National Parks (BNP), Nepal, as reported in the literature. Data are separated by location of the incidents: within the national park and in the surrounding buffer zone

Sources: (1) = Gurung et al. 2008; (2) = Dhungana et al. 2017; (3) = Bhattarai, 2009

Table 1 Fates of problem tigers identified in Chitwan and Bardia National Park

Park	Time period	Estimated number of tigers in the park*	Census year*	Number of problem tigers identified	Number of problem tigers killed by authorities	Number of problem tigers killed by local people	Number of tigers placed in captivity	Total number of tigers removed from wild populations	Number of tigers relocated within a National Park	Number of problem tigers against which no action taken
Chitwan National Park	1979-2006 ¹	91	2005	36	9	1	5	15	2	18
Chitwan National Park	2007-2016 ²	121	2013	22	1	4	8	13	4	5
Bardia National Park	1989-2009 ³	18	2009	6	1	4	1	6	0	0
Total		N/A		64	11	9	14	34	6	23

Sources: ¹= Gurung et al., 2008, ² = Lamichhane et al., 2017, ³ = Bhattarai & Fischer, 2014

*Source: GoN 2016a