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Original Research Article

Are conflict-causing tigers different? Another perspective for understanding human-tiger conflict in Chitwan National Park, Nepal

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ABSTRACT

We analyzed characteristics of the problem-causing tigers in Chitwan National Park (Nepal) to determine if specific groups or individuals in the source population have higher probability to get involved in conflicts with humans. From 2007 to 2016 we identified a total of 22 such tigers including 13 that killed humans, six serial livestock killers and three tigers that threatened human safety (with no reported human and livestock casualty). Thirteen of these tigers were controlled or killed and four were relocated. We compared a subset of 15 'problem tigers' involved in conflict between 2009 and 2013 with the Chitwan's tiger population obtained from three different sessions of camera trapping (2009, 2010 and 2013). We found that <5% of this source population (tigers recorded in camera trap) were involved in conflict. We conclude that transient tigers without a territory or physically impaired animals are more likely to be involved in conflict and recommend an early warning system be adopted to anticipate conflicts before they occur. This system should include regular monitoring and timely identification of problem tigers followed by decisive management action to either remove the tiger or encourage local people to modify their behavior to reduce the risk of conflict.
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1. Introduction

Along with legal and institutional protection of endangered species like tigers (*Panthera tigris*), support is needed from local communities living in fringes of protected areas (Inskip et al., 2014). Such support is especially important in locations

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where tigers occurs in small isolated protected areas in human dominated landscape (Wikramanayake et al., 2004). Local tolerance can quickly be compromised if tigers repeatedly threaten humans and their livestock (Goodrich, 2010). To gain local support, managers need to respond quickly and decisively (Barlow et al., 2010). The Terai Arc Landscape (TAL) in Nepal and India is a typical example of the challenges. In recent years, increased tiger population with reduced poaching and forest regeneration in community forests in buffer zones has increased the possibility for human-tiger conflict (Wegge et al., 2016; Chanchani et al., 2014; Gurung et al., 2008). One of the core tiger areas in TAL, the Chitwan National Park (CNP), currently supports >100 tigers (Walston et al., 2010; Karki et al., 2015). The high-quality tiger habitat in CNP serves as a source for tigers dispersing into more marginal habitat adjacent to human (Smith, 1993).

Human-tiger conflict (HTC) is generally expressed in three forms - i) tiger attacks on humans, ii) tiger attacks on livestock and iii) threat to human safety from tigers living in close proximity to human habitation (Goodrich, 2010). Human deaths by tigers in and around CNP have increased six folds from an average annual deaths of 1.2 (1979–1998) to 7.2 (1998–2006) (Gurung et al., 2008). Between 2007 and 2014, an average of 4 persons have been killed and 2.7 injured per annum. In the same period an average of 44 livestock killed per annum (Dhungana et al., 2017). These deaths and conflicts reduce support for tiger conservation (Goodrich, 2010) and in retaliation people kill tigers by poisoning or physical attacks with guns or spears (CNP, 2012). The government has initiated a program to identify and promptly respond to problem individuals; this effort may reduce retaliatory killings.

Studies on human-tiger conflicts have analyzed factors that contributed to human tiger-conflict and also assessed their socio-economic impacts (Dhungana et al., 2017; Silwal et al., 2016; Bhattarai and Fischer, 2014; Gurung et al., 2008). Many factors like season, distance to park boundary, number of livestock and community attitude have been identified as related to the level of conflict (Van Bommel et al., 2007). However, only a few studies have focused on the individual characteristics (e.g. age, sex, physical condition, territorial behavior) of problem causing animals and their management (Barlow et al., 2013). Most previous studies regarded the entire tiger population as conflict causing with the general assumption that when a population increases, conflict also intensifies.

Protected areas in Nepal and India are typically surrounded by buffer zones with marginal habitats and high human density (Spiteri and Nepal, 2008; Gurung et al., 2008). Younger tigers are often pushed out of the core areas of reserves into buffer zones by mature, resident tigers (Smith, 1993; Kolipaka et al., 2017). Older and weaker male tigers are also driven from their territories by dominant males. Both these younger and the older post-reproductive tigers living in marginal habitat are the most likely to come in conflict with humans. However, despite frequent reports of conflict caused by tigers (Gurung et al., 2008; Silwal et al., 2016) from Chitwan NP, Sunquist (2010) described explicitly that by nature tigers are very adaptive and can live very close to people but stay un-noticed in areas with sufficient prey, space and cover. Carter et al. (2012) suggested that, in Chitwan, temporal separation allows humans and tigers to use the same area at a fine spatial scale. These apparent contradictory findings about tiger behavior and their interactions with people have evoked a debate among conservationists about the balance between conflict and coexistence (Karanth et al., 2013; Harihar et al., 2013). In a study that focused on livestock killing, Linnell et al. (1999) suggested that a specific subset of animals were responsible for most of the human-carnivore conflict and they proposed intensive monitoring of movement and predatory behavior to identify these animals.

Our study examined human-tiger conflict in greater depth and tested the hypothesis that conflict causing tigers differ in individual characteristics (age, sex, territorial behavior and physical condition) from the other tigers in the population. We anticipate that not all individuals in a tiger population are equally involved in conflict. Instead we suggest most conflict results from the behavior of specific group of animals which are pushed out of the core areas and adopt the human or livestock killing activities (Linnell et al., 1999). We used camera trap data to compare problem tigers to the general tiger population of Chitwan.

2. Methods

2.1. Study area

Chitwan National Park (27°16.56′- 27°42.14′N and 83°50.23′ - 84°46.25′E; area 953 km^2), designated in 1973 as the first national park of Nepal, has a monsoon dominated sub-tropical climate with an average monthly maximum temperature between 24 °C and 38 °C, monthly minimum temperature between 11 °C and 26 °C, annual rainfall ~ 2250 mm and relative humidity 89–98% (2000–2010). It is a World Heritage Site (UNESCO, 2016) with a unique assemblage of rare and threatened fauna which include approximately 70 mammal species, over 600 bird species, 56 species of reptiles and amphibians, 156 species of butterflies and 120 species of fish (CNP, 2017). Chitwan is a priority tiger conservation area with a population of >100 tigers (Dhakal et al., 2014). CNP also supports the world's second largest population of the greater one-horned rhinoceros (DNPWC, 2015; Subedi et al., 2013).

Situated in the south central lowlands in the inner Terai (Fig. 1), the park is dominated by forest (80%) including sal forest, riverine forest and mixed hardwood forest. In addition, there are grasslands (12%), exposed surface (5%) and water bodies (3%) (Thapa, 2011). The park is drained by three major rivers systems, i.e., Narayani, Rapti and Reu rivers. The Narayani River marks the western boundary, the Rapti River marks the northern boundary, Reu River and the international border with India along the Valmiki Tiger Reserve marks the southern boundary for CNP (Fig. 1). Parsa National Park is contagious with the boundary of CNP. A corridor forest, Barandabhar, connects park with the northern hill forest (Fig. 1).

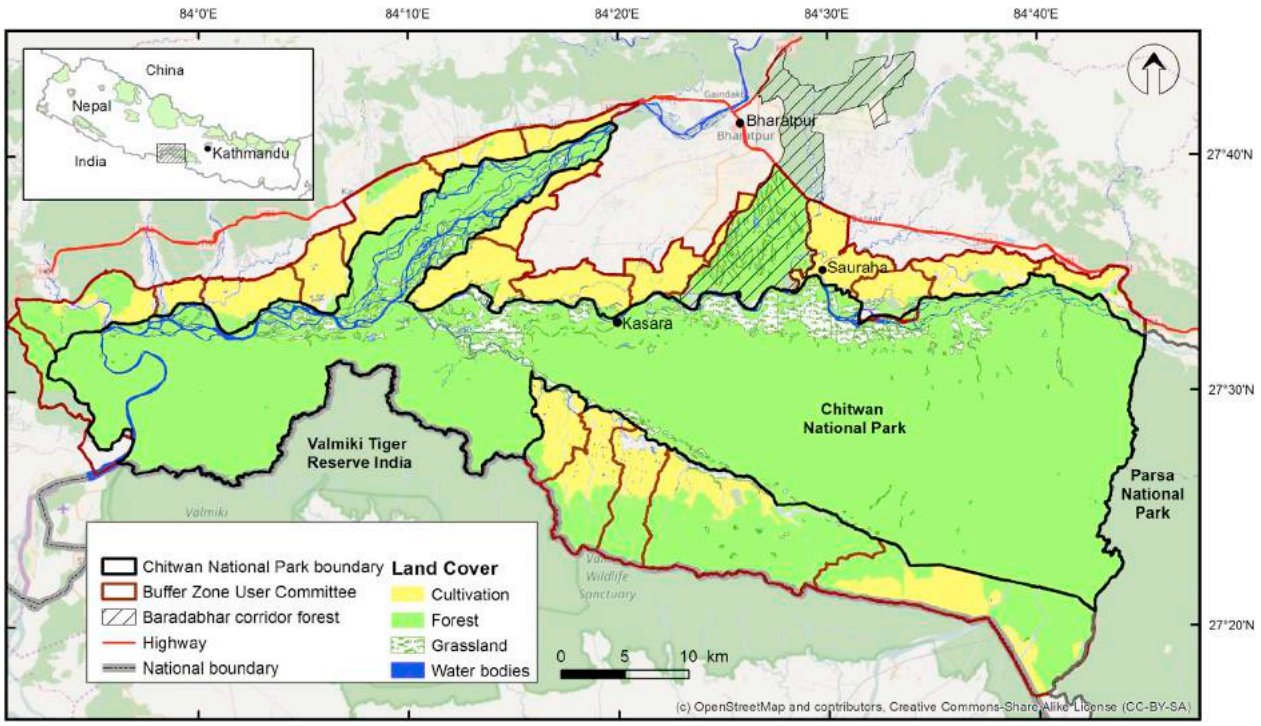

Fig. 1. Study area: Chitwan National Park, buffer zone area and adjoining forest areas.

An additional 750 km^2 buffer zone (BZ) surrounding CNP was created in 1996 (21 km^2 of BZ was later included into the core area in 2016). More than half (55%) of the BZ is useable wildlife habitat including forests, grasslands, shrub land, river and water bodies; the rest is agriculture and settlements (Karki et al., 2015). The BZ includes >45,000 in 12 municipalities from four districts (Chitwan, Makawanpur, Nawalparasi and Parsa) (CBS, 2012). Historically, only few settlements of the indigenous Tharu, Bote and Darai communities surrounded the Park. However, many people from the hilly area migrated into the Chitwan Valley after malaria eradication in mid 1950s. Now the community is a mix of indigenous people and immigrants from hills (e.g. Brahmin, Chhetries, Tamang, Gurung, and Magar) (CBS, 2012). A majority of people rely on subsistence agriculture but dependence on agriculture is decreasing as the younger generation prefers off–farm activities like tourism (nature-guides and work in hotels), service and foreign employment. Livestock keeping is an integral part of subsistence agriculture, and grazing was common in the buffer zone until the last decade. In recent years there has been a gradual shift towards stall feeding with grazing restrictions, adoption of improved livestock and shortage of labor (Gurung et al., 2009). Adjoining forests outside of the buffer zone (National forest and community forests) is administered by the District Forest Offices.

2.2. Problem tigers in Chitwan

Records of problem tigers (e.g. rescued, euthanized, poisoned, shot) in the period between 2007 and 2016 were compiled from the headquarter and veterinary section of the CNP office, the National Trust for Nature Conservation (NTNC) and the personal records of the first author who has been involved in fieldwork in CNP since 2009. Based on the type of problems caused, these tigers were categorized into four categories i) accidental human-killer - killed but did not eat one human, ii) Repeated human-eater - killed and ate one to several humans (Gurung et al., 2008), iii) serial livestock killer - involved in >3 livestock killing incidents within a month from the same locality in the buffer zone and iv) safety threat (no attack or livestock kill but threatened people by entering into a village). In our dataset we have not included the opportunistic livestock killers (involved in <3 livestock killing incidents within a month) as we lack the identity of such tigers. We set cut-off of 3 livestock kills per month based on the dietary requirement of the tiger. If a tiger primarily depends on livestock for its diet, it would kill at least three livestock in a month.

Each case of a problem tiger was verified with wildlife technicians of NTNC and veterinary officers of CNP who participated during rescue or control activities. Detailed records including date, GPS location, age, sex, physical condition and photographs of the captured/killed tigers were maintained. Age and sex of the tigers which were not controlled were identified through unique track characteristics or measurement and camera trap pictures. Controlled problem tigers were

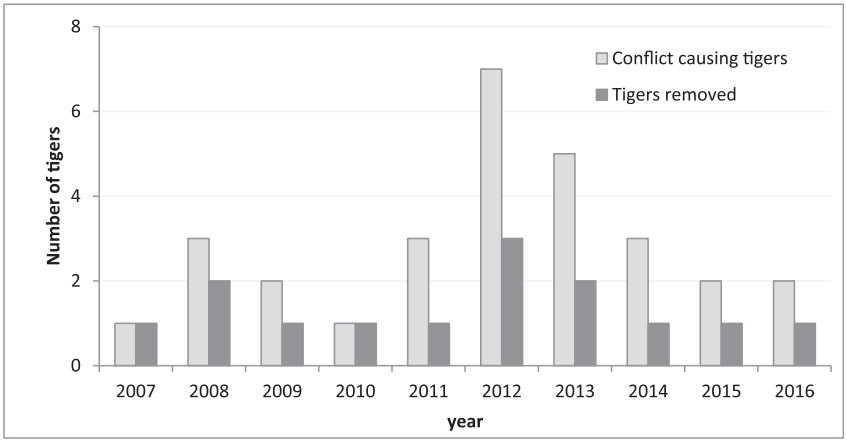

Fig. 2. Number of problem tigers recorded and controlled in Chitwan National Park and surrounding forest areas.

classified as adults (>3 years), sub-adults (2–3 years) and cubs (<2 years) based on their size, weight or dentition at the time of capture.

2.3. Spatial and temporal distribution of problem tigers

The unique stripe pattern of tigers enabled us to trace the history of problem tigers by comparing their photos with previous camera trap images. The first comprehensive camera trapping in the lowland of Chitwan was done in 2008/09 (Karki et al., 2009). The entire national park (lowland as well as Churia hills) was covered in successive camera trapping efforts in 2010 (Karki et al., 2015) and 2013 (Dhakal et al., 2014). Photographs of problem tigers obtained during their capture between 2009 and 2013 were thus compared with the photo library of Chitwan's tiger population. Additionally, we also compared problem tiger photos with a tigers of Parsa National Park and Valmiki Tiger Reserve, India (Chanchani et al., 2014; Maurya and

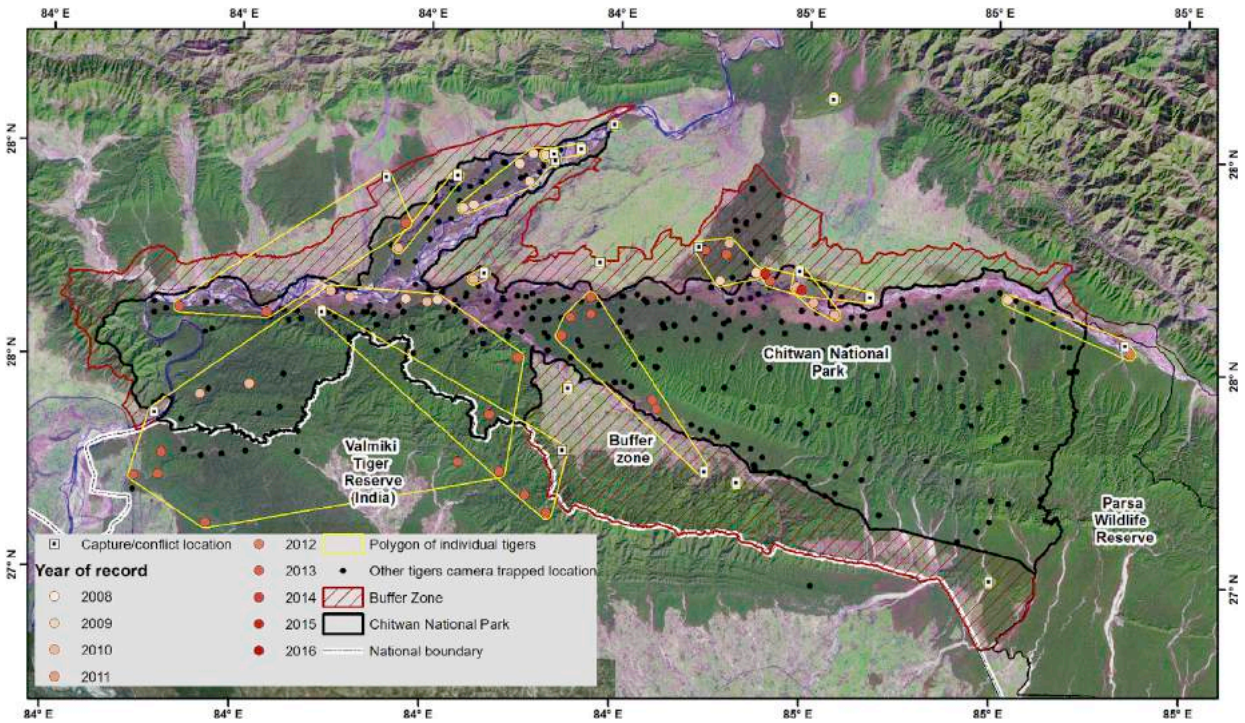

Fig. 3. Problem tigers camera trapped, rescued or killed location in Chitwan National Park and surrounding areas during 2008–2016. The white square with black point inside represents locations where problem tigers caused conflict or captured, colored dots represent the camera trapped location of problem tiger in different years and black dots represent the camera trap locations of other tigers (source population) in 2013. The polygons represents the locations of problem tigers based on camera trap captured & tiger rescued locations.

Table 1
Number of tiger individuals captured in camera trap (M_{t+1}) during the 2009, 2010 and 2013 surveys in Chitwan National Park, Nepal.

Year	Adult	Sub-adult	Cub	Unknown	Total
2009	36	8	5	–	49
2010	53	3	6	–	62
2011	27	4	1	–	32[a]
2012	30	3		1	34[a]
2013	55	5	7	1	68
Total	**201**	**23**	**19**	**2**	**245**

[a] Derived based on common individuals captured in 2010 and 2013.

Borah, 2013). Camera trap location and date were recorded for each problem tiger. Camera trapped and conflict locations of the tigers are presented as points and polygons in a map (Fig. 3).

2.4. Data analysis - comparison of problem animals and source population

Tiger individuals identified from camera trap surveys during three different sessions 2009, 2010 and 2013 in CNP were used to represent the Chitwan tiger population (generally known as the minimum tiger population or 'Mt + 1'). Wegge et al. (2004) showed that >80% of the tigers present in the area are captured during a 15-day survey consisting of a systematic camera trap grid of 2 × 2 sq km. All the three camera trapping sessions followed this as recommended by the Tiger Monitoring Protocol of Nepal (DNPWC, 2009). We assumed that the problem tigers recorded between 2009 and 2013 in Chitwan Valley (including the core area, buffer zone and surrounding forest areas) originated from the CNP population. We identified individuals analyzing unique stripe pattern, estimated their age and sex in most cases based on camera trap photos. A multi-annual dataset of the tiger population was compiled for 2009–2013 and (Table 1). A tiger captured in camera trap in a year was regarded as one observation. This dataset was used as a measure for the Chitwan tiger population. We coded '0' - non problematic' and '1' - problematic for the tiger in a particular year based on conflict records.

We used a binomial logistic regression by constructing a Generalized Liner Mixed Model (GLMM) (Zuur et al., 2009) to test the hypothesis that conflict causing tigers have different characteristics than those in the source population. In the GLMM, conflict-causing tiger between 2009 and 2013 was used as dependent variable. Four independent variables i.e. age, sex, physical condition, territorial behavior and their interaction (age* territory and territory* fitness) were used to examine their contribution to tiger becoming a problem causing individual. Year was treated as random variable as some tigers were active in multiple years. Analysis was done in R (R Core Team, 2016).

Age (cub, sub-adult, adult or unknown) and sex (male, female or unknown) of the tigers in the population were identified from camera trap photos. Males have visible testes which allowed us to identify the sex. We categorized the age of animals based on their size and body configuration and also comparing changes from photos obtained in previous years. Tigers of uncertain age were categorized as 'unknown'. Physical condition was categorized as impaired (1) or healthy (0) based on veterinary examination of captured/rescued problem tigers or from examining camera trap photos for signs of injury, limping or other abnormalities. The impaired category is defined as the severe injury or illness which threatens a tiger's survival and was visible in the camera trap photo. Tigers were categorized into three territorial behavior categories: 1) Resident: Tigers captured in multiple years from nearby (periphery of 20 km of previous CT capture) location, or female tigers with cubs, or tigers frequently re-captured (at least three times) in adjacent locations (20 km) in a single camera trap session; 2) Transient: Tigers captured from different locations (>20 km from the periphery of previous CT capture) during different camera trap sessions or sub-adult tigers captured in different locations from the natal territory or sub-adult tigers with linear movement over time; 3) Unknown: Tigers captured only in a single year with fewer than three recaptures for which we are not sure about their territorial behavior.

Table 2
Type of conflict caused by the tigers and management action taken in Chitwan National Park, Nepal and surrounding areas during 2007–2016.

Action taken	Type of problem tiger				Total
	Attacks to human (accidental)	human-eater	Safety threat	Serial livestock killer	
Killed by authority	–	1	–	–	1
Killed by villagers	–	1	–	3	4
Put in enclosure or zoo	2	4	1	1	8
Released in wild	–	–	2	2	4
No Action[a]	4	1	–	–	5
Total	**3**	**7**	**3**	**6**	**22**

[a] These tiger might have captured or killed in different locations or in different years as we lack their detail identity.

Table 3
Age and sex composition of problem causing tigers recorded from Chitwan National Park and surrounding forests during 2007–2016.

Sex	Adult	Sub-adult	Unknown	Total
Female	4	1	1	6
Male	5	8	1	14
Unidentified	–	–	2	2
Total	**9**	**9**	**4**	**22**

Table 4
The land use type where problem tigers occurred in Chitwan National Park, buffer zone and national forest between 2007 and 2016. The buffer zone is a designated zone surrounding the national park (~5 km); all forest lands outside the buffer zone are labelled here as national forests.

Location	Habitat		Total
	Forest or grassland	Agriculture or settlements	
National Park	2	–	2
Buffer Zone	8	9	17
National Forest	3	–	3
Total	**13**	**9**	**22**

3. Results

3.1. Problem tigers and their management

Between 2007 and 2016 a total of 22 problem tigers were recorded in Chitwan NP and surrounding areas including 13 that killed humans (including six human-eaters), six serial livestock killers and three tigers that threatened the human safety (no actual attack or loss) (Table 2). Thirteen out of 22 identified as conflict-causing tigers were removed from their habitat (killed or put in captivity) and four were relocated (released at different location). Annually, an average of 2.8 (SD = 1.9, range 1–7) tigers were involved in conflict and 1.4 (SD = 0.7, range 1–3) tigers were removed from Chitwan NP or surrounding forests (Fig. 2). Some problem tigers were poisoned (n = 3) or killed in defense using spear (n = 1) by villagers. Only one of the conflict causing tiger (human-eater) was killed by army (park authority) in 2007. Since, 2007 such tigers were captured and

Table 5
Tigers of Chitwan National Park and surrounding forests, involved in conflict with humans during 2007–2016. The symbols in the table represents, '1' = involved in conflict, '0' = tiger present but not involved in conflict, 'C' = tiger in captivity, '-' = Status unknown, and 'x' = dead.

SN	Tiger ID	Conflict type	Years (2007–2016)										Remarks
			07	08	09	10	11	12	13	14	15	16	
1	Jagatpur SA (F)	Attacked human	–	–	–	–	–	–	–	–	0	1	Died in enclosure at CNP (2015)
2	Kumroj (M)	Killed human	–	–	–	–	–	–	0	0	1	x	Died in enclosure at CNP (2015)
3	Triveni (M)	Killed human	–	–	–	0	0	0	0	1	x	x	Died in enclosure
4	UK Bhale2 (M)	Killed human	–	–	–	–	–	–	–	1	–	–	
5	Madi -Sitalpur (M)	Killed livestock	–	–	–	–	–	0	1	0	0	0	Came from Valmiki Tiger Reserve (VTR) India, released in CNP camera trapped later in VTR
6	Madi – Ganeshkunja SA (M)	Killed livestock	–	–	–	–	–	0	1	–	–	–	Released in Chitwan, recaptured and released in Bardia
7	Devnagar pothi (F)	Killed human	–	–	0	0	0	0	1	x	x	x	Old female - died in enclosure
8	UK7 (U)	Killed human	–	–	–	–	–	–	1	–	–	–	
9	Kawasoti SA pothi (F)	Safety threat	–	–	–	–	–	1	0	0	0	0	Released in Chitwan, subsequently camera trapped
10	Pratappur pothi (F)	Killed human	–	–	0	0	0	1	x	x	x	x	Old female - Killed by villagers on self-defense
11	Meghauli SA (M)	Killed human	–	–	–	0	0	1	C	C	C	C	Transferred to Kathmandu zoo
12	UK6 (U)	Killed human	–	–	–	–	–	1	–	–	–	–	
13	Barandabhar pothi (F)	Killed human	–	–	–	–	–	1	–	–	–	–	Outside of Buffer zone
14	Nirmalbasti bhale (M)	Killed livestock	–	–	–	–	–	1	x	x	x	x	Poisoned
15	Madi – Gardi SA pothi (F)	Safety threat	–	–	–	–	1	C	x	x	x	x	Died in enclosure
16	Kawasoti SA (M)	Killed livestock	–	–	–	0	1	C	x	x	x	x	Died in enclosure
17	Sauraha SA (M)	Safety threat	–	–	–	1	x	x	x	x	x	x	Released in Bardia (poisoned by poacher)
18	Majhuwa SA Male (M)	Killed human	–	0	1	x	x	x	x	x	x	x	Died in enclosure
19	Nangra pothi (F)	Killed human	–	1	1	0	1	1	1	1	1	1	Killed 19 persons
20	Buddhanagar SA (M)	Killed livestock	0	1	x	x	x	x	x	x	x	x	Poisoned
21	Lamichaur (M)	Killed livestock	0	1	x	x	x	x	x	x	x	x	Poisoned
22	Temple tiger SA (M)	Killed human	1	x	x	x	x	x	x	x	x	x	Shot by army

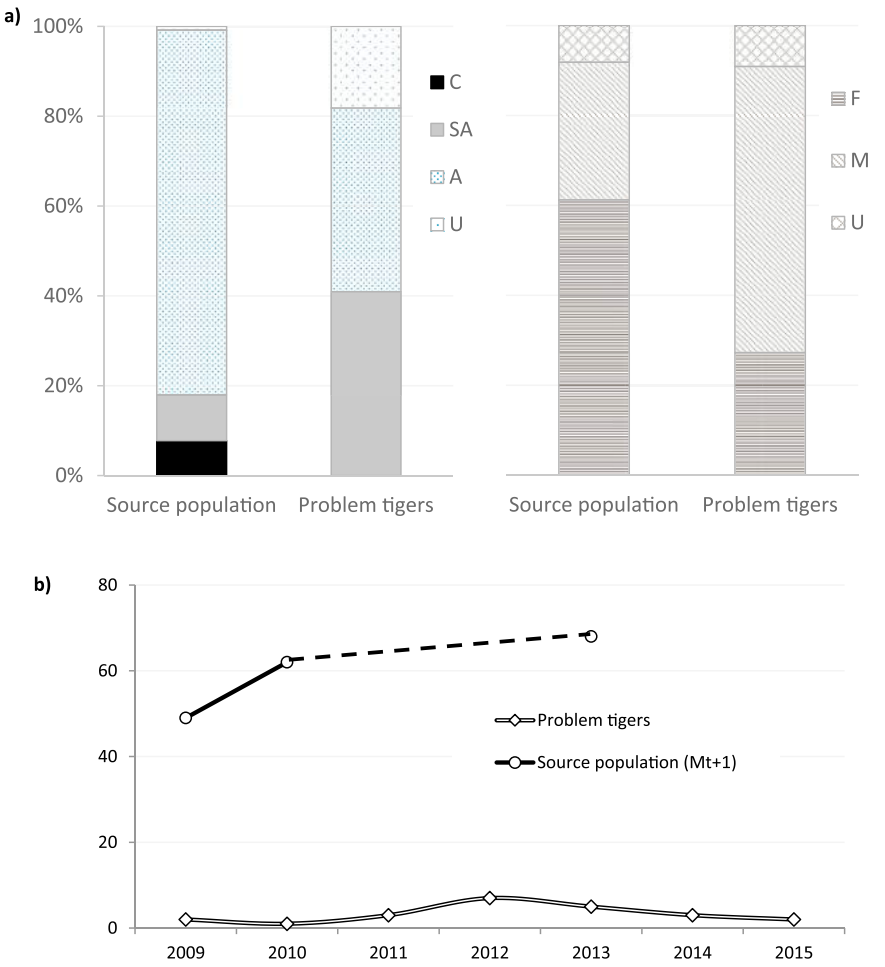

Fig. 4. **a)** Age & sex structure of the source population and problem tigers in Chitwan National Park in between 2009 and 2015. (C – Cub, SA – Sub-adult, A – Adults, U – Unknown age, U – Unknown sex, M – Male and F – Female). **b)** Number of problem individuals and tigers in source population. The camera trapped tigers (Mt+1) was used as source population, the estimated tiger population is higher than this. Dotted line of the source population represents expected number of tigers based on 2010 and 2013 data as survey was not done in between (2011 and 2012).

either released in the wild (4), or moved to a park enclosure or sent to a zoo (n = 8). No action was taken for five of the identified problem tigers because these tigers either accidentally attacked people in the buffer zone or attacked people only in the core areas of the park (Table 2). Most tigers that repeatedly killed livestock or attacked people in the buffer zone are controlled by the park authority as they pose a threat to human safety.

Four of the conflict-causing tigers (serial livestock-killers and safety threats) were released in core areas of CNP or Bardia National Park. Two tigers successfully rehabilitated in CNP (2012–2014) and photographed in healthy condition in successive camera traps. Two others, translocated to Bardia, and fitted with satellite collars. One of them was poisoned by poachers in buffer zone after three months (April 2011) and the other tiger's satellite signal was lost after two weeks (Jan, 2014).

We sexed 20 problem tigers recorded between 2007 and 2016, 6 were female. Equal number of adults and sub-adults (9) were involved in conflict with humans (Table 3).

3.2. Spatial and temporal distribution of problem tigers

A majority of the problem tigers (17) were found in the buffer zone area but originated from the park. Nine of the 22 problem tigers were found in settlements and cultivated areas outside of the forest (Table 4). Two of the problem tigers had trans-boundary movement, i.e. using both CNP and Valmiki Tiger Reserve of India in southern side (Fig. 3). Out of 22 problem tigers, we only obtained photos of 15 individuals, 13 of them matched to the camera trap photos (including two tigers photographed after release into wild). A few (n = 4) were captured in camera traps as a cub with their mother and were involved in conflict after leaving their natal territory. Two thirds (67.6%, n = 71) of the camera trapped locations of problem tigers were in the park. With the exception of one (called Nangra pothi, human-eater, that was active for eight years in the

Table 6
Likelihood Ratio Test (LRT) of logistic regression models fitted to 'problem tigers' of Chitwan National Park. Model: glmer (formula = ProbTig ~ Territory + Fitness + Sex + Age + (1|Year), family = binomial, link = logit).

Model	Df	AIC	LRT	Pr(>Chi)	Model structure
FULL		97.98			Territory + PhyCondition + Age + Sex
Territory	2	106.36	12.38	0.002**	Full model - territorial behavior
Physical Condition	1	103.36	7.38	0.006*	Full model - PhyCondition
Sex	2	96.73	2.74	0.25	Full model - sex
Age	2	94.55	0. 56	0.75	Full model - age

Western part of park) all the problem tigers were involved in conflicts with humans temporarily (for a few months to a year only) (Table 5).

3.3. Source population and problem animals

An average of 4.3% of the tigers captured in camera traps were found to be involved in conflict in 2009, 2010 & 2013(Fig. 4). A total of 131 unique tiger individuals were recorded in camera traps in CNP in 2009, 2010 & 2013 including 15 tigers which were identified as conflict causing individuals between 2009 and 2013. About two thirds (64.4%) of the tigers were captured in a single year only. Including the multiple year observation of some tigers, we recorded 245 observations of tigers in five years.

The logistic regression analysis showed that physical condition and territorial behavior are the important factors related to problem tigers, but age and sex had no significant effect (Table 6). The transient and physically impaired tigers are more likely to be involved in conflict compared to territorial and healthy ones (Table 7). In our study, 2% of the resident tigers and 30% of the transient tigers were involved in conflict. The majority (62.2%, n = 37) of these transient tigers includes dispersing sub-adults searching to establish territory. Similarly, only 5% of the healthy tigers and nearly two third (63%) of the physically impaired tigers were involved in conflict. Full model that considers all four factors predicts that the probability of a resident tiger to be involved in conflict is 0.003, while this probability of transient tigers is 0.08, healthy tiger is 0.0002 and physically impaired tiger is 0.68.

4. Discussion

Our study compared the characteristics of problem tigers in relation to the population as a whole. We observed that only a small portion of the tigers (<5%) in the population, or an average two individuals per year, are involved in conflict with people. Prompt action by park authority in removing or killing 13 of 22 problem tigers may have reduced human-tiger conflict. We found that transient tigers, including dispersing sub-adults and pushed out old individuals that have lost their territories have a higher probability of becoming problem tiger compared to territorial residents. Earlier studies in Chitwan reported similar observations about dispersing sub-adults (Smith, 1993). Also in India young and inexperienced tigers were more likely to be involved in livestock killing and later shifted to natural prey gradually with experience (Kolipaka et al., 2017, in press). In our study, attacks on humans most often were by physically impaired tigers or animals that were driven from their territories by another tiger. For example, we have observed one male and two females captured in camera traps for multiple years without reports of conflict (Table 5). They became human-killers only after they were driven out from their territories into marginal habitat.

Only a few studies have focused on a subset of problem-causing individuals in carnivore population (Linnell et al., 1999; Barlow et al., 2013). Our results of 4.3% of the tigers in total population involved in conflict is comparable to data reported by Barlow et al. (2013) in Bangladesh Sundarbans. Barlow and colleagues profiled 110 human-killing tigers based on location and year of the people killed in 23 years (1984–2006), and estimated 8 human-eater tigers were responsible for human mortalities. In comparison with the recent population estimate of 106 tigers (Dey et al., 2015) in the Sundarbans, only 7.5% of the tigers were involved in human-killing. In contrast to Barlow et al. (2013) we have also included livestock killers and tigers

Table 7
Parameter values of individual variables of GLMM fitted to tigers (problem individuals and source population) of Chitwan National Park.

Parameters	Estimate	Std. Error	z-value	Pr(>|z|)
(Intercept)	−3.29E+00	4.81E-01	−6.849	7.42E-12***
TeritoryTransient	2.50E+00	7.90E-01	3.164	0.00155**
TeritoryUnknown	−3.63E+01	1.07E+07	0	1.0
PhyConditionImpired	2.54E+00	9.66E-01	2.632	0.00848**
PhyConditionUnknown	1.10E+02	4.91E+07	0	1.0
SexM	−6.48E-01	7.03E-01	−0.923	0.356
SexU	−3.22E+01	7.43E+06	0	1.0
AgeC	−3.51E+01	1.58E+07	0	1.0
AgeSA	−1.31E-01	8.38E-01	−0.156	0.87629

causing safety threats in the group of 'problem tigers' and compared with the minimum count of the source population (camera trapped individuals i.e. Mt + 1) only. If we compare the subset of problem tigers with the estimated tiger population of Chitwan given by capture-recapture models (i.e. 120, Dhakal et al., 2014), only 2.4% of the tiger population is involved in conflicts in CNP which is much lower than the estimate from Bangladesh.

Our observations show that residential territorial males or females are less likely to be involved in conflicts with people when they occur in prey rich areas like Chitwan as described by Sunquist (2010). In the recovering buffer zone forests (Barandabhar corridor) of Chitwan, Carter et al. (2012) found that resident tigers co-exist with humans and avoided conflict by temporal separation. Multiple year camera trapping surveys in Barandabhar by NTNC shows that the tiger population has increased since 2013 (four to eight residential tigers) (NTNC-BCC, 2016). In contrast, more attacks on humans by tigers were recorded in 2012 (two persons killed) & 2013 (two killed, one injured) when a human-killing tigress was active (Table 5, Devnagar pothi F). Although more residential tigers are using Barandabhar, the number of human casualties in this area has dropped (only a human death during 2015–2016). Most resident tigers live compatibly with humans in undisturbed habitat with abundant prey but there are occasional individuals which are involved in conflicts that should be identified and removed in a timely way. Thus, tiger range countries including Nepal should consider criteria for responding rapidly to problem tigers. Along with removal or other mitigation measures for intense conflict scenarios, providing safe passage through corridors to other protected areas or forests with low density (Wegge et al., 2016) could reduce possibility of conflict. Enhancing quality of grasslands and wetlands through intensive management and increasing prey density inside core areas and dispersal corridors is equally important to reduce conflict and facilitate dispersal. A similar observation was made in Parsa National Park where tiger population has escalated from seven in 2013 to 20 in 2016 where dispersing tigers from Chitwan contributed a lot to the increase (Lamichhane et al., 2017, in press; Pickles, 2016).

Our study provides a new perspective and detailed insight into understanding of human-tiger conflict. It demonstrates that most problem causing tiger fall into two categories, 1) old and injured animals and 2) young dispersing animals forced to reside in the periphery until they establish breeding territories. Regular monitoring of the tigers in fringe areas using camera traps or satellite telemetry, paired with involvement of local communities, can provide crucial information about such potential problem individuals (Gurung et al., 2008). Rapid response teams (RRT) formed under the buffer zone user committees (BZUC) can be trained and mobilized as para-ecologists (Schmiedel et al., 2016) in tiger monitoring and communicating respective communities (early warning) if such tiger is detected. This can save human lives and reduce livestock depredation through preparedness of communities. Vulnerable human settlements located close to the forest also need to adapt their activities by avoiding the forests or entering in groups with proper alertness when such potential problem individuals are detected in their locality. Technical support, data management and analysis should also be conducted by appropriate authorities and experts.

Previous studies on problem animal management proposed different actions such as translocation, lethal control or captivity (Treves and Karanth, 2003; Goodrich and Miquelle, 2005). In contrast, Barlow et al. (2010) and Gurung et al. (2008) highlighted identification and regular monitoring of problem individuals by radio and satellite collaring as the top priority action for mitigation of the human-tiger conflicts. Translocation of problem individuals shows mixed results (Fonturbel and Simonetti, 2011; Linnell et al., 1997) but it can be a viable option for healthy and non-human-killing tigers with a proper post-release monitoring. There is an increased public concern regarding lethal measures but it is a viable option to control individuals with sustained involvement in conflicts (especially human-killing) or physically impaired individuals with less potential for recovery. A limited number of such animals can also be housed in captivity in rescue centers or zoos for educational purposes.

5. Conclusions

Based on our study, we conclude that most tigers can live in close proximity to humans but a small portion (<5% in our study) of the population is involved in conflict and these individuals can be labeled as 'problem animals'. Such individuals need to be properly identified and removed quickly. Their removal may reduce the conflict, decrease anger of villagers. Tigers, especially dispersing sub-adults, need to be monitored (i.e. using camera traps; satellite telemetry) in habitat edges where high interaction between people and tigers occur. Information about such tigers should be communicated through a participatory early warning system. Awareness programs focusing on the most vulnerable communities will be helpful to reduce human and livestock mortality from tigers. As the Chitwan tiger population increases, more sub-adults and transient tigers are likely to disperse out of core areas and come into conflict with local people. Facilitating dispersal of such tigers through corridors can also reduce risks of conflict.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.gecco.2017.06.003.

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