Prioritizing threats to improve conservation strategy for tigers *Panthera tigris* in the Sundarbans Reserve Forest of Bangladesh

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SUPPLEMENTARY TABLE S1 Information used for ranking threats to tigers in the Sundarbans Reserve Forest.

Threat	Ranking criteria	Information source & rational for ranking
Poaching	Scope	We assume tigers could be poached from anywhere in the Sundarbans Reserve Forest, which may reduce both the tiger population size & occupancy.
	Severity	At present low numbers of poaching incidents are reported from the Sundarbans Reserve Forest, with up to two tigers each year being recorded (Gani, 2002; Ahmad et al., 2009; Forest Department records), but the majority of incidents are unlikely to be detected because of the covert & illegal nature of this activity. Tiger poaching has also been documented as a threat elsewhere, driven in part by the traditional Asian medicine trade so this is reason to assume that it is also taking place in the Sundarbans Reserve Forest (Nowell, 2000; Newman, 2004; Shepherd & Nolan, 2004; Nowell & Ling, 2007). Recent anecdotal evidence from dacoits (local pirates) suggests that at least five tigers have been poached between October 2009 & April 2010. On the 16 February 2011, a poacher was caught in a village adjacent to the Sundarbans Reserve Forest with three tiger skins & four tiger skulls.
	Irreversibility	Reversing this threat relies on improved law enforcement & change in consumption behaviours. If the threat of tiger poaching is reduced/removed then the tiger population can recover through normal reproduction.
Killing of strays	Scope	Killings of stray tigers are restricted to the northern village areas & adjacent forest areas of the Sundarbans Reserve Forest (Gani, 2002; Barlow, 2009), so this threat will only affect occupancy of tigers that frequent the forest area bordering the villages. However, dependent on the scale, this additional source of tiger loss could have long-term impact on the size of the tiger population (Chapron et al., 2008; Goodrich et al., 2008).
	Severity	Records show that up to three stray tigers are killed each year (Gani, 2002; Reza et al., 2002; Ahmad et al., 2009; Barlow, 2009) but an unknown number may also be killed but undetected by authorities.
	Irreversibility	Loss of stray tigers can be reversed by improving attitudes of local villagers towards tigers, creation of tiger response teams, & monitoring of problem tigers (Ahmad et al., 2009; Barlow et al., 2010). If the threat of killing of stray tigers is reduced/removed then it is assumed that the tiger population can recover through normal reproduction.
Disease	Scope	All tigers across the Sundarbans Reserve Forest are potentially at risk from a variety of pathogens transmitted by domestic animals (Ahmad et al., 2009). Domestic cats are kept in Forest Department guard posts throughout the forest, to control vermin, & some posts keep chickens (Hossain et al., 2009). Domestic animals are also present in the villages outside the northern & eastern boundaries of the forest. Livestock enters the forest in some areas & some tigers predate livestock in both forest & villages areas (Rahman et al., 2010). As a result, disease may be easily transmitted to tigers from these active sources, which could potentially reduce the tiger population size.
	Severity	No empirical studies are available on tiger disease in the Sundarbans Reserve Forest so the potential severity of this threat is unknown, but

Threat	Ranking criteria	Information source & rational for ranking
		assumed to be medium until further research is carried out. It is likely that tigers that die from disease will do so undetected because the population is not subject to intensive study (Ahmad et al., 2009). Captive tigers elsewhere in the world have died from avian influenza, & captive & wild tigers have died from canine distemper (Appel & Summers, 1995; Myers et al., 1997; Keawcharoen et al., 2004). Both diseases are transmitted by domestic animals.
	Irreversibility	Reversing the threat of disease depends on the type of disease & the scale of the outbreak. Given the difficulty inoculating a wild tiger population (& assuming there is no current outbreak in the Sundarbans Reserve Forest) then it may make more sense to inoculate domestic animals & prevent contact between domestic animals & tigers. If the threat of tiger disease is reduced/removed then it is assumed that the tiger population should be able to recover over time through normal reproduction.
Inbreeding depression	Scope	Inbreeding depression could potentially affect all the tiger population (Smith & McDougal, 1991) but is assumed currently to be unlikely to do so considering the dispersal capabilities of tigers (Smith, 1993) & the relatively large tiger population size (Barlow, 2009). Inbreeding depression may potentially reduce the tiger population size.
	Severity	Severity of this threat is assumed to be low considering the relatively large size of the population (Barlow, 2009).
	Irreversibility	Inbreeding depression can be reversed by translocation of tigers from other populations of similar genetic ancestry. However, tigers in the Sundarbans Reserve Forest appear to have a distinct morphology compared to other tiger groups (Barlow, 2009), & their genetic relationship to other tiger groups is currently under investigation. Dependent on the results of genetic analysis, there may be limited sources of suitable tigers to translocate to the Sundarbans Reserve Forest from other populations.

SUPPLEMENTARY TABLE S2 Information used for ranking threats to prey in the Sundarbans Reserve Forest.

Threat	Ranking criteria	Information sources & rational for ranking
Poaching	Scope	Depletion of prey populations has already been documented (Reza et al., 2002; Jagrata Juba Shangha, 2003). Prey may be poached from any part of the Sundarbans Reserve Forest because of the widespread distribution of forest users, which may reduce both the prey population size & occupancy.
	Severity	An initial study on the scale of consumption of prey parts in the villages immediately adjacent to the Sundarbans Reserve Forest suggests that a large number of prey are consumed each year (c. 10,000 deer per year) (Mohasin, unpubl. data). As yet there is no estimate of the scale of the consumption of deer in other areas (e.g. by forest users whilst at work inside the forest). The impact of poaching of prey on the Sundarbans Reserve Forest deer population has yet to be estimated because no population estimate or research on vital rates have been carried out. However, it is assumed that current poaching levels will have a large impact on the prey population.
	Irreversibility	Reversing this threat would require improved forest protection & reducing demand for prey products.
Disease	Scope	Prey population & their occupancy could be depleted through disease introduced by domestic animals; in some northern parts of the forest deer share habitat with cows, buffalo, goats & dogs (Rahman et al., 2010).
	Severity	No empirical studies are available on diseases of prey in the Sundarbans Reserve Forest so the potential severity of this threat is unknown but assumed to be low until further research is carried out.
	Irreversibility	Reversing the threat of diseases of prey depends on the type of disease & the scale of the outbreak. Given the difficulty inoculating a wild prey population (& assuming there is no current outbreak in the Sundarbans Reserve Forest) then it may make more sense to inoculate domestic animals & prevent contact between domestic animals & prey. If the threat of diseases of prey is reduced/removed then the prey population should be able to recover over time through normal reproduction.

SUPPLEMENTARY TABLE S3 Information used for ranking threats to habitat in the Sundarbans Reserve Forest.

Threat	Ranking criteria	Information sources & rationale for ranking
Sea level rise	Scope	Although improved understanding of sea level rise is required, some current estimates of sea level rise are >1 m by 2100 (Hansen, 2007; Rahmstorf, 2007). This has scope to affect the whole area, which is low lying & has a mean elevation of c. 1 m (Loucks et al., 2010). Thus, sea level rise may greatly increase salinity levels & reduce habitat coverage (Smith et al., 2008).
	Severity	Not accounting for other factors such as sedimentation rate, predicted sea level rise may inundate >70% of the terrestrial habitat in the next 100 years (Loucks et al., 2010). Beyond 28 cm sea level rise, the Sundarbans tiger populations are unlikely to remain viable (Loucks et al., 2010).
	Irreversibility	Reversing this threat would require reduction of greenhouse gas emissions to reduce global temperatures.
Upstream water extraction/ divergence	Scope	Decreased freshwater supply has the scope to affect the whole Sundarbans Reserve Forest mangrove ecosystem. Decreased freshwater flow may increase salinity levels, particularly in the dry season, which could change vegetation patterns (Agrawala et al., 2003). Population of the Ganges River dolphin, because of their obligate dependency on freshwater flow, will be affected by the decrease of freshwater flow in the Sundarbans Reserve Forest (Smith et al., 2008).
	Severity	The pattern of the flow from the Ganges at Hardinge bridge has changed since 1975 because of the diversion of water at Farakka barrage in India, 17 km upstream from the Bangladesh border; the minimum daily flow has decreased by 43% (Karim, 1994). There has been further loss of freshwater because of increasing upstream water use driven by a burgeoning human population & the construction of additional barrages & dams in Bangladesh & India (Sarkar & Bhattacharya, 2003; Wahid et al., 2007).
	Irreversibility	Reversing this threat would require reduction of upstream water extraction & divergence.
Wood collection	Scope	Wood is collected for many uses, including house construction, furniture, boat building & fuel (Iftekhar & Islam, 2004). Wood collection occurs across the whole Sundarbans Reserve Forest. Goran *Ceriops decandra* & sundri *Heritiera fomes*, appear to be the main targets for felling, but other species such as gewa *Excoecaria agallocha*, keora *Sonneratia apetala*, baen *Avicennia officinalis* & passur *Xylocarpus mekongensis* are also taken (Iftekhar & Islam, 2004), which could substantially reduce the density of these tree species.
	Severity	The terrestrial habitat of the Sundarbans Reserve Forest has degraded over time, probably in part due to harvesting trees beyond the replenishment capacity of the forest, including both legal & illegal extraction (Chaffey et al., 1985; Salam & Noguchi, 1998; Blasco & Aizpura, 2002; Iftekhar & Islam, 2004; Iftekhar & Saenger, 2008). It is estimated that gewa has been depleted by 40% & sundri reduced by 45% from a combination of cutting & disease (Chaffey, 1985; Iftekhar & Islam, 2004).

Threat	Ranking criteria	Information sources & rationale for ranking
	Irreversibility	Can be reversed with improved forest protection, reducing the demand for Sundarbans Reserve Forest wood, & making adjustments to wood harvesting regimes.
Fishing & harvesting of other aquatic resources	Scope	Fishing, crab collection, prawn collection & shrimp fry collection are widespread in the Sundarbans Reserve Forest (Islam & Haque, 2004). These ongoing resource extractions/activities may adversely affect the population of Ganges River dolphin in the channels of the Sundarbans Reserve Forest.
	Severity	Degradation of the Sundarbans Reserve Forest aquatic environment through continued overexploitation of the fisheries may also have a negative effect on the overall ecosystem (Miah et al., 2003; Islam & Haque, 2004).
	Irreversibility	Reversing this threat will require improved forest protection, increased availability of alternative livelihoods for local people, & reduction in demand for Sundarbans Reserve Forest aquatic resources.
Invasive species	Scope	A Sundarbans Reserve Forest-wide survey found almost 88% of the investigated plots were affected by invasive species (Biswas et al., 2007). Of the identified 23 invasive species, notable species such as the *Derris trifoliata, Micania scandens* & *Eupatorium odoratum* have been known to pose serious threat to seedlings & saplings of the major mangrove species (Biswas et al., 2007), which may affect the density of trees.
	Severity	More than 55% of the investigated plots were severely affected, 25% are moderately affected & only 8% did not show any significant affect (Biswas et al., 2007).
	Irreversibility	A 2007 study found that invasive species in the Sundarbans Reserve Forest were still at a manageable level (Biswas et al., 2007). However, monitoring & management intervention activities are not in place, & the impact on tiger & prey habitat is not fully understood.
Sea acidification	Scope	It is assumed that sea acidification may have some detrimental effect on the survival, reproduction & dispersal of mangrove tree species, and thus may degrade their abundance & density. This threat may also affect the aquatic ecosystem component (e.g. dolphins) of the Sundarbans Reserve Forest.
	Severity	Unknown
	Irreversibility	Unknown
River pollution	Scope	Considering orientation of the river system, river pollution has scope to affect about a quarter of the Sundarbans Reserve Forest fed by the Passur River; this may transport pollutants from nearby Khulna or as far away as Dhaka, and may affect both the terrestrial (e.g. tree density) & aquatic ecosystems (e.g. dolphin population).
	Severity	River pollution due to run-off of indiscriminate use of fertilizers, pesticides in agriculture & aquaculture, effluents from upstream industries, housing & urban wastes, & oil spills from ships has been documented (Lacerda et al., 1988; Wahid, 1995; Miah & Bari, 2001; IUCN Bangladesh, 2003). The current & future

Threat	Ranking criteria	Information sources & rationale for ranking
		impact on the mangrove ecosystem is unknown but assumed to be medium pending further research.
	Irreversibility	Unknown
Mineral & gas extraction	Scope	Large-scale fossil fuel exploration & extraction has not been carried out so far in the Sundarbans Reserve Forest but the potential for such activities remains a threat (Roy et al., 2002; Mukhopadhyay, 2004). Both terrestrial & aquatic ecosystem components (e.g. tree density & dolphin population size) would be affected if such activities take place in the Sundarbans Reserve Forest.
	Severity	Unknown
	Irreversibility	Reversing this threat would require political efforts to block mineral or gas extraction projects in the Sundarbans Reserve Forest.
Storm & tidal surge	Scope	Periodic cyclones can lead to uprooting, leaf shed, & general tree damage in the Sundarbans Reserve Forest (Harun-or-Rashid et al., 2009). Vegetation of c. 152,800 ha in the eastern Sundarbans Reserve Forest was affected by the cyclone Sidr (Bangladesh Forest Department, 2007). Thus, vegetation damage by storm & tidal surge may deplete tree density. However, tidal surges are transient & are assumed to have little effect on the mangrove ecosystem, which is adapted to periodic inundation of saline water.
	Severity	Habitat alteration by cyclones is a natural component of the Sundarbans Reserve Forest ecosystem (McLeod & Salm, 2006). However, climate change modelling studies suggest a potential future increase in the destructive potential of cyclones from 40% to 60% (Emanual, 1987). However, so far there has been no overall increasing trend in cyclone frequency since 1900 (Islam & Peterson, 2008).
	Irreversibility	A rise in global air & sea temperatures would result in a higher frequency & intensity of cyclones, so solutions would require a decrease in the green house gas emissions responsible for rising temperatures.
Melting Himalayan glaciers	Scope	Himalayan glacial melt would probably only affect rivers in the east of the Sundarbans Reserve Forest; rivers in the west are largely cut off from river systems fed by Himalayan glaciers. The ultimate reduction of freshwater flow from melting Himalayan glaciers would adversely affect vegetation (e.g. tree density) as well as components of the aquatic ecosystem (e.g. dolphin population).
	Severity	Freshwater flow into the Sundarbans Reserve Forest may be affected by climate change-induced melting of Himalayan snows (Agrawala, et al. 2003; MoEF, 2008). Glacial melting will probably increase water flow initially but water flow will then decrease over the long-term because of the reduction in ice mass available for melting (Rees & Collins, 2006).
	Irreversibility	Would require a reduction in green house gas emissions.
Temperature change	Scope	Temperature fluctuations can affect mangrove growth & development (McLeod & Salm, 2006). However, temperature

Threat	Ranking criteria	Information sources & rationale for ranking
		rise is unlikely to adversely affect mangrove ecosystems in general (McLeod & Salm, 2006).
	Severity	The recent forecast of the Intergovernmental Panel on Climate Change reveals that the global mean temperature is expected to increase by 2.4°C by the end of this century (Alam & Ahmed, 2010). This temperature rise is not thought to be a severe threat to the mangroves, considering their temperature tolerance (McLeod & Salm, 2006).
	Irreversibility	Reversing this threat would require a reduction in greenhouse gas emissions.
Plant disease	Scope	Top dying disease occurs across the whole of the Sundarbans Reserve Forest (Rahman, 1994). However, it only affects some tree species such as sundri & passur & thus depletes their density (Salam & Noguchi, 1998; Blasco & Aizpura, 2002; IUCN Bangladesh, 2003). Information on other diseases of vegetation is lacking.
	Severity	For those affected species, out of 55 administrative compartments of the Sundarbans Reserve Forest, disease incidence was recorded as severe in 16 of 55 compartments & moderate in six compartments (Rahman, 1994).
	Irreversibility	Treatment unknown
Commercial infrastructure	Scope	This is a threat because commercial infrastructure reduces the area for mangroves to grow & tree density because of cutting forest trees in establishing commercial infrastructure. Commercial infrastructure is restricted to Dubla island & nearby coastal beaches where seasonal fishing industries have been established (Huda & Haque, 2001).
	Severity	It is reported that a total of 78 seasonal fishing depots were present between 1999 & 2000 in the Sundarbans Reserve Forest (Huda & Hauqe, 2001).
	Irreversibility	Reversing this threat would require political will to reduce/ban commercial infrastructure within the forest boundary.
Housing infrastructure	Scope	This is a threat because housing infrastructure reduces the area of mangrove habitat. There is no permanent human habitation permitted inside the forest apart from by the Forest Department, coast guard & navy camps. However, there is semi-permanent housing infrastructure at Dubla (Ahmad et al., 2009).
	Severity	Reports shows that a total of 696 houses were established by fishermen between 1999 & 2000 during the fishing season (Blower, 1985; Canonizado & Hossain, 1998; Huda & Hauqe, 2001).
	Irreversibility	Reducing this threat would require political will to remove housing infrastructure.
Livestock grazing	Scope	Villagers sometimes let their livestock graze inside the forest, particularly in the north-east of the Sundarbans Reserve Forest; encompassing approximately a third of the forest-village boundary (Rahman et al., 2010). Livestock grazing may diminish the tree density & may also affect the tiger & prey population by introducing disease agents.
	Severity	Some forest areas close to the villages in the north & north-east

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		appear to be degraded. This may be in part due to livestock grazing in these areas (Rahman et al., 2010). Additional degradation to this small forest area is unlikely to severely impact the forest as a whole, considering the threat's scope.
	Irreversibility	Reversing this threat would require changing livestock grazing practices & improving law enforcement.
Fire	Scope	Fires in the Sundarbans Reserve Forest are generally uncommon & restricted to the eastern boundary between the forest & the villages during the dry season (February–April). For example, in 2010 a forest fire damaged c. 5 acres of forest in east of the Sundarbans Reserve Forest. Since 2001, at least nine forest fires have occurred in Sarankhola & Chandpai ranges, which might have depleted the area of available habitat.
	Severity	Forest fires are unlikely to be a severe threat considering their frequency & scope.
	Irreversibility	Reversing this threat would require improved understanding of the causes of these forest fires.
Collection of non-timber forest products	Scope	Collection of non-timber forest products is carried out throughout the Sundarbans Reserve Forest. The main forest products collected are honey, sun grass & golpata (Iftekhar & Islam, 2004). At this moment, no tangible impacts affecting the vegetation of the Sundarbans Reserve Forest have been observed but may be affected if such extraction goes beyond the carrying capacity.
	Severity	Hundreds of thousands of people enter the Sundarbans Reserve Forest every year to harvest non-timber forest products (Ahmad et al., 2009). It is unknown how much is extracted each year but it is assumed that collection of these products is sustainable & has little negative impact on overall habitat quality.
	Irreversibility	Reducing this threat would require increased law enforcement, & reduction in demand for non-timber forest products.