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Original Research Article

Investigating patterns of tiger and prey poaching in the Bangladesh Sundarbans: Implications for improved management

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ABSTRACT

Poaching of tigers and their key prey threatens the survival of tigers across their range. This study investigated the methods, intensity, and driving factors of tiger and prey poaching in the Sundarbans Reserved Forest of Bangladesh, to help better design and direct future management interventions. The study identified a range of snaring methods used to catch prey and an approach to killing tigers by poisoning prey carcasses with a Carbofuran pesticide. We recorded six poisoned baits set to kill tigers and 1427 snare loops in 56 snare sets to kill tiger prey. With an average of 23 snare loops/snare set, this is equivalent to an estimated 6268 snare loops across the Sundarbans or 147 snare loops/100 km^2. Poachers selected sites that tended to be away from guard posts, and close to river banks, but were not influenced by protected area status or distance to the forest boundary. The current poaching pressure is likely to have contributed to a recent decline in relative tiger abundance. We recommend using better regulation of Carbofuran use across tiger range countries, and using remote camera traps set up around snares and poisoned baits to help authorities identify poachers for arrest. This study demonstrates a simple approach to investigating the methods, intensity and distribution of poaching, that could be replicated across all tiger landscapes to better direct mitigating actions and monitor changes in threat levels over time.

1. Introduction

Global tiger *Panthera tigris* populations have collapsed from an estimated 100 000 to 3500 tigers in just 100 years (Morell, 2007; Sanderson et al., 2006), and now occupy less than 7% of their historic range (Sanderson et al., 2006). The remaining tigers are mostly now restricted to small pockets of protected areas across their range (Walston et al., 2010b), and their

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numbers continue to decline in important areas despite significant conservation efforts by international agencies, local conservation groups and governments (Dinerstein et al., 2007; Seidensticker et al., 1999).

Poaching of tiger and prey has been identified as one of the major threats to tiger populations where they still persist (Aziz et al., 2013; Damania et al., 2003; Dinerstein et al., 2007; Goodrich et al., 2008; Jhala et al., 2008; Karanth and Stith, 1999; Wikramanayake et al., 2011). Tiger poaching is thought to be mainly driven by the international demand for tiger parts in traditional Asian medicine (Ellis, 2005; Jackson, 1990), while prey poaching may be driven by more localized demand (Damania et al., 2003; Mohsanin et al., 2013) and trade (Knapp et al., 2010; Madhusudan and Karanth, 2002).

However, due to the difficulty and risk involved in studying these covert and illegal activities (Karanth and Stith, 1999; Madhusudan and Karanth, 2002) it has been difficult to collect the information needed to address this problem across the 76 tiger conservation landscapes (Sanderson et al., 2006). Critical to assessing the level of tiger and prey poaching across each landscape, is the monitoring of the spatial scale and intensity of these threats to enable conservationists to design effective interventions, and to be able to monitor the impact of their activities (Duangchantrasiri et al., 2016; Hotte et al., 2016; Johnson et al., 2016; Stokes, 2010). To date, few studies have assessed the scale and spatial intensity of tiger and prey poaching to design improved law enforcement strategy at a specific site of Sumatra (Linkie et al., 2015; Rifaie et al., 2015).

To refine patrolling strategies and enhance evidence gathering efforts, it is also necessary to catalogue the specific methods that poachers employ (Karanth and Stith, 1999; Watson et al., 2013; Linkie et al., 2015). Previous studies have identified some site-specific poaching methods for tigers such as iron spring traps in India (Wright, 2010), traditional common wire cable, traps and gun in Sumatra (Linkie et al., 2015; Shepherd and Magnus, 2004; Treep, 1973), direct shooting in the Russian Far East (Goodrich et al., 2008), and poisoning by pesticides in Sumatra and India (Tilson et al., 2010; Treep, 1973; Wright, 2010) and explosive traps and snares in Laos and Cambodia (Johnson et al., 2016; O'Kelly et al., 2012). Likewise, the methods for prey poaching documented so far include guns and snares in India (Madhusudan and Karanth, 2002), snares in the Sundarbans (Jagrata Juba Shangha, 2003; Khan, 2004), and traps in Sumatra (Linkie et al., 2015).

The Sundarbans Reserve Forest (SRF) of Bangladesh currently has incomplete information on the scale, intensity, and methods of tiger and prey poaching. The SRF is part of the wider Sundarbans landscape, which is classified as a tiger 'source site' (Walston et al., 2010a) and a Class III Tiger Conservation Landscape of global priority (Sanderson et al., 2006). Tiger and prey poaching have been highlighted as key threats in this landscape for several decades (Ahmad et al., 2009; Aziz et al., 2013; Salter, 1984), and the nature and scale of local use or consumption of tiger and prey parts as well as people involved in tiger killing has recently been documented (Mohsanin et al., 2013; Saif et al., 2016, 2015). Over the last few years, law enforcement agencies have confiscated piles of tiger skins, bones, and live tiger cubs in the country (Table A.1; Fig. 1). A pilot study also managed to gain insight into the scale of general illegal activities in the SRF (Hossain et al., 2016), but data on tiger and prey poaching inside the forest are still lacking.

The objectives of our study in the SRF were, therefore, to (1) identify tiger and prey poaching methods, (2) assess the spatial intensity of poaching activities, and (3) identify the factors influencing the spatial distribution of poaching. To this end, we collected and analysed field data on tiger and tiger prey poaching incidents sampled from four representative areas of the SRF. We believe that our findings will be useful in developing focused patrolling and effective law enforcement strategies to secure the survival of tigers in the SRF, and present an approach that could be replicated across all landscapes where large carnivore and ungulate poaching are a threat.

2. Methods

2.1. Study site

The SRF is 6017 km^2, of which 1750 km^2 is water (Iftekhar and Islam, 2004) consisting of a maze of rivers and creeks that make most of the forest areas accessible by water-based vessels. The SRF is bordered on the south by the Bay of Bengal and on the west by the international boundary with India, demarcated by the Raimongal and Hariabhanga rivers. The north and east sides are bounded by districts of densely populated human settlements (Hussain and Acharya, 1994) (Fig. 2).

The SRF has a high diversity of floral communities comprising 330 plant species dominated by *gewa* (*Excoecaria agallocha*) and *sundri* (*Heritiera fomes*), and a diverse assemblage of vertebrate fauna including eight species of amphibians, 35 species of reptiles, over 300 species of birds, and 42 species of mammals (Islam and Wahab, 2005; IUCN-Bangladesh, 2001). The major ungulates which make up the tiger's prey are the chital (*Axis axis*), wild boar (*Sus scrofa*), rhesus monkey (*Macaca mulatta*) and barking deer (*Muntiacus muntjak*) (Khan, 2008).

The SRF is managed as a Reserve Forest and three areas within the forest are designated as wildlife sanctuaries: Sundarbans West (715 km^2), Sundarbans South (370 km^2), and Sundarbans East (312 km^2). These sanctuaries have been collectively declared a UNESCO World Heritage Site (Iftekhar and Islam, 2004). Administration of the SRF is overseen by three Divisional Forest Officers (DFO East, DFO West and DFO Wildlife) working under a Conservator of Forests based in Khulna. For management purposes, the SRF is delineated into 55 compartments under four ranges, with over 90 guard posts distributed across the forest (Ahmad et al., 2009) (Fig. 2).

The SRF provides a wide range of forest and aquatic resources which are fundamental to the wellbeing of local communities (Islam and Wahab, 2005; Tamang, 1993). Several million people earn their livelihood from the SRF by collecting fish, nypa palm (*Nypa fruticans*) and honey (Ahmad et al., 2009; Tamang, 1993). Fishing activities continue throughout the year but the collection of nypa palm and honey usually starts between February and April, and lasts for a few months. The

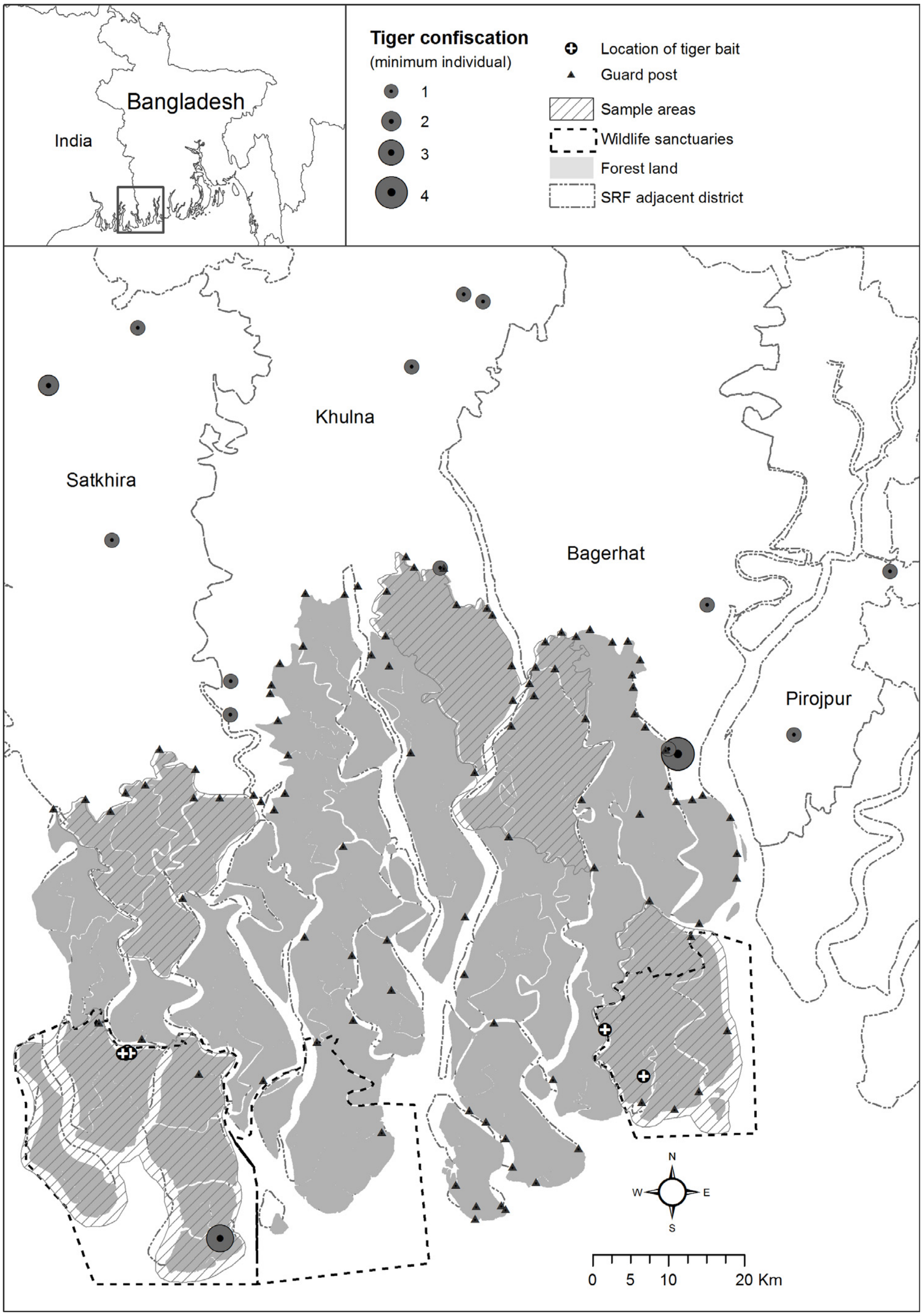

Fig. 1. Tiger confiscation locations in and around the SRF in relation to sampling areas, tiger bait stations and guard posts. Data of tiger confiscations were collected from secondary sources after validation against the wildlife crime database of WildTeam, which keeps records only after verification with Forest Department and law enforcing agencies.

Bangladesh Forest Department issues permits for limited collection of these resources across the SRF, apart from the wildlife sanctuaries. The fishermen, however tend to move towards the wildlife sanctuaries to benefit from the perceived better fish stock in these areas (Russ and Alcala, 2011).

No permanent human habitations exist within the forest, except forest department, navy, and coast guard camps. However, there are some temporary fishing villages on several islands (e.g., *Dublar char*) located on the south edge of forest

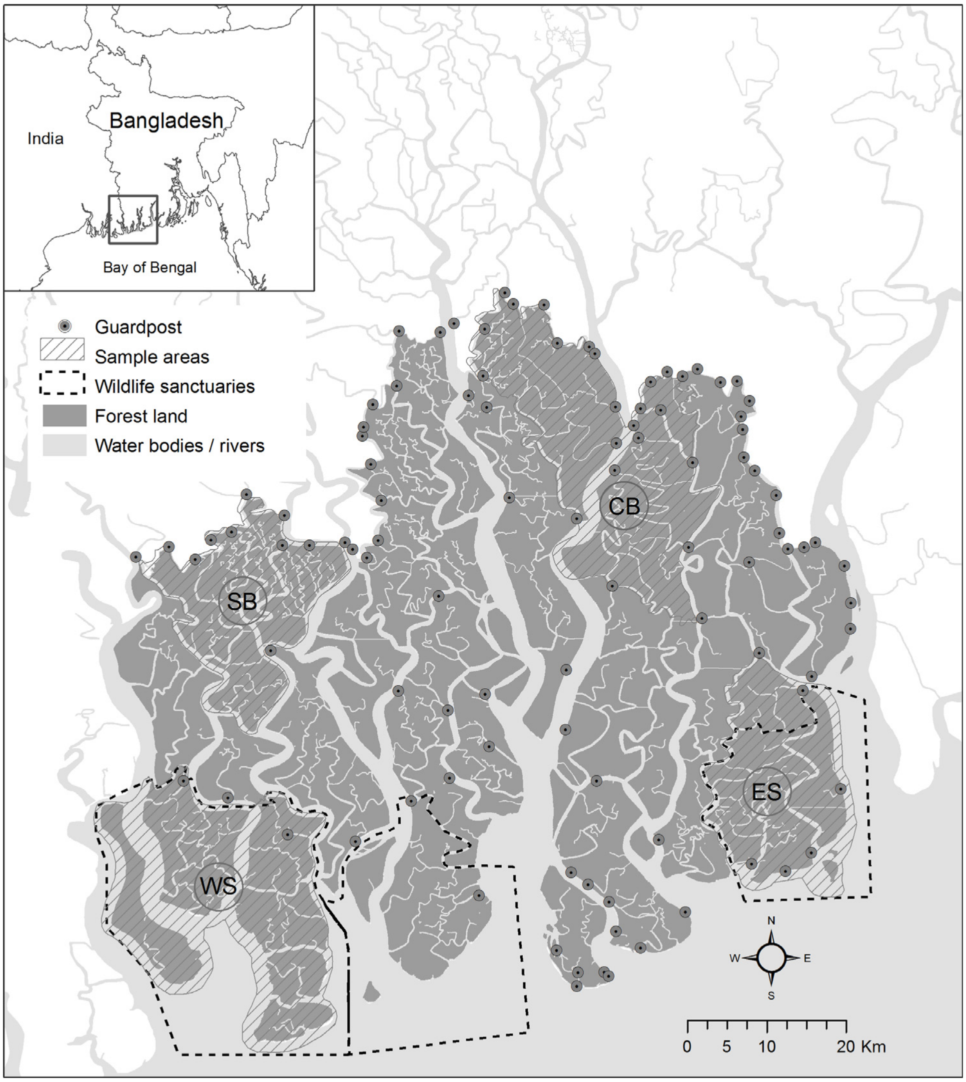

Fig. 2. Sampling area and associated features of the SRF. SB = Satkhira Block, CB = Chandpai Block, WS = West Wildlife Sanctuary, ES = East Wildlife Sanctuary.

where *ca* 8000 fishermen make their temporary home for fishing activities in the winter months (October to March) (Huda and Haque, 2001).

2.2. Sampling approach

We selected four areas (totalling 1994 km^2) to sample within the SRF; East Wildlife Sanctuary (ES, 383 km^2), West Wildlife Sanctuary (WS, 715 km^2), Satkhira Block (SB, 342 km^2), and Chandpai Block (CB, 554 km^2) (Fig. 2). We selected these areas as they differed in location, protection status, and human use. The ES and WS areas have higher protection status and are situated away from human settlements, whereas the CB and SB areas have lower protection status and are located close to local villages (Fig. 2).

Following approaches used in other studies (Kimanzi et al., 2015; Wato et al., 2006; Watson et al., 2013), to select sampling points, we first divided each of our areas into 2 × 2 km grid cells, creating a total of 373 grid cells for potential sampling across the four areas. We then aimed to sample all grid squares with three separate transects (using one transect each time), walked by teams of four observers. Starting points for each transect were selected by where the grid cell could be easily accessed by boat. From the start point the observers walked a transect roughly in the direction of the opposite side of the grid square. Each transect was continued for a length of 1 km, or until the observers could not continue further because of particularly dense habitat or a large water body. The observers walked in parallel along the transect line, with the distance between the first and last observer being kept to 15 m (5 m between each observer).

Five teams of four observers were used to simultaneously survey a sample area over a short (13–22 days) period of time, to reduce the possibility that poachers in the area would be able to remove signs of poaching activity due to the presence of the survey teams. Teams collected data on the number, location (using a *Garmin GPSMAP 64*), and method of tiger and prey poaching evidence encountered. We also noted any indirect evidence of poaching such as sites where poached animals had been stored or processed. If a suspected poisoned bait carcass was encountered, we collected a sample of the poison. We then analysed the poison in the laboratory of the School of Biosciences, University of Kent, using liquid chromatography-mass spectrometry (Ameno et al., 2001; Reljić et al., 2012), to identify what type of poison it was.

We chose winter months for sampling to avoid extreme weather conditions, with sampling of SB area from 20 November to 11 December 2014 and WS area from 17 to 30 December in 2014, and with sampling of ES and CB areas from 4 to 26 February 2015. We managed to survey 10 grid cells with four transects, 297 grid cells with three transects, 7 grid cells with two transects, and 32 grid cells with one transect. 27 grid cells were not surveyed at all due to inaccessibility and security issues.

2.3. Covariate selection and analysis

We considered a set of four covariates that might have influenced poachers on selecting sites for poaching activities: protection status (wildlife sanctuary versus reserve forest), distance to the nearest forest guard post, distance to the nearest river, and distance to the nearest human habitation. The protection status was included to investigate if poaching was distributed due to the perceived differences in protection levels (Watson et al., 2013) or abundance of tiger and prey (Kimanzi et al., 2015). Distance to forest guard posts was included to investigate if the actual intensity of protection influenced the distribution of poaching (Kimanzi et al., 2015). The distance to the nearest river was used as a covariate to investigate if poachers selected sites close to rivers because of the ease of access to those areas (Fitzgibbon and Mogaka, 1995). Likewise, the distance to forest boundary was used to investigate if areas closer to human habitation also had higher poaching levels due to ease of access (Hoffer et al., 2000; Wato et al., 2006). The covariates were analysed with respect to the density of all types of poaching evidence within a sampled grid square. Grid squares where poaching activities were not detected were not used in the analysis because of issues relating to imperfect detection (Lahoz-Monfort et al., 2014). Preliminary data analysis using a generalized linear model indicated that the dataset was over-dispersed (Crawley, 2007; Zuur et al., 2010), so we used a negative binomial regression model with Poisson distribution commonly applied for over-dispersed data (Kimanzi et al., 2015; Zuur et al., 2010).

We performed an initial analysis on our explanatory variables according to Zuur et al. (2010) to confirm that none were collinear. We also performed the global Moran's I test for each sampling area independently to check for potential spatial autocorrelation, which would be a potential constraint for regression analysis (Koenig, 1999).

Following approaches in other studies (Bavaghar, 2015; Rivera et al., 2013), we prepared a risk map with different levels of probability relating to poaching activities in the SRF. Using parameter estimates of the negative binomial regression model, the probability of poaching activity (P) was determined by,

$$Y = \beta_0 + \Sigma \beta_i X_i$$

where β_0 is the constant coefficient, β_i represents the significant independent variable coefficients, and X_i represents their associated independent variables. Through incorporating the natural exponential (e) into the previous equation the probability of poaching activity was constructed by the following equation,

$$P = e^Y / 1 + e^Y.$$

One-way analysis of variance (ANOVA) was used to investigate the differences in poaching activity between sampled areas.

We used R (R Core Development Team 2016) and ArcGIS 10.3 for our statistical and spatial analyses.

3. Results

3.1. Poaching methods

The only tiger poaching method detected was poisoned baits. Spotted deer, the principal prey of Sundarbans tiger, was used as bait in all cases. Poisoned bait was typically attached to a tree trimmed to the approximate height of a tiger, and placed next to tiger trails (indicated by tiger tracks). A single spotted dear was used to create 2 bait stations, with body parts being prepared by removing the intestines, dismembering, skinning, and coating in poison (Fig. 3, A). The liquid chromatography-mass spectrometry analysis identified the poison as a carbamate pesticide (Carbofuran).

The prey poaching methods detected were snares and shooting. The snares were set up to target either catch the deer's neck or leg. The neck snares were either set up individually (locally known as *fush*) or in lines of multiple snares all tied to a single rope (locally known as *daon*). The *fush* snare is held by small sticks or tree branches (for holding and acting as a trigger) with an open noose placed vertically above the ground. Each individual snare was positioned and fenced by sticks and twigs to direct the ungulate prey towards the snare set. The *daon* snare is placed in a line by clearing the forest undergrowth and suspending hundreds of nooses suspended vertically from a common rope that is tied on both ends to trees. (Fig. 3, B.)

Photographs © M. Abdul Aziz

Fig. 3. Tiger bait, snares and killed tiger prey in the SRF: (A) Tiger bait station, (B) *Daon*, (C) *Fush* with bait, (D) *Chhitka*, and (E) Spotted deer that died from bullet injuries.

The leg snare (locally called *chhitka*) contains a loop placed on animal trails and attached to a spring pole (usually adjacent to a small trimmed tree) by a fine trigger thread, with a fence of twigs and sticks to guide animals into the snare (Fig. 3, D). The *chhitka* snare is the technically complex snare type, and was often found set up in conjunction with *fush* neck snares (Fig. 3, D). We noted that poachers used twigs and leaves of Keora (*Sonneratia apetala*) and epiphytes as bait on either side of a snare set up in order to lure ungulates (Fig. 3, C). Both neck and leg snares were made from a nylon rope (80–100 mm diameter) that is commonly used for fishing nets, which is locally available, and inexpensive. All snares appeared to be set with higher intensity around ungulate trails.

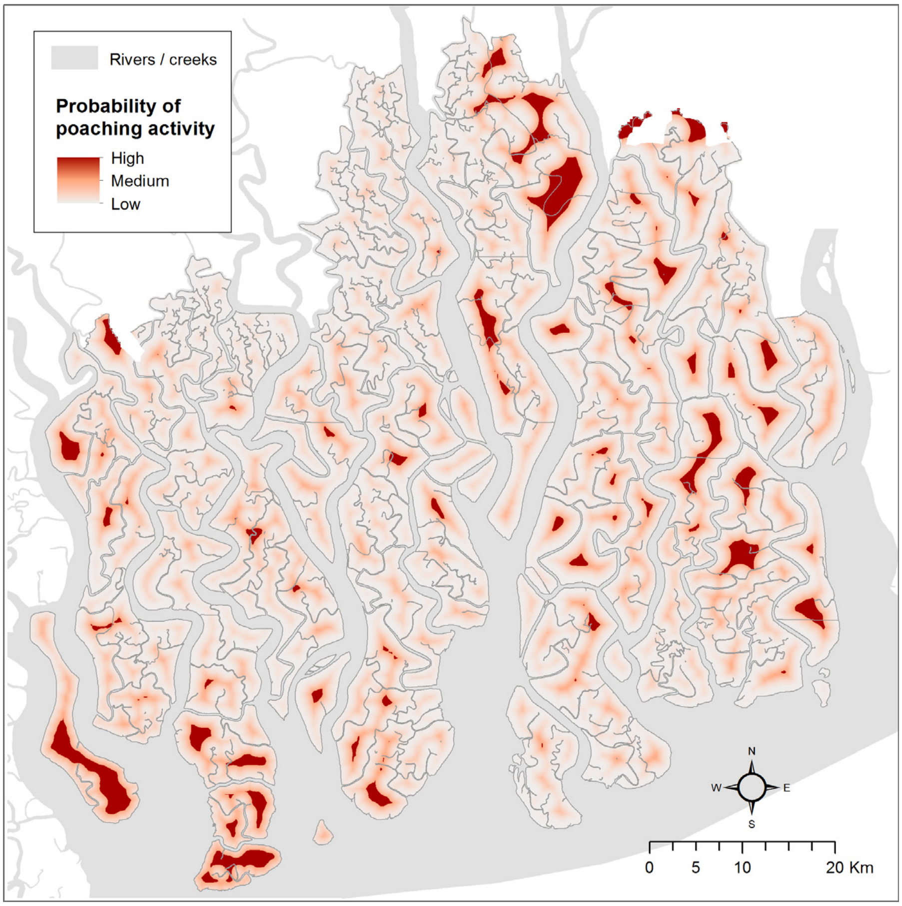

Fig. 4. Probability of poaching activity derived from negative binomial regression coefficients of the distance to guard posts and distance to water.

The method of shooting deer was indicated from one case of a deer carcass with bullet wounds (Fig. 3, E). We also observed small-sized snares ($n = 9$) targeted for the red jungle fowl (*Gallus gallus*) in the SB.

3.2. Poaching intensity

Of the six tiger poison baits, four were recorded in the WS and two in the ES. No bait stations were found in the CB and SB. We recorded 1427 ungulate snare loops in 56 snare sets across the SRF. Of these, 1141 snare loops were found in 12 *daon*, 237 snares in 15 *fush* and 29 *chhitka*. Overall, 83% were neck and 17% were leg snare sets. The number of snare loops in each set ranged from a single neck snare (usually *chhitka*) to a maximum of 296 neck snares in a single *daon*. The estimated mean density of snare set was 6 snare sets/100 km^2 of forest, which is equivalent to 273 snare sets (95% CI: 204–341) for the whole SRF landscape. With an average of 23 (range = 1–296, SDEV = ±54) snare loops/set, this is equivalent to approximately 6268 (95% CI = 4692–7843) snare loops set out in the SRF at any one time, or 147 snare loops/100 km^2.

Dead animals found in snares were one spotted deer, one wild boar, and one red jungle fowl, all of which were found in the SB. In addition, we observed ungulate slaughter locations in the ES with evidence of spotted deer skin ($n = 5$), and in the South wildlife sanctuaries with skin, guts, and head of spotted deer ($n = 15$) and wild boar ($n = 2$). In the SB we released a live spotted deer and a rhesus monkey from snares.

3.3. Drivers influencing poaching intensity

Overall higher poaching activities were recorded in WS (37%) following ES (25%), SB and CB (19%) areas. One-way ANOVA analysis ($\alpha = 0.05$) showed that the difference in poaching activities between sample areas was not significant, $F(3, 59) = 2.169, p = 0.101$. The negative binomial regression model identified two significant drivers that likely influenced poachers to select sites for poaching activity in the SRF: distance to forest guard posts and distance to the nearest river (Table 1). The occurrence of poaching activity was significantly positively correlated with the distance from forest guard

Table 1
Predictors associated with poaching activity in the SRF using negative binomial regression fit to Poisson distribution.

Response	Predictors (drivers)	β	SE	Z value	Pr(>|z|)
Occurrence of poaching activity	(Intercept)	4.43	0.51	8.65	2e−16
	Protection status	0.05	0.49	0.09	0.925
	Distance to guard post	0.06	0.03	2.21	0.027
	Distance to the river	2.97	1.03	2.87	0.004
	Distance to forest boundary	−0.06	0.51	−1.44	0.149

posts ($\beta = 0.06$, $SE = 0.03$, $p = 0.027$), and significantly positively correlated with the distance from the nearest river ($\beta = 2.97$, $SE = 1.03$, $p = 0.004$). However, protection status ($\beta = 0.05$, $SE = 0.51$, $p = 0.925$) and distance from the forest boundary ($\beta = -0.06$, $SE = 0.51$, $p = 0.149$), did not significantly predict the number of poaching activities (Fig. 4).

4. Discussion

4.1. Poaching methods

This is the first field-based study to specifically identify carbofuran as a poison used to kill tigers in the Sundarbans. Although previous studies reported unknown poison in baiting carcasses (Neumann-Denzau, 2006), and arrestees with unidentified liquid intended to poison tiger's kill in the SRF (Khan, 2004). A recent study based on interview data reported range of poison including carbofuran used in tiger killing (Saif et al., 2016). The carbofuran pesticide used to poison carcasses to catch kills tigers is readily and cheaply available in local markets, and is widely used in crop production worldwide (Reljić et al., 2012). While it appears that the use of carbofuran to kill tigers is significant, it is not well reported in peer-reviewed literature, though there are numerous reports of its use in poisoning other wild animals (Guitart et al., 2010; Hernández and Margalida, 2008; Jung et al., 2009; Satar et al., 2005; Wobeser et al., 2004). In Africa in particular, carbofuran has lead to substantial reductions in populations of lions (Frank et al., 2006), vultures and large mammals (Brown, 2006, 1991) and hyenas (Hofer and Mills, 1998). Use of such poisons may kill both the target animal and any other animal that consumes the poisoned carcass. In the SRF, for example, this would include monitor lizards, wild boar, and lesser adjutant storks (Adam Barlow, personal observation). This is supported by our study, which found four dead monitor lizards within 3 m of a poisoned tiger bait. Carbofuran is classified by the US Environmental Protection Agency (EPA) as a group I toxin, and in most cases, animals die from respiratory failure following ingestion (Tomlin, 2000).

Poaching of deer with snares has been reported from the SRF over several decades (Jagrata Juba Shangha, 2003; Salter, 1984). A previous study documented a case where poachers had been arrested with a snare intended for deer poaching in the ES (Khan, 2004), but our study is the first to document the different types of snare sets used in the SRF. Of all the snare types identified in the SRF, the *daon* snare, with its multiple snare loops, was particularly destructive, as it had the potential to capture large number of animals at a time. The observed practice of setting snares near to trails and using prey-preferred bait plants suggests that poachers have been well adapted to the SRF landscape and applied local knowledge about the species' behaviour to increase their chances of success, as poachers have done in other landscapes (Gadgil et al., 1993).

Interestingly, in one instance we found a plastic sack full of snares, which may suggest that the poachers store their snares in the forest rather than carrying with them. This practice may reduce the poaching effort and also reduce the chances of capture with incriminating evidence by authorities.

Although poaching of tigers using snare traps or cable snare has been detected in most tiger range states (Johnson et al., 2016; Shepherd and Magnus, 2004; Wright, 2010), in the SRF the snare materials, placement, and association with prey food suggest that the snares were set up to only target tiger prey. Similar to the poison baits, snares may also lead to the capture, injury, and death of non-target species (Barlow, 2009). For example, in 2013 in the SRF a tiger was seen with the loop of a nylon snare tightly constricting its forearm. Another tigress were rescued from a village adjacent to the SRF in 2012 that had probably escaped from a prey snare and had lost its right hind leg (Reza et al., 2012).

Although only detected once in this study, poaching of tigers and prey by shooting with a gun may be more widespread in the SRF, as it is in other South-Asian landscapes (Madhusudan and Karanth, 2002). For example, in 2016 a group of deer poachers was arrested with hides and guns from the SRF.

4.2. Poaching intensity

It seems reasonable to conclude that tiger poaching, particularly by poison bait, could be one of the underlying causes of the recorded decline in relative tiger abundance in the SRF over the past 7 years (Aziz et al., 2013; Rahman et al., 2012). Likewise, the estimated 147 snare loops/100 km^2 in the SRF indicates a widespread and large-scale threat to the tiger's prey base in the SRF. This level of snaring intensity in the SRF is very high compared to approximately 21 trap sets/100 km^2 recorded in Kerinci Seblat National Park of Sumatra (Linkie et al., 2015). The estimated snare loop density in our study is also higher than the estimate of 55 snares/100 km^2 reported from the Tsavo National Park, Kenya where bush meat hunting is a common practice (Wato et al., 2006). The widespread and intensified prey snaring in the SRF is likely driven by the high levels of prey meat consumed by local people, that may account for 11 195 deer being killed annually (Mohsanin et al., 2013). The continued reduction of the tigers' prey base may well also be contributing to the overall recent decline in tiger abundance (Chapron et al., 2008; Karanth and Stith, 1999). However, additional modelling of the response of the tiger population to tiger and prey poaching levels is needed to better quantify these threats.

4.3. *Drivers influencing poaching intensity*

The relatively high concentrations of poaching activities within the sanctuaries, may be due to the relatively high density of tigers and prey in these areas (Dey et al., 2015). We found that there was higher poaching intensity in the WS compared to the ES, which is in line with a recent study assessing the frequency of illegal human activity associated with wildlife crimes detected in these areas (Hossain et al., 2016). Of note, the highest number of prey snare loops in a single *daon* ($n = 296$) was also recorded in the WS. The positive relationship of poaching activities with the distance to forest guard posts suggest that poachers avoid these guard posts to reduce their chances of detection from the authorities. This also explains why a high intensity of poaching activities was recorded in the south and southwest areas of WS, where two forest guard posts were either destroyed or temporarily abandoned (Fig. 4). In the Khao Yai National Park of Thailand, Jenks et al. (2012) observed similar situation where poaching activity generally increased away from ranger stations.

While seemingly reducing their chances of detection, poachers seem to be reducing their effort by carrying out their activities close to the navigable rivers and creeks. Unlike in other landscapes where poachers avoid transport networks (Kimanzi et al., 2015), the poachers use of the SRF transport network may indicate either a low level of patrolling by the authorities (Hossain et al., 2016) or an ability of the poachers to disguise their intentions while using the transport network. The reduction of effort may also have the added advantage of enabling the poachers to check the bait and snare sets more regularly to avoid animals escaping or decomposing (Wato et al., 2006). Our observations of intensive human foot-prints around baits and snares suggest that poachers checked their bait and snare regularly to ensure a timely capture of ensnared or poisoned animals, and replacement of bait.

Our finding that there was no significant effect of distance from the forest boundary on bait and snare intensity in the SRF differed from studies in other landscapes where poaching signs were shown to either increase with distance to the forest boundary (Wato et al., 2006; Kimanzi et al., 2015), or decrease with the increase of distance from the forest boundary (Fitzgibbon and Mogaka, 1995). However, our results approached significance ($P = 0.101$), suggesting that there was some effect that may have become significant with larger samples.

A camera trap study that detected high levels of activities such as fishing and wood collection in the SRF wildlife sanctuaries did not detect any poaching activities (Hossain et al., 2016), despite there being high numbers of snare and bait sets in those areas. This indicates that poaching in the SRF is being carried out as an ancillary activity by other types of resource collectors, where nylon rope in particular can be used and transported for repairing fishing gear or making snares. This would be a similar situation to other landscapes such as Tsavo West National Park, Kenya, where honey gatherers were found to be setting snares while staying in the forest (Wato et al., 2006). Alternatively, poachers could be disguising themselves as honey collectors or fishermen, or simply travelling with these groups.

4.4. *Conservation implications*

This study demonstrated a simple approach to investigating the methods, intensity and distribution of poaching, that could be replicated across all tiger landscapes to better direct mitigating actions and monitor changes to tiger and deer poaching. However, the approach we used does not appear an effective means of detecting the poachers themselves. Like the SRF, many conservation situations involve dealing with poachers that are difficult to detect because they actively avoid check points and/or disguise their activities. Although reducing poaching ultimately requires tackling the demand for the wildlife products outside the forests, there is scope to improve how poachers are detected and identified while trying to catch animals in the forest. For example, the effectiveness of existing patrolling techniques could be increased by concentrating efforts away from guard posts and close to waterways, using randomized patrol times and routes, and searching boats for poaching implements and captured prey. Likewise, improving anti-poaching intelligence networks is an effective and cost-effective way to strengthen any patrolling efforts, as well as incorporating the use of new intelligence technologies and software to enhance poaching detection. While drones or remote sensing methods may be able to detect the presence of vehicles and people in a landscape, they do not necessarily facilitate the linking of those vehicles and people to an illegal activity. As an alternative, our study suggests that remote camera traps would be a useful tool to identify poachers when they return to their snare or bait sets. Camera traps are relatively low cost, are generally more robust and harder to detect, and can produce better evidence than a forest guard trying to collect the same evidence. However, camera traps may be less intrusive than ranger patrols but they should be hidden and made secure to reduce the risk of detection and theft.

Wildlife sanctuaries in the SRF are closed to all resource extraction, including fishing and honey collection. Since the only access to the sanctuaries is by boat, excluding people from these areas would relatively simple matter by increasing the surveillance and patrolling of rivers and waterways. Boats are easily detected, relative to poachers travelling on foot through dense forest as is the case throughout much of tiger range, and therefore could be easily captured by rapid response teams equipped with appropriate speedboats. Future developments would include technology like drones and camera traps with real time GSM or satellite uplinks which could help to guide patrols to suspect boats.

In addition, this study and others suggest that there is a risk of wide spread use of carbofuran as a poison to kill tigers across their range. Tigers have been killed by an unidentified poisons in Nepal (Martin, 1992), India (Wright, 2010) and

Sumatra (Tilson et al., 2010), and the use of carbofuran is commonly reported by conservation practitioners in S and SE Asia (J. Goodrich, unpublished data). Banning the use of carbofuran, or at the very least restricting its use in the SRF and other tiger range states would be an important first step in making it more difficult for poachers to use this method. In other parts of the world such as the European Union, Canada, the United States of America and parts of Africa, carbofuran use has already been prohibited or severely restricted (Ogada, 2014; Reljić et al., 2012; Ruiz-Suárez et al., 2015).

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Appendix

Table A.1
Records of seizures of tiger parts in Bangladesh from 2011 to 2016.[a]

Date	Location of seizure	Tiger parts seized	Seizure notes
26-Aug-16	Koyra, Khulna	1 tiger skin	Six poachers arrested
21-Jul-16	Paikghacha, Khulna	Tiger bones (15 pieces)	Two poachers arrested
04-Mar-16	Bhatiagat, Khulna	1 tiger skin	Two traders arrested
04-Mar-16	Koyra, Khulna	1 tiger skin	Two traders arrested
26-Aug-15	Khulna city, Khulna	1 tiger skin	Two smugglers arrested
25-Aug-15	Koyra, Khulna	Tiger bones (5 pieces)	Bones recovered by Forest Department
09-Aug-15	Mandarbaria, Sundarbans	3 tiger skins	Five poachers arrested
08-Aug-15	Rupsha, Khulna	Tiger bones (69 pieces)	Two poachers arrested
09-Jun-15	DCCmarket, Dhaka	1 tiger skull, 15 bones	Also seized 20 vanity bags made of skins of tiger, fishing cat, monitor lizard and snake
13-May-15	Sarankhola, Bagerhat	1 skull and157 tiger bones, deer snares	One poacher held
05-Feb-15	Tala, Satkhira	1 tiger skin	One poacher held
25-Feb-15	Assassuni, Satkhira	1 tiger skin, 4 deer skins	Three poachers arrested
20-Feb-15	Bhandaria, Pirojpur	1 tiger skin, 14 deer skins	One poacher held
19-Jan-15	Kalabagan, Dhaka	1 skin, 5 deer skins	Tiger skin had bullet holes indicating killed by gun
14-Jan-15	Morrelganj, Bagerhat	1 skin, 1 skull, 25 bones, 29 teeth	Skin was about 10 ft long; immediate destination was Bagerhat
17-Oct-14	Satkhira sadar, Satkhira	2 tiger skins	Six poachers arrested with 2 fresh skins without any bullet signs
27-Jan-14	Khulna, Sundarbans	1 injured tiger	Female tiger rescued but eventually died; tiger escaped from rope snare on her right arm
13-Apr-13	Uttara, Dhaka	1 tiger skin	Two foreigners arrested with a skin
11-Jun-12	Shaymoli, Dhaka	3 tiger cubs	Honey collectors caught them live from Satkhira range and then handed over to group of smugglers
08-Dec-11	Mothbaria, Pirojpur	1 tiger skin, 18 pieces of bones	No sign of bullet or trap on skin; destination was Benapole close to Indian border
16-Feb-11	Sarankhola, Bagerhat	3 skins; 4 skulls, 32 kg bones (138 pieces) of tigers	Tigers poisoned with baits comprising 2 males and 1 female, with another skull

[a] This information was collected from different secondary sources, and validated with wildlife crime database of WildTeam, which keeps records only after verification with Forest Department and law enforcing agencies.

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