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ORIGINAL ARTICLE

# Profiling Tigers (*Panthera tigris*) to Formulate Management Responses to Human-Killing in the Bangladesh Sundarbans

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**Abstract**

Human-killing by tigers (*Panthera tigris*) in the Bangladesh Sundarbans may lead to negative attitudes and retribution killings by local communities, which in turn may have a substantial impact on the long-term viability of the tiger population. The objectives of this paper were therefore to (1) assess the scale and historical trend of tiger attacks on humans in the Bangladesh SRF, and (2) build a profile of the tigers carrying out the attacks. We collated available literature cataloging official government records of tiger attacks on humans, and built tiger profiles using the location and time of each attack. A total of 1 396 human deaths were recorded over 63 years, or an average of 22 human deaths/year. An estimated total of 110 tigers killed humans in the SRF over 23 years with a mean five victims/tiger, and most tigers that killed humans were concentrated in the west. An estimated 50% of tigers only killed one person, and tigers that killed more than one person accounted for 81% of total human fatalities. These results support recommendations for the collaring human-killing tigers and the formation of tiger response teams to reduce the number of humans killed by tigers over time.

## Introduction

With probably less than 4 000 individual tigers (*Panthera tigris*) left in the wild, conservationists face an uphill struggle to secure the future of this iconic species [1]. One of the important issues contributing to the tiger's demise is human-tiger conflict (HTC), manifested in the loss of humans, livestock, and tigers. Human-killing and livestock-killing by tigers may lead to negative attitudes towards tigers and to retribution killings by local communities [2-4]. This additional source of mortality for tigers may have a substantial impact on the long-term viability of the tiger population in question [3, 5]. HTC has already contributed to the extinction of the Bali (*P. t. balica*) and Javan (*P. t. sondaica*) tiger subspecies [6], and threatens many of the remaining populations [4].

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Possibly one of the most extreme HTC situations is found in the Sundarbans Reserved Forest (SRF) of Bangladesh, which results in the killing of tigers, livestock, and humans [7]. The probability of a human being killed by a tiger in the SRF is low [8], but the loss of life can devastate the remaining family members both emotionally and economically; the tiger victim may well be the main bread-winner for a family [4]. It is therefore noted in the Bangladesh Tiger Action Plan that it is essential to minimize human-killing by tigers to reduce the unnecessary misery inflicted on local communities to help secure their support for tiger conservation [9].

The first step for management is to build a solid information base on the scale and historical trend of human-killing in the SRF, thus allowing to formulate responses to the problem and assess the effectiveness of those responses over time [7].

In terms of reducing the human-killing aspect of HTC, there is a wide range of management solutions available to the authorities [10]. However, the selection of solutions involving dealing with the tigers directly (euthanasia, translocation, and collaring) requires building a profile of the tigers involved [7] (estimation of the number of tigers involved in killing humans, the number of human victims attributable to each tiger, the length of time the tigers continue to kill humans, and the distribution of conflict tigers).

Collecting information on tiger attacks with respect to individual tigers is, however, very difficult; without having all tigers monitored throughout their lifetime, there is no means to collect these data empirically. A previous study in the SRF used the timing and location of attacks to investigate the number of tigers involved in three outbreaks of human-killing [11]. However, so far no study has provided information on tigers attacking humans in sufficient detail or scale to help formulate a management response.

The objectives of this paper were therefore to (1) assess the scale and historical trend of tiger attacks on humans in the Bangladesh SRF, and (2) build a profile of the tigers carrying out the attacks.

## Methods

### *Study area*

The Sundarbans is located between N' 21°30' – 22°40' and E' 88°05'- 89°55', and covers 10 263 km$^2$, of which 6 017 km$^2$ is in Bangladesh and 4 246 km$^2$ is in India. The Sundarbans is made up of low elevation islands, surrounded by a network of tidal waterways that connect the Ganges-Brahmaputra river systems to the Bay of Bengal. Tigers in the SRF of Bangladesh occur at high densities relative to other tiger habitats [12], and are notable for their small body size relative to tigers from other populations [13]. In the SRF, tigers mainly subsist on chital (*Axis axis*) and to a lesser extent wild boar (*Sus scrofa*) [14].

Several hundred thousand people enter the SRF each year to collect a range of forest resources including wood, fish, golpatta and honey; creating essential income to both the local and regional economy [4, 8]. Human use within the SRF is administrated by the Bangladesh Forest department, who has delineated the area into two divisions, four ranges, and 55 compartments. There are human activities within the SRF all

year, but number of people and type of activity vary due to government imposed time restrictions and temporal variation in resource availability (e.g. honey).

*Estimating the scale and historical trend of tigers killing humans*

Records on human-killing by tigers in the Sundarbans were obtained from 63 of the years between 1935 and 2006 [11, 15, Bangladesh Forest Department records 1984-2006]. The records included humans killed inside the forest and in the villages along its border. Records of tiger attacks that did not result in a fatality were not used as these were not always recorded in early records. Records were not included from sources with overlapping data sets or if the reported human deaths from the Bangladesh side of the Sundarbans could not be differentiated from those of the Indian side. A trend line was fitted to the data and $R^2$ value calculated in Microsoft Excel. A t-statistic was used to calculate the significance ($\alpha = 0.05$) of any trend in the number of humans killed by tigers over time. A check for autocorrelation was carried out using ARIMA time-series analysis in SYSTAT.

*Building tiger profiles*

Using Bangladesh Forest Department records (1984-2006), the number of tigers killing humans/year was estimated as the number of compartments with human deaths. Earlier records of humans killed by tigers were not included because the location of incidents was not recorded consistently. The total number of human-killers was calculated with a deterministic model that used the time between consecutive human deaths within each compartment. It was assumed that if a tiger, having killed someone previously in a compartment, did not kill again within time t then it had ceased to operate in that area. Time *t* was set at 12 months to take into account the variation in environmental conditions (such as rainfall and hours of daylight) and availability of victims over the course of a year. Human use intensity and type vary throughout the year, but there are some humans present each month in all compartments of the Sundarbans, which means that a tiger would have the opportunity to take a human victim every month.

Considering time *t* and the compartment where the attack took place, victims were assigned to a particular tiger, from which the number of human deaths/tiger and the number of months a tiger was operational was also calculated. The number of tigers killing humans/compartment was used to investigate the spatial distribution of the conflict.

There were four sources of potential error in this approach. Firstly, we assumed that compartment-wise attacks were independent, i.e. a tiger did not kill humans in more than one compartment. This assumption holds to some extent because recorded female tiger home range for Sundarbans tigers (n = 2, $\bar{x}$ = 14.2 km$^2$, range 12.2-16.2 km$^2$) is smaller than compartment sizes ($\bar{x}$ = 91 km$^2$ range = 28-194 km$^2$) [12]. Female tiger territories, however, may be larger in different parts of the Sundarbans [12]. Also, male tigers are likely to have larger territories, possibly three to seven times the size of females [16] and transients can move over relatively large distances [17]. Therefore, there is potential for an overestimation in the number of tigers killing humans.

Secondly, the approach assumes that no more than one human-killer/compartment was operational at any time, which could lead to an underestimation of the number of tigers involved. This assumption is supported to some degree by the natural spacing of tigers; adult tigers aggressively defend their territories from intrusion by conspecifics of the same sex [16]. However, more than one tiger may be operational in the same area at any given time, because (1) mean female home ranges were smaller than mean compartment size [12], (2) male and female territories overlap [16], (3) adult females may have dependent offspring that take part in attacking humans [3], and (4) transient animals move through other tiger's territories [17].

Thirdly, government records do not record all human deaths because people without official permits to work in the forest are generally under reported [18]. Although there are estimates of this degree of error [18], they were not incorporated into the analysis as this would have required additional assumptions regarding the temporal and spatial distribution of missing records.

Finally, the selection of a $t = 12$ months is arbitrary, and may not reflect a reasonable cut off point, after which subsequent kills are attributed to a new tiger. For sensitivity analysis, more stringent (8 months) and relaxed (16 months) values of t were used, to test the results' dependencies on this parameter.

## Results

### *The scale and historical trend of tigers killing humans*

A total of 1 396 human deaths were recorded (Fig. 1), with a mean 22 human deaths/ year (SD = 16.6, range 0-96). The negative trend (-0.035) in humans killed over time was not significant ($t$ = -0.323), and the ARIMA analysis revealed no evidence of autocorrelation (MSE = 309.2, p = 0.774).

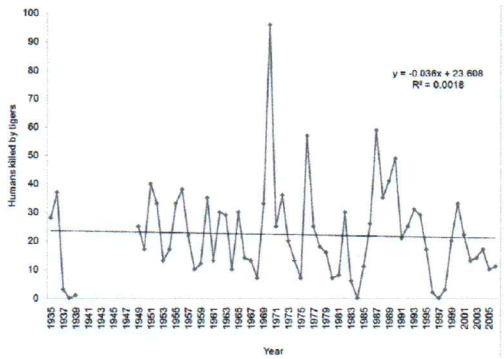


Fig. 1: Number and trend of humans killed by tigers in Bangladesh Sundarbans.

### *Tiger profiles*

Between 1984 and 2006, 490 human deaths from tiger attacks were recorded; these were used to create the tiger profiles. The estimated mean number of tigers killing humans, based on the number of compartments recording human deaths was 8 tigers/ year (SD = 5, range = 0-16).

Using $t$ = 12 months, an estimated total of 110 tigers killed humans in the SRF over 23 years, with a mean five victims/tiger (SD = 7.1 range 1-39). Approximately 50% of tigers only killed one person (Table 1), and tigers that killed more than one person accounted for 81% of total human fatalities. The mean time a human-killing tiger was operational was 8.2 months (SD = 13.4, range 1-68) (Table 1).

The sensitivity analysis (using $t$ = 8 months or 16 months) showed that variation in $t$ did not have a large effect on the number of estimated tigers killing humans (Table 1), the number of victims/tiger, or the length of time each tiger was operational (Table 1).

The number of tigers killing humans was not distributed evenly across the area; most tigers that killed humans were clustered in the west, but there were also patches of tigers killing humans in the south and north (Fig. 2).

Table 1: Estimated number of human-killing tigers, months human-killers were operational, and victims/tiger.

| $t$ (months) | Human-killers[a] | Months operational | | | Victims/tiger | | |
|---|---|---|---|---|---|---|---|
| | | Mean | SD | Range | Mean | SD | Range |
| 8 | 142 | 4.1 | 6.6 | 1-35 | 4 | 5.6 | 1-37 |
| 12 | 110 | 8.2 | 13.4 | 1-68 | 5 | 7.1 | 1-39 |
| 16 | 101 | 10 | 16.4 | 1-74 | 5 | 7.8 | 1-39 |

[a] The number of human-killing tigers, and the number of victims per tiger was estimated using Forest Department records of tiger human fatalities in each of 55 compartments, over a 24 year period. Time $t$ is the time limit between human fatalities in a compartment, after which attacks are attributable to a new tiger.

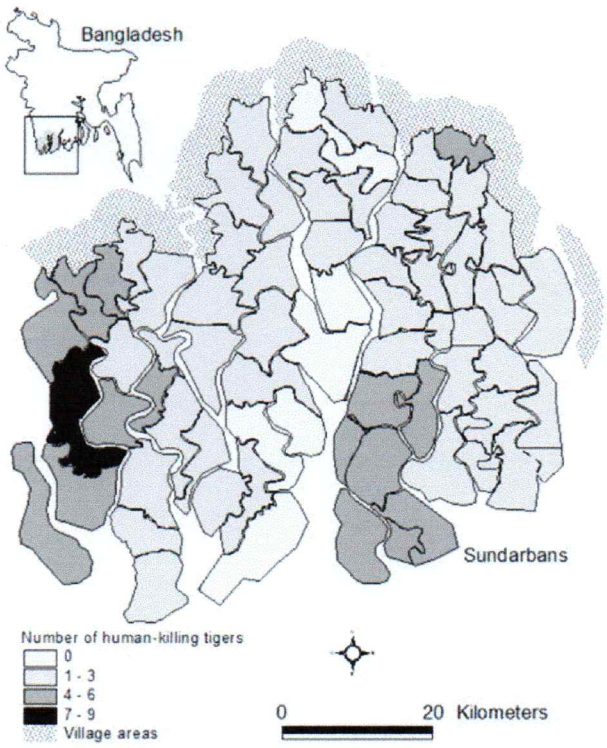


Fig. 2: Distribution of human-killing tigers in the Bangladesh Sundarbans.

## Discussion

### *The scale and historical trend of tigers killing humans*

People killed while working illegally in the forest or those that later die due to injuries, tend either not to be reported by their companions, or not catalogued by the authorities [18]. Therefore the number of humans killed reported in official records is an underestimate of the total number of incidents; the mean number of incidents missed by official records has been estimated at 33% from a three year study [18]. However, even considering only the official records, with a mean 22 human deaths/year, the SRF probably has the highest level of human-killing anywhere in the tiger's current range [19], and the trend in humans killed by Sundarbans tigers appears to be relatively consistent over time.

With respect to other areas, tiger attacks on humans exerted a heavy toll in many places in the Indian subcontinent and parts of South-East Asia a century ago [19-20]. Since then, tiger numbers and the forests in which they once lived have been reduced at alarming rates [1]. This has led to a reduction in human-killing cases and the number of places where tiger attacks occur [19]. However, human-killing still remains a problem in other areas. From 1978 to 1997, a total of 146 people were killed by tigers on the island of Sumatra, at an average of 7.1 human deaths/year [21]. Human-tiger conflict is also a serious conservation issue in Nepal; 88 people were killed in Chitwan from 1976-2006, and the rate of human killing has increased from 1.2 human deaths/year (1976-1997) to 7.2 human deaths/year from 1998-2006 [3]. Other areas, such as the Russian Far East, have much lower levels of human deaths; 19 humans attacked over a nine year period [10].

The ecological correlates of the human-tiger conflict (e.g. intensity of area use by humans, incidence of tiger killings by humans, variation of prey abundance, or conditions otherwise suboptimal for tigers) should be considered in future studies in order to better understand the importance of landscape and human factors influencing the spatial pattern of the conflict.

Considering additional human deaths on the Indian side of the Sundarbans, and the additional human deaths not recorded in official documents, means that the Sundarbans as a whole may also have the highest number of human deaths caused by carnivore attacks in the world [22]. The second highest is probably Tanzania, where >563 human deaths from lion attacks were recorded from 1990 to 2004 [23].

### *Tiger profiles*

Due to multiple sources of potential error, it is not possible to know with certainty how many tigers were involved in killing humans, how many victims/tiger, or how long each tiger continued to kill humans. Overall, the high level of uncertainty in the estimates making up the tiger profiles means that they should only be considered primarily in the context of identifying management solutions, rather than adding insight into tiger behavior. However, the sensitivity analysis of varying $t$ by 50% did not have a large effect on the tiger profiles, indicating that the analysis was not highly dependent on this arbitrary parameter setting. Another option would have been to use a longer time $t$ for sensitivity analysis, up to the average age of tiger land tenure found

in other studies [24]. However, this would make it possible for two humans killed six years apart to be attributable to the same tiger. We do not think this is reasonable considering the much higher rate of human killing by tigers profiled in other studies [3, 11], and the availability of humans in the Sundarbans throughout the year.

The longest estimated time a tiger was operational (68 months) is possible, considering that the mean land tenure for resident female tigers is approximately 72 months [24]. Furthermore, the high proportion of estimated tigers that only killed one victim (50% of total), is similar to findings in Nepal, where 17 (47%) out of 36 human-killers, only killed one person [3]. If 50% of human-killers only took one victim, despite the high availability of humans throughout the SRF, then this might indicate that at least some of these human-killers were provoked into an attack through defense of their food, their cubs, or themselves, after which they did not continue to attack humans. Furthermore, The remaining 50% of human-killers that killed more than one victim may have actively hunted humans as prey, killed humans opportunistically, or been provoked into multiple attacks. However, considering the data set and analysis presented in this study, no inferences can be made about the health, age, or sex of the tigers involved, or any ecological factor that may have contributed to the frequency and distribution of tiger attacks.

*Conservation implications*

Although the probability of anyone being killed by a tiger is very small [8], tiger conservation, must take into account the local socio-economic conditions of which human-tiger conflict is an important feature [10]. Human killing of tigers exerts considerable stress to local communities that rely of the forest for their livelihoods; working in the jungle is the only potential source of income for many people living along the forest border, and those killed are normally the main providers of income for a family [2-3].

Furthermore, tiger abundance is currently unevenly distributed across the SRF, and there is potential to increase tiger numbers in some areas through improved management [25-26]. Increased tiger numbers may lead to increased HTC in the SRF, which places additional pressure on the authorities to deal with this issue.

Results suggest that approximately 110 tigers have been responsible for human-killing with an estimated 8 human-killers operational each year in the SRF over a 23 year period. If this is representative of future conditions, then this result supports recommendations to collar human-killing tigers as a cost-effective and high impact management intervention to reduce human deaths over time [3, 7, 10]. Under this system, teams would monitor tigers on a daily basis so that people forest users could be warned of the human-killer's presence in an area. Ideally, villagers would also be members of these monitoring teams; to help build understanding and stewardship of tigers. Furthermore, considering that 50% of human-killers killed one person, and the other half accounted for 81% of victims, suggests that collaring human-killers should only be considered after they have killed at least two victims [7]. An additional benefit of collaring tigers would be improved understanding of human killing behavior. Furthermore, being able to keep track of tiger movements would serve as an early warning system that could help the authorities reduce the number of tigers that are killed when they stray into villages (26).

Another potential intervention would be to impose zoning in the SRF to temporarily limit or exclude human activity from compartments with operational human-killing tigers, enforced by regular patrolling of FD or village teams [10]. Developing and distributing deterrents to tiger attacks (such as fire crackers, pepper spray, and flares) may also increase the safety of forest users, if it can be done on a large enough scale. The clustered distribution of human-killing tigers suggests that management response should be primarily focused in the west of the SRF, and that there may be particular ecological factors (e.g. prey availability or habitat type) or human activities (e.g. high levels of honey collection) that predispose tigers to kill humans. In response to these finding, the Bangladesh Forest Department, in collaboration with the WildTeam, and the Zoological Society of London (ZSL), have set up a Tiger Response Team; the duties of which include (1) providing first aid to tiger attack victims, (2) providing tiger attack victims with rapid transport to medical facilities, (3) tiger victim body retrieval and transport, (4) scaring tigers away that have strayed into villages. WildTeam and ZSL are also working with the Bangladesh Forest Department to improve HTC data collection, storage, and reporting so that management interventions can be effectively evaluated.

The approach used in this study could also be used to help devise management interventions for other human-carnivore conflict scenarios which have similarly high levels of uncertainty regarding the profile of the carnivores involved.

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