European Journal of Wildlife Research (2019) 65:34
https://doi.org/10.1007/s10344-019-1270-x

REVIEW

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

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Received: 2 April 2018 / Revised: 16 March 2019 / Accepted: 22 March 2019

Abstract

Successful conservation outcomes for the tiger (*Panthera tigris*) 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 key 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 since 1979, 34 tigers from these Parks have been killed due to HTC. HTC presents major threats to local people and to the continuing success of tiger conservation programmes. 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 programmes focussed on changing livestock husbandry practises, 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 developments and refinements are 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 This paper provides a synthesis of published and unpublished reports of HTC, in order to demonstrate the magnitude of the problem faced in Nepal.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 practises 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.

Keywords Human-tiger conflict · Predators · Compensation · Prey · Problem-wildlife · Human attack

Background

Human-tiger conflict (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). Historical conflict with humans has resulted in local and regional extirpations of tigers, e.g. from the islands of Java and Bali in Indonesia and from the Caspian and Aral Sea regions (Nowell and Jackson 1996). Recent work by Wilting et al. (2015) recommended revision of the taxonomy of tiger subspecies, suggesting that only two subspecies should be recognised: these are *Panthera tigris sondaica* (critically endangered), which occurs on the island of Sumatra, and *Panthera tigris tigris*, Bengal Tiger (endangered) whose range includes Nepal (Goodrich et al. 2015; Wilting et al. 2015).

Tiger range countries, including Nepal, are characterised by dense human populations and a high dependence of people on local forest resources (Dinerstein et al. 2007). In Nepal, livestock are grazed in forests; and fodder, firewood and various herbs are gathered from the forest to 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;

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Published online: 09 April 2019

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).

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, result in more frequent contact between tigers, humans and livestock as the big cats search for food and home ranges including in buffer zone areas (Karanth and Gopal 2005; Woodroffe and Ginsberg 1998). In 2010, as part of The Global Tiger Recovery Plan (Wikramanayake et al. 2011), a target to double the world's tiger numbers by 2022 was endorsed in the St. Petersburg Declaration on Tiger Conservation. Several populations of Bengal tiger (*P. t. tigris*) are located in Nepal, mostly within key national parks. Doubling the Nepalese tiger population equates to an aspirational target of 250 breeding tigers by 2022. Since the target was set in 2010, a 94% increase has already been achieved (DNPWC and DFSC 2019). Continued increases in tiger numbers are likely to increase pressure on park resources and will affect human populations living in buffer zone areas surrounding the reserves (Aryal et al. 2015b; Thapa et al. 2016). These communities depend on natural resources both within the parks and in buffer zone areas (Bhattarai et al. 2017; Thapa and Chapman 2010).

Buffer zone areas associated with Bardia and Chitwan National Parks support dense human populations (Fig. 1). These areas include community forests, which are used extensively by both tigers and humans. Tigers sometimes kill livestock and attack humans (Karanth and Gopal 2005; Nyhus and Tilson 2010; Smith et al. 2010). In response, tigers may be killed, either by park management authorities or by angry victims or their families (Gurung et al. 2008; Lamichhane et al. 2017). Increasing incidents of livestock loss and attacks on humans can also result in negative attitudes towards tigers and tiger conservation among local communities. Such attitudes, together with revenge killings, can seriously undermine conservation efforts (Aryal et al. 2015a; Carter et al. 2014; Singh et al. 2015).

This review considers the characteristics and consequences of HTC, with a particular focus on Nepal. Current HTC countermeasures are identified. The efficacy of these measures is then considered and discussed, with recommendations for further evaluation and assessment through dedicated research.

Summary of documented incidents of HTC in Nepal

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

Human casualties

Evidence of human casualties due to tigers is found at both CNP and BNP, with fewer incidents 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).

Predation of humans by tigers is not a new phenomenon (Nyhus and Tilson 2010); however, 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 are thought to 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 44 people were killed by tiger attacks in the period 1979–2006, who were collecting grass to feed cattle, buffaloes and goats. Similar results were found elsewhere. In the Sunderban Tiger Reserve (which extends across the border of Bangladesh and India), humans are sometimes 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 Ranthambore 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 (e.g. wounded, with broken teeth or 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.

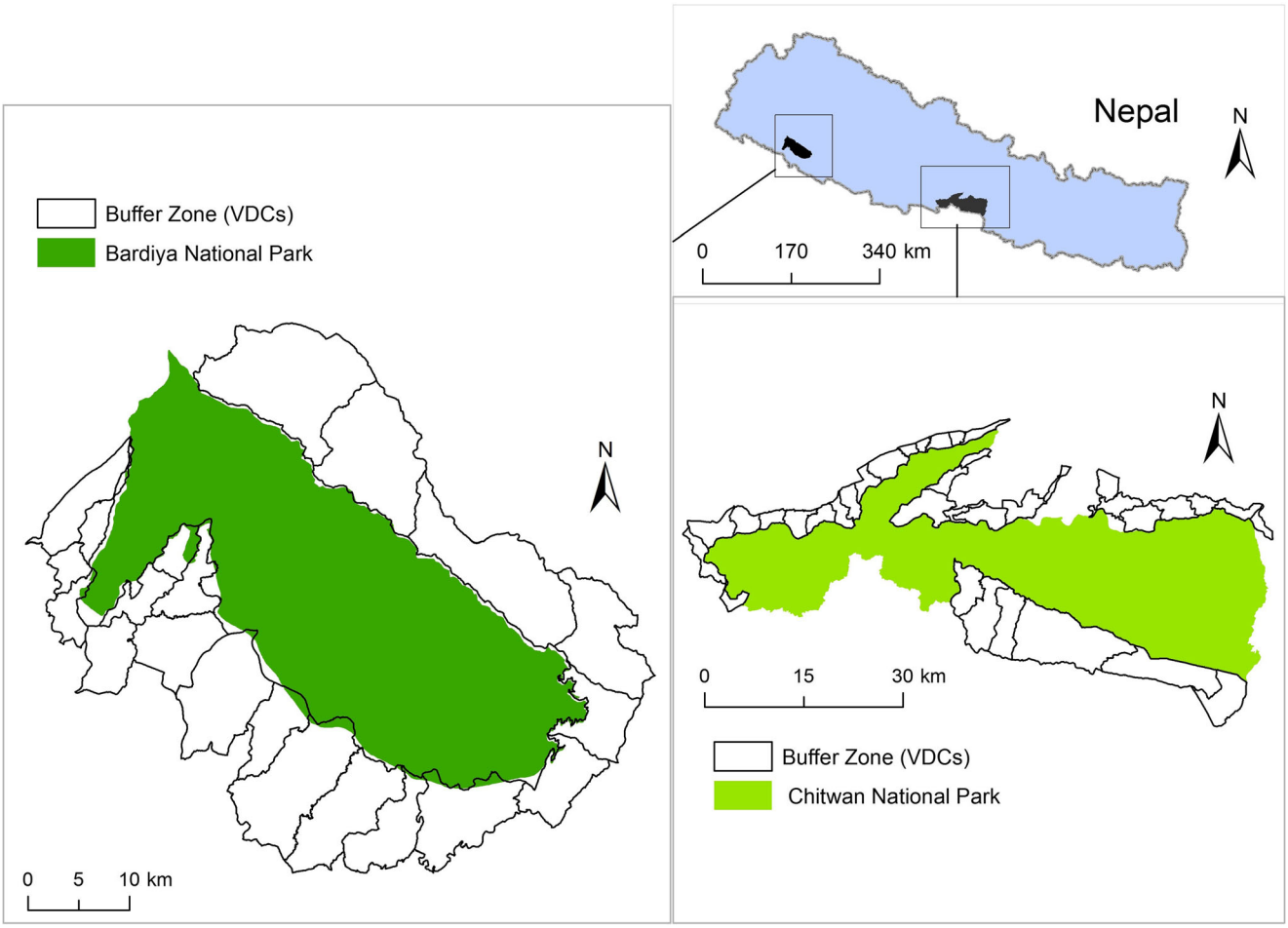

Fig. 1 Location of Bardia and Chitwan National Parks and their surrounding buffer zones

2008). This suggestion is certainly supported by the available data. Gurung et al. (2008) documented that nearly 60% of 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).

Overall, available data reporting human fatalities lists 110 tiger-related deaths for CNP (1979–2014) and 12 for BNP (1994–2007), both inside the park and within adjacent buffer zones. Following the calculation method recommended by Pezzullo (2009), the annual rate of deaths was statistically higher for CNP (mean, 3.1; 95% CI, 2.5–3.7) compared with BNP (mean, 0.9; 95% CI, 0.4–1.5). No statistical difference for annual rates of deaths occurring within buffer zones compared with inside parks was found for either CNP or BNP (Fig. 2).

In Nepal, tigers may frequently encounter humans 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 buffer zones and the restoration of buffer zone forests (1998–2006) (Gurung et al. 2008). A later study by Dhungana et al. (2017) documented four human deaths per year at CNP from 2007 to 2014. In this study, most incidents (75.9%) occurred in the buffer zones (the remaining 24.1% occurred within the park).

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

Higher annual death rates at CNP may be associated with the higher density of both tigers and humans at this location. Although 2018 tiger census data shows that the population of

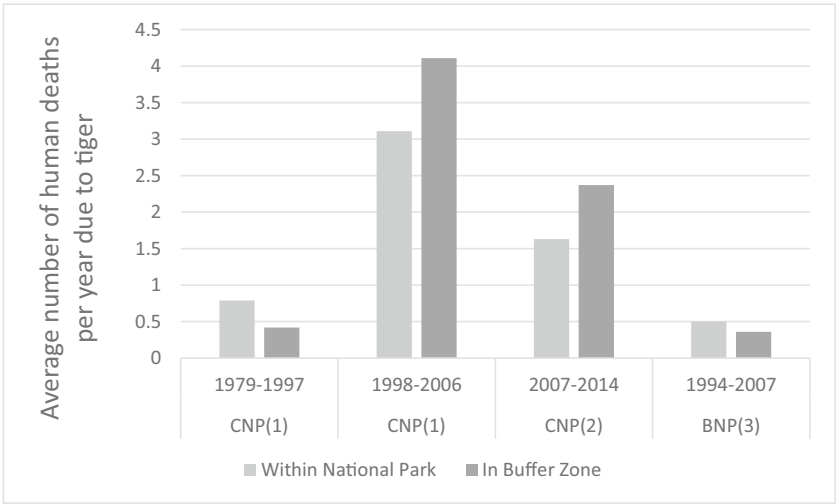

Fig. 2 Human deaths caused by tigers in and around Chitwan (CNP) and Bardia National Parks (BNP), Nepal, as reported in the literature. Data are separated by location of the incidents: within the national park and in the surrounding buffer zone. Sources: (1) = Gurung et al. (2008); (2) = Dhungana et al. (2017); (3) = Bhattarai (2009)

breeding tigers at CNP and BNP is now similar (93 and 87, respectively; DNPWC and DFSC 2019), historically, tiger numbers have been higher in CNP (the 2013 tiger census recorded 120 and 50 tigers, respectively, at CNP and BNP; GoN 2014); and the number of people living in areas surrounding CNP is twice as high as around BNP (DNPWC and DFSC 2019; GoN 2015a, b). There are some indications that the higher number of human deaths due to tigers in CNP is associated with cultural and geopolitical factors. In CNP, *Bote* and *Darai* communities have funeral practises that include burying the dead in shallow graves along the *Narayani* River. Tigers often excavate the corpses (Pers com. Yadav, R. 2017 October). In addition, passenger buses sometimes veer off into the river (in road accidents). The bodies are sometimes carried away by the river current. Tigers have been observed to consume these corpses (Dhungana et al. 2017). These factors may mean that tigers are more familiar with humans as prey and may increase the likelihood of attacks on living people.

Livestock loss

Communities surrounding both CNP and BNP regularly experience the loss of livestock due to predation by tigers and leopards. Unlike attacks on humans, where the predator is often clearly identified, reports of livestock losses do not necessarily distinguish between these two large cats. Reporting is further complicated because, although there are different words for tiger (*Bagh*) and leopard (*Chituwa*) in the Nepali 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 3-year period 2007–2009, 28% of the surveyed householders reported livestock losses due to tigers. These authors documented that in surveyed buffer zone communities, each household lost, on average, 0.25 domestic animals per year due 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 due to predators in a 6-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.

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 stocks are grazed inside tiger habitat areas, or when tigers expand their home ranges 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 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 2017/2018 describe the densities of tiger prey species in BNP and CNP as 77.5 (SE, 6.6) and 70.7 (SE, 7.5) animals per square kilometre, respectively, and the breeding tiger densities in BNP and CNP are 4.74 (SD, 0.28) and 3.28 (SD, 0.19) per 100 km^2, respectively, (DNPWC and DFSC 2019). According to Karanth and Stith (1999), prey density of 25–50 ungulates/km^2 can sustain 66–100 breeding females in 1000 km^2 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 with 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 parks and grazing of livestock on the floodplain (technically legal, since one side of the river is not located inside the park) is common. Limited grazing (in prescribed zones and at prescribed times) is also permitted in some buffer zone forests. Tigers have ready access to river floodplains and to buffer zone areas.

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

Losses of tigers associated with HTC

Park authorities may remove tigers from the breeding population as a result of HTC. 'Problem tigers', once identified, are often killed or placed in captivity. Combined data from studies conducted in 1979–2006 (Gurung et al. 2008) and 2007–2016 (Lamichhane et al. 2017) indicates that 58 animals were deemed to be problem tigers in CNP and the surrounding buffer zone forests. Between 1979 and 2016, 28 of these 58 problem tigers identified in and around CNP were removed from this protected habitat (Table 1).

Although BNP and CNP are comparable in area, until recently, BNP had a smaller tiger population (GoN 2014; Table 1) and fewer incidents of attacks on humans by tigers. Thus, fewer problem tigers have historically been identified at BNP and management interventions are also less frequent. From 1989 to 2009, six tigers were identified as problem tigers in and around BNP. All were either killed or removed from the protected area (Bhattarai 2009). No tigers were removed from BNP between 2010 and 2016 (Pers. com. Dahal, B. February 15, 2017). On the other hand, 28 tigers were removed from CNP in the period between 1979 and 2016. The removal of a total of 34 tigers from the two parks represents a significant cost to conservation (Table 1).

Lethal control of problem tigers has been practised 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 Kerinci Seblat 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 clarify how many of these animals were killed by poachers, park authorities or local people.

Killing problem tigers in order to reduce HTC is a strongly debated management approach. In Nepal, the removal of problem tigers has not reduced the occurrence of conflict incidents (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. 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 individual tigers which have killed and eaten humans. In Nepal, where the dominant religions are Hinduism and Buddhism, the killing of tigers is generally not supported. 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 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).

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 in body parts (Chapron et al. 2008; Dinerstein et al. 2007; Karanth and Stith 1999). Therefore, where lethal control is adopted, the demography of the tiger populations should be considered along with socio-political factors.

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

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 and Fischer (2014)

*Source: GoN (2016)

Critical review of existing strategies for minimising 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.

Preventive measures

Four key preventive measures are currently in place in Nepal to prevent human-wildlife conflict (including HTC). These are described briefly below.

1. 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; Sunquist 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 the resettlement programmes and the bans on access to park resources was to reduce the frequency with which humans encountered dangerous wildlife, including tigers, while also protecting core areas of wilderness from anthropogenic disturbances (Sunquist 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 coexistence policy, which encourages local people to live harmoniously alongside wild animals, applies to multiple-use (buffer zone) areas surrounding the national parks. These include areas used for community forestry and agricultural activities as well as forested wildlife corridors (Aryal et al. 2015b). Coexistence with tigers is tacitly encouraged (GoN 1999; GoN 2016).

Various authors support the use of exclusion policies in tiger conservation. Karanth and Madhusudan (2002) note that spatial coexistence with large carnivores has costs in the form of human casualties and has effects on livelihoods (e.g. when

livestock are predated) and may increase mortality of the wildlife. Therefore, physical separation of human and wildlife populations is promoted by various authors to prevent conflict and benefit wildlife (Karanth and Gopal 2005). Harihar et al. (2014) suggest that resettlement of human communities should be prioritised in areas of high tiger occupancy to reduce conflict and to keep the tiger habitat inviolate. Further resettlement programmes may not be feasible in Nepal 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 the concern regarding the potential disruption of location-based social and cultural community values and identities (Ghimire and Pimbert 1997; McLean 1999). Predation on livestock and attacks on humans are acknowledged as normal behaviour for tigers, and some degree of conflict is considered unavoidable (Treves and Karanth 2003). Coexistence strategies are acknowledged to be suitable only in low tiger density and low human population (Karanth 2005). The coexistence strategy in buffer zone areas surrounding Nepal's key tiger reserves, where both human and tiger densities are high, needs careful monitoring (Aryal et al. 2015b).

2. Removal of problem tigers

As practised in other countries, Nepal is moving towards removal of problem tigers to prevent repeated incidents of HTC. It is usual practise 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 (1) killed humans on multiple occasions inside the park and (2) killed once only, outside the park (e.g. in a field or village) or (3) 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), 1973,[1] 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 descriptions of different treatments applied in similar scenarios. A study by Gurung et al. (2008) noted that 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 (Gurung et al. 2008). 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 the core area of the park. A third and a fourth tiger (the latter had killed livestock) were 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 'problem tigers' to a zoo or keeping them confined in enclosures within the National Parks are alternative options to killing, 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 (e.g. from one national park to another) 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 home range in fringe or marginal habitats, so increasing the probability of further conflict with humans (Smith 1993). Another concern associated with tiger relocation is that, while establishing a home range, newly translocated tigers may kill the cubs of resident tigers (Barlow et al. 2009). This could be seen as an adverse conservation outcome and has been documented elsewhere (Barlow et al. 2009). 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 3 months and the satellite signal from another was lost after 2 weeks; it was 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 conflict (Lamichhane et al. 2017). Similar outcomes are reported by Goodrich and Miquelle (2005) for tigers in the Russian Far East where, of four translocated problem tigers, two survived in their new locations without further conflict with humans.

[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).

Responding to an incident of HTC is a complex task for authorities. Where there are human casualties, immediate capture and translocation, including euthanising the tiger or sending the animal to a zoo, are 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 regarding the location of the animals (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 continuing 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 traps in CNP; out of these 131 individuals, 15 tigers were involved in conflict (livestock and human attacks and threats to humans). It is likely that increasing tiger populations will eventually saturate or exceed the carrying capacity of the habitat, which will lead to greater numbers of problem tigers (Karanth and Gopal 2005).

3. Provision of predator-proof corrals to protect stock

In the buffer zone communities surrounding BNP and CNP, the traditionally constructed night corrals used to house livestock do not prevent attacks by wild predators. Nepalese authorities, working with national and international conservation agencies and organisations, are supporting local communities to build predator-proof night corrals for smaller domestic animals, such as goats, sheep and pigs. However, the efficacy of such corrals has yet to be examined, and corrals for larger animals such as cattle and buffalo have not yet been trialled or implemented.

4. Conservation education

Since the early 1990s, conservation education programmes, 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), but, its effectiveness in Nepal has not yet been tested.

Mitigative measures

Despite the implementation of the preventive measures described above, HTC still occurs. The policy of coexistence inevitably causes some level of conflict, which negatively affects communities surrounding tiger habitat. To overcome this, Nepal has implemented some mitigative measures.

1. 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 park entrance fees paid by international visitors (DNPWC 2016). Various community development activities such as school maintenance, rural road improvement, irrigation, and grassland management were conducted (Bhattarai et al. 2017). Importantly, involvement of local communities in the planning stages of the buffer zone development programme has created a sense of ownership among local people (Paudel et al. 2007). The primary aim of these community development projects is to change mind-sets 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 programmes 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).

The community-led buffer zone programme has engendered positive attitudes towards conservation among local community members (Bhattarai et al. 2017). Communities benefit from these programmes through additional income derived from the conservation of wildlife. Such schemes encourage local people to view wildlife as valuable community assets.

2. Compensation payments

Financial compensation for damage caused by wildlife was formally initiated in Nepal in 2009 after the promulgation of

the 'Wildlife Damage Compensation Guideline' by the Ministry of Forests and Soil Conservation. 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. They also received financial benefits in the form of payments from poachers in return for the provision of assistance, information or turning a 'blind eye' to the poachers' activities (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). Assistance provided to poachers and revenge killing of wildlife have both reduced after the formal compensation scheme began in Nepal (Acharya et al. 2016).

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 (Nyhus et al. 2005). However, there are 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 5-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 (Ogra and Badola 2008). Rigorous administration and documentation are 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 practise of compensation according to current official guidelines in Nepal has attracted criticism 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 6 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).

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, and help increase our understanding of the extent of the HTC problem as well as better inform 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 minimised 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).

Clear guidelines or recommendations for the consistent management of problem tigers must be established, including the location of rapid incident response teams in all protected areas supporting tiger conservation. Though the concept of rapid response teams is envisioned in the current tiger conservation action plan (GoN 2016), these are yet to be established. Failure to take a consistent approach to the management of problem tigers may erode the hard-won support for tigers and tiger conservation among communities adjacent to the major conservation reserves, and so lead to adverse conservation outcomes (Carter et al. 2014). Experiences in the Russian Far East indicated that regular removal of old, diseased and wounded tigers could reduce the frequency of conflict events (Goodrich et al. 2011). Pre-emptive removal could be considered for Nepal's tiger zones.

Further improvements in farming practises can also assist in the reduction of HTC. On-farm fodder production reduces the dependency of local farmers on park resources, thereby minimising the frequency of encounters between humans and tigers, while also improving living conditions for local people.

Such improvements should be continued and promoted on a larger scale.

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

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

Finally, local governments in Nepal are not currently involved effectively in HTC prevention and mitigation. Coordinated and collective efforts of all concerned stakeholders, specifically including local governments, are required (Inskip et al. 2013).

Conclusion

Continued focus on the reduction and mitigation of HTC events in Nepal and across the other tiger range countries is crucial for continuing conservation success, especially given the international commitment to double tiger numbers by 2022. Key strategies to reduce HTC and mitigate the costs of HTC events involve the separation (in time or space) of human and tiger activities, including reducing the dependence of human communities on park resources, appropriate and consistent responses to the identification of problem tigers and prompt and suitable compensation for the economic costs of HTC along with equitable sharing of the financial benefits from the conservation based tourism for all local stakeholders. These measures will increase the likelihood of human and tiger coexistence. However, efforts to double the number of tigers in Nepal's protected areas in order to fulfil international commitments may lead to an increase in HTC events and compromise the goals of the current coexistence policy.

Funding information This review paper forms part of the literature review for BB's Ph.D. project, which is supported by an Australian Government Research Training Programme RTP Fee Offset Scholarship through Federation University, Australia. The Rufford Foundation and the Zoological Society of London's Nepal program have also contributed funding for the study.

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