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

Abdul Aziz, Adam C. D. Barlow, Christina C. Greenwood and Anwarul Islam

Abstract Tigers *Panthera tigris* face a wide and complex array of threats. Given limited time and resources it is essential to direct conservation actions based on the relative importance of each threat. The Sundarbans Reserve Forest is the last stronghold of tigers in Bangladesh and supports one of the largest populations of tigers in the world. As in other tiger landscapes, the threats faced by the tigers have yet to be assessed. This study follows an approach developed by The Nature Conservancy to identify and prioritize threats and set a time-frame for their reduction. We identified a total of 23 threats; four were linked to tigers, two to prey and 17 to habitat. Of the identified threats, the highest ranked included poaching of tigers, poaching of prey, sea-level rise, upstream water extraction/divergence, wood collection, fishing, and harvesting of other aquatic resources. All threats were then scheduled for reduction, based on the rank and current information base for each threat and the likely time-frame for implementing potential solutions. This study demonstrates how the application of a prioritization framework can greatly improve the focus and likelihood of success of any species- or ecosystem-based conservation programme.

Keywords Bangladesh, *Panthera tigris*, Sundarbans Reserve Forest, threat prioritization, tiger

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Introduction

Wild tiger *Panthera tigris* populations have declined by at least half over the last decade alone, with the current number estimated to be 3,200–3,600, excluding cubs (Seidensticker, 2010). To reverse the current downward trend of tiger populations, protecting source sites (Walston et al., 2010) and maintaining metapopulations (Wikramanayake et al., 2011) have been proposed as conservation goals. To achieve such goals and to design, prioritize and implement conservation actions that will save tigers from extinction, threats to tigers need to be identified and ranked in terms of their potential impact (TNC, 2007). If all threats are not considered and explicitly assessed there is a risk that conservation efforts are wasted on low-priority threats while the biological target is degraded or lost as a result of higher priority threats. In addition, given limited time and resources, we need to identify the optimum allocation of the available resources for conservation actions (Sinclair et al., 1995).

Guidelines for threat assessment have been created by The Nature Conservancy (TNC, 2007). The first step in this assessment is to set the scope and biological targets upon which the threats are acting and to assess the viability of those targets (TNC, 2007). The scope provides the overall goal and the scale of the conservation issue, and the specified targets establish a clear focus upon which planning and monitoring steps are concentrated (TNC, 2007). To achieve conservation goals, a threat reduction time-line can then be developed to deal with each threat, based on its priority.

Despite decades of conservation efforts, however, there has been little assessment or identification of the multitude of threats facing tigers and the landscapes they inhabit. A study in Russia documented tiger mortality from poaching (Kretchmar, 2006), and theoretical models have been developed to investigate the potential impact of poaching (Kenney et al., 1995) and depletion of prey (Karanth & Stith, 1999). Furthermore, habitat destruction is the only threat that has been examined across all of the remaining 76 Tiger Conservation Landscapes (Sanderson et al., 2006; Nagendra et al., 2010). Assessing threats to tigers and the effects of conservation actions involves monitoring the status of the tiger population in question and the status of the resources, such as prey and habitat, on which the population depends (TNC, 2007).

One of the most important remaining Tiger Conservation Landscapes is the Sundarbans Reserve Forest of Bangladesh and India. The Bangladesh Tiger Action Plan was developed to provide guidelines for tiger conservation efforts from 2009 to 2017 (Ahmad et al., 2009). The vision of the Action Plan is 'protected tiger landscapes in Bangladesh, where wild tigers thrive at optimum carrying capacities and which continue to provide essential ecological services to

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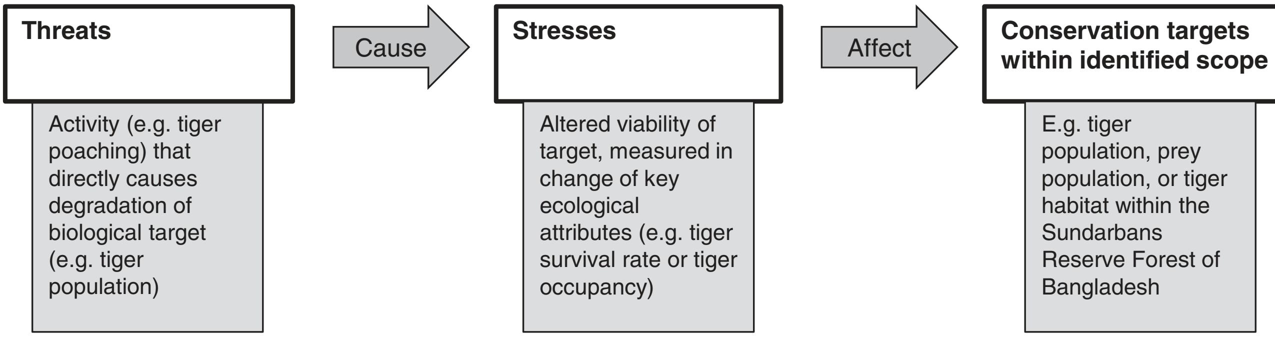

FIG. 1 Relationship between threats, key ecological attributes, and biological targets (adapted from TNC, 2007).

mankind' (Ahmad et al., 2009). The Sundarbans Reserve Forest constitutes almost half of the remaining forest in Bangladesh and is the last stronghold of tigers, with an estimated population of 300–500 (Ahmad et al., 2009; Barlow, 2009). The prey of tigers in this forest comprises mainly spotted deer *Axis axis* and wild boar *Sus scrofa* (Reza et al., 2001). Both the tiger and its prey rely on a healthy ecosystem for food and shelter (Seidensticker, 1986; Sunquist, 2010). The Action Plan highlights many of the threats to tigers and their prey and habitat in the Sundarbans Reserve Forest but does not identify all threats or rank those threats.

The overall aim of this study was to demonstrate how application of existing conservation planning tools can improve understanding of a conservation setting and increase the focus of conservation strategy. The specific objectives, in the context of tigers in the Sundarbans Reserve Forest, were to (1) set the scope for biological targets and actions, (2) assess the viability of the biological targets, (3) identify and rank threats to the biological targets, and (4) set a time-line for reduction of threats. We followed TNC's conservation planning approach, supported by *MIRADI v. 3.0* (CMP, 2010), specialized project management software developed by the Conservation Measures Partnership. Using tigers in the Sundarbans as a case study we demonstrate how using a structured approach to threat prioritization could improve planning for species conservation in other landscapes.

Methods

Defining project scope and biological targets

The TNC approach requires a definition of the project scope ('the place where the biodiversity of interest to the project is located'; TNC, 2007). For this case study the scope was defined as the 6,017 km^2 Sundarbans Reserve Forest of Bangladesh (Fig. 2); a UNESCO world heritage site, a RAMSAR site, and a Tiger Conservation Landscape of global importance (Sanderson et al., 2006). The Bangladesh Forest Department is the custodian of the Forest, which is delineated into four ranges and 55 compartments, contains three Wildlife Sanctuaries (Sundarbans West, 715 km^2; Sundarbans South, 370 km^2; Sundarbans East, 312 km^2), and is protected by > 90 guard posts (Ahmad et al., 2009).

Biological targets, which can be components of the ecosystem or focal species, are then selected as the basis for setting conservation objectives, carrying out conservation actions and evaluating progress (Salafsky et al., 2002; TNC, 2007). For the Sundarbans Reserve Forest, the tiger was selected as the focal species, tiger prey because its status is directly linked to the status of the tiger population (Karanth et al., 2004), and habitat because it is essential for the survival of tiger and prey (Seidensticker, 1986; Sunquist, 2010).

Assessing viability of biological targets

The biological targets were assessed in terms of their current and desired viability. The viability of a target is the state or health of that target, defined in terms of key ecological attributes (TNC, 2007). Such an attribute is 'an aspect of a target's biology or ecology that if present defines a healthy target, and if missing or altered would lead to the outright loss or extreme degradation of that target over time' (TNC, 2007). Each attribute has one or more indicators that allow measurement of the attribute's state; their value can be set as very good, good, fair, or poor (TNC, 2007). A value is set for the current state of each indicator based on existing knowledge, and a second value is set for the desired future state of each indicator based on what the conservation project would like to achieve given the current state and potential for improvement (TNC, 2007). These key ecological attributes therefore provide a way of evaluating changes in the state of each target over time and act as a basis for measurement of success of the conservation project (Fig. 1). The attributes and their indicators were selected for each target, considering the information available and the approaches available to monitor their change over time. A literature review was carried out to collect information to assess the current viability of the targets in terms of the current state of their key ecological attributes. The desired

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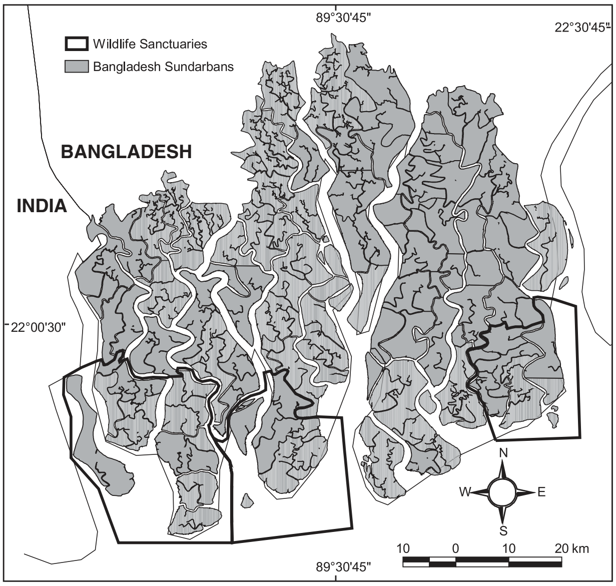

FIG. 2 Location of wildlife sanctuaries in the Sundarbans Reserve Forest.

states of the biological targets were set, considering their current state and their potential for improvement over the time-frame of the Bangladesh Tiger Action Plan.

Identifying and prioritizing threats

Threats were identified for each of the selected targets. Threats are 'the proximate activities or processes that have directly caused, are causing, or may cause stresses and thus the destruction, degradation and/or impairment of focal biological targets' (TNC, 2007; Fig. 1). To ensure consistency of threat type we used only direct threats (also known as 'sources of stress' in the TNC framework; e.g. wood cutting) rather than indirect threats (e.g. lack of alternative firewood; TNC, 2007). A list of threats was created based on the Bangladesh Tiger Action Plan, the literature review, and discussions amongst the authors about threats that may emerge in the future, following TNC (2007). The generic TNC threat category list in *MIRADI* was also referenced to ensure that a thorough threat list was developed.

The approach chosen to rank threats depends on how the identified threats act on the selected targets. Threats can act on targets in two different ways: a simple system where the effect of threats is aggregated on all stresses, and a complex system where the threats act on each individual stress (TNC, 2007). We selected the simple system because we felt this better reflected the relationship between the threats and targets in the case of the Bangladesh Tiger Action Plan. In this simple threat-rating system each threat is scored based on three components: scope, severity and irreversibility. Each of these components was ranked as very high, high, medium, or low, depending on the available information for that threat and its effect on the biological target (Table 1). The overall rank for a threat was then calculated by *MIRADI*, using a rule-based approach that accounts for the accumulative ranks of the threat's scope, severity and irreversibility.

A literature review was carried out to gather information on aspects of each threat. The scope, severity and irreversibility ratings of each threat component were then assigned by the authors, based on the available information. There was a lack of information for many of the threats, so assumptions (based on the authors' experience of conservation in the Sundarbans Reserve Forest and advice from senior Bangladesh Forest Department staff with experience working in this Forest) were made regarding some ratings, pending further research.

Creating a time-line for threat reduction

A time-line for reduction of each threat was created, considering (1) the threat's rank, (2) the current information base for the threat, and (3) the likely time-frame for implementing potential solutions for the threat. Threats were scheduled for reduction in the short term (2009–2017), medium term (2018–2025), or long term (2026+), or unscheduled pending further research. The outlined time-frame does not cover when activities need to be started to ensure the required reduction of the threat; for example, activities may need to be started in the short term to achieve reduction of a threat in the medium or long term.

Results

Based on the available information the indicators for the viability of the three biological targets (tigers, their prey, and habitat) were judged to be fair to very good, with most indicators in need of improvement to reach desired target states (Tables 2–4). A total of 23 threats were identified; four were linked to tigers, two to prey, and 17 to habitat (Table 5, Supplementary Tables S1–S3). In terms of ranking, six threats were prioritized as high, 10 as medium and seven as low (Table 5). Poaching of tigers and their prey, sea-level rise, upstream water extraction/divergence, wood collection, and fishing and harvesting of aquatic resources were the highest ranked threats (Table 5).

The threats scheduled for reduction in the short term (2009–2017) were poaching of tigers, killing of stray tigers, diseases of tigers and their prey, poaching of prey, and livestock grazing. There were a further three threats scheduled for medium-term reduction (2018–2025), five threats were scheduled for long-term reduction (2026+), and nine were unscheduled pending further research (Table 5).

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TABLE 1 Definitions of components and associated ratings used to prioritize each threat (adapted from TNC, 2007).

Component and rating	Definition
Scope	The geographical scope of impact on the biological target that can reasonably be expected within 10 years under current circumstances
Very high	The threat is likely to be pervasive in its scope, affecting the target across all or most (71–100%) of its occurrence/population
High	The threat is likely to be widespread in its scope, affecting the target across much (31–70%) of its occurrence/population
Medium	The threat is likely to be restricted in its scope, affecting the target across some (11–30%) of its occurrence/population
Low	The threat is likely to be very narrow in its scope, affecting the target across a small part (1–10%) of its occurrence/population
Severity	The level of damage to the biological target that can reasonably be expected within 50 years under current circumstances
Very high	Within the scope, the threat is likely to destroy or eliminate the target or reduce its population by 71–100% within 10 years or 3 generations
High	Within the scope, the threat is likely to seriously degrade/reduce the target or reduce its population by 31–70% within 10 years or 3 generations
Medium	Within the scope, the threat is likely to moderately degrade/reduce the target or reduce its population by 11–30% within 10 years or 3 generations
Low	Within the scope, the threat is likely to only slightly degrade/reduce the target or reduce its population by 1–10% within 10 years or 3 generations
Irreversibility	The degree to which the effects of a source of stress can be reversed
Very high	The effects of the threat cannot be reversed and it is very unlikely that the target can be restored, and/or it would take >100 years to achieve this (e.g. wetlands converted to a shopping centre)
High	The effects of the threat can technically be reversed and the target restored, but it is not practically affordable and/or it would take 21–100 years to achieve this (e.g. wetland converted to agriculture)
Medium	The effects of the threat can be reversed and the target restored with a reasonable commitment of resources and/or within 6–20 years (e.g. ditching and draining of wetland)
Low	The effects of the threat are easily reversible and the target can be easily restored at a relatively low cost and/or within 0–5 years (e.g. off-road vehicles trespassing in wetland)

TABLE 2 Key ecological attributes, indicators and measurements to assess the current viability of the tiger *Panthera tigris* in the Sundarbans Reserve Forest (Fig. 2; Barlow et al., 2008, 2009).

		Measurement ratings			
Item	Measurement type	Poor	Fair	Good	Very good
Key ecological attribute: tiger population size					
Indicator: relative tiger abundance	Mean no. of tiger track sets per km of khal in 65 sample units	0.8–0.99	1.0–1.19	1.2–1.4	> 1.4
Measurement (1 Mar. 2009)			1.12		
Desired future indicator measurement (1 Jan. 2017)					> 1.4
Key ecological attribute: tiger occupancy					
Indicator: tiger presence	Presence in % of 65 sample units	< 80%	80–89%	90–99%	1
Measurement (29 Mar. 2009)				0.98	
Desired future indicator measurement (1 Jan. 2017)					1

Discussion

The main strength of the TNC framework is that it focuses on and measures success with respect to biological targets, and thus the process is not constrained by the perceived capabilities or interests of the individuals or groups involved in the threat prioritization process. The three targets selected for the Sundarbans Reserve Forest are useful for directing conservation activities at the present time but new targets can be added in the future if that improves planning and management. Additional species that represent large taxonomic groups or act as flagship or umbrella species for

TABLE 3 Key ecological attributes, indicators and measurements to assess current viability of prey in the Sundarbans Reserve Forest (I.U. Ahmad, unpubl. data).

		Measurement ratings			
Item	Measurement type	Poor	Fair	Good	Very good
Key ecological attribute: prey population size					
Indicator: prey population	Total number of prey	< 60,000	60,000–79,000	80,000–100,000	> 100,000
Measurement (1 Apr. 2009)				80,000–100,000	
Desired future indicator measurement (1 Jan. 2010)					> 100,000
Key ecological attribute: prey occupancy					
Indicator: prey presence	Presence in % of sample units	< 80	80–89	90–99	1
Measurement (1 Apr. 2009)					1
Desired future indicator measurement (1 Jan. 2017)					1

TABLE 4 Key ecological attributes, and measurements to assess current viability of habitat in the Sundarbans Reserve Forest (Siddiqi, 2001; Smith et al., 2006; Wahid et al., 2007; Iftekhar & Saenger, 2008; Islam & Peterson, 2008).

		Measurement ratings			
Item	Measurement type	Poor	Fair	Good	Very good
Key ecological attribute: tree species density					
Indicator: overall tree density	Total number of stems (> 2.5 DBH*) per ha of forests in 55 sample units	< 3,000	3,000–3,500	3,499–4,000	> 4,000
Measurement (1 Apr. 2009)					
Desired future indicator measurement (1 Jan. 2010)					
Key ecological attribute: Ganges river dolphin population size					
Indicator: Ganges river dolphin	Total number of Ganges river dolphins across Forest channels	< 100	100–149	150–200	> 200
Measurement (1 Jan. 2010)					
Desired future indicator measurement (1 Jan. 2010)					
Key ecological attribute: water salinity					
Indicator: water salinity	Salinity ppt	> 30	20–29	15–19	Oct-14
Measurement (1 Jan. 2010)			20–29		
Desired future indicator measurement (1 Jan. 2010)				15–19	
Key ecological attribute: freshwater flow					
Indicator: freshwater flow change	Water flow m^3s^{-1}	< 499	500–999	1,000–1,499	1,500–2,000
Measurement (1 Apr. 2009)			500–999		
Desired future indicator measurement (1 Jan. 2010)				1,000–1,499	
Key ecological attribute: cyclone frequency					
Indicator: cyclone frequency	Number of grade 4+ cyclones per year	> 1	1	0.5	0.33
Measurement (1 Apr. 2009)				0.5	
Desired future indicator measurement (1 Jan. 2010)				0.5	

*DBH, Diameter at breast height

other aspects of the Sundarbans Reserve Forest landscape (e.g. birds) could be added either as targets or key ecological attributes, depending on the conservation need.

The viability assessment and threat-ranking parts of the framework allow the use of information from other projects on related taxa, communities or ecological systems in similar settings. However, with respect to the current Sundarbans targets, there is considerable scope to improve the key ecological attributes for habitat in particular; so far we have had difficulty identifying attributes related to the terrestrial and aquatic components of the Sundarbans Reserve Forest ecosystem that would reflect the system's viability and could be tracked through time by associated indicators. Improving the choice of key ecological attributes

TABLE 5 Ranking score, overall priority, and schedule of reduction for threats to tiger, prey, and habitat for the Sundarbans Reserve Forest.

Target	Threat	Ranking			Priority	Short-term reduction (2009–2017)	Medium-term reduction (2018–2025)	Long-term reduction (2026+)	Unscheduled pending further research
		Scope	Severity	Irreversibility					
Tiger	Poaching	High	High	Medium	High	×			
	Killing of strays	Medium	Medium	Medium	Medium	×			
	Disease	High	Medium	Medium	Medium	×			
	Inbreeding depression	Low	Low	Medium	Low				×
Prey	Poaching	High	High	Medium	High	×			
	Disease	Medium	Medium	Medium	Medium	×			
Habitat	Sea level rise	High	High	High	High			×	
	Upstream water extraction/divergence	High	High	High	High			×	
	Wood collection	High	High	High	High		×		
	Fishing & harvesting of aquatic resources	High	High	High	High		×		
	Invasive species	Medium	Medium	High	Medium		×		
	River pollution	Medium	Medium	Medium	Medium			×	
	Mineral & gas extraction	Medium	Medium	Medium	Medium				
	Storm & tidal surge	Low	Low	Very high	Medium			×	
	Melting Himalayan glaciers	Low	Low	Very high	Medium			×	
	Temperature change	Low	Low	Very high	Medium				×
	Sea acidification	Medium	Medium	Very high	Medium				×
	Commercial infrastructure	Low	Low	High	Low				×
	Plant disease	Low	Medium	High	Low				×
	Housing infrastructure	Low	Low	Medium	Low				×
	Livestock grazing	Low	Low	Low	Low				
	Fire	Low	Low	Low	Low				×
	Collection of non-timber forest products	Low	Low	Low	Low				×

and indicators will be a priority activity, as they are fundamental to evaluating the response of the targets to the conservation actions that are implemented.

The framework helped to identify a large number of threats not normally associated with tiger conservation (e.g. plant disease may not be directly linked to the tiger population but is a direct threat to tiger habitat). Some of the threats identified in this case study may be unique to the Sundarbans Reserve Forest (e.g. sea acidification) but others may affect all Tiger Conservation Landscapes to some degree (e.g. tiger poaching and prey poaching).

Current threat rankings are best judgements based on the available information, so threat rankings will undoubtedly change in the future following improvement of the information base through additional research, and implementation of conservation actions that affect those threats (e.g. improved law enforcement and development of alternative livelihoods). Another option would be to not rank threats with a poor information base. However, we feel that sometimes the risk of wasting money on unnecessary management actions because of a poor information base for a particular threat assessment would be greatly outweighed by the risk of biodiversity loss from inaction during the often lengthy time taken to assess the threat more comprehensively. Research to improve understanding of threats should of course be carried out but in parallel to (rather than instead of) the management activities to mitigate that threat.

High levels of livestock grazing are associated with high levels of livestock depredation by tigers and may also be one of the factors that encourage tigers to stray into villages (Rahman et al., 2010). Therefore, although livestock grazing was only ranked as a low-priority threat, it was scheduled for reduction in the short term because it is closely linked to the medium-ranked threat of the killing of stray tigers.

Although sea level rise and upstream water extraction/diversion were prioritized as high-ranked threats, these two threats were scheduled for reduction in the long term because of the extrinsic nature of these threats and considering the time-frame required to mitigate them. Similarly, wood collection and fishing and harvesting of other aquatic resources were placed in the medium term despite being ranked as high-category threats, because mitigating these threats would entail reducing the considerable direct economic dependency of millions of local people on the Sundarbans Reserve Forest (Canonizado & Hossain, 1998). In addition, many threats were categorized as unscheduled, pending further research to understand the scope, severity and irreversibility of these threats to the biological targets.

Despite lacking some information on target viability and threats, however, the framework helped the Forest Department and the WildTeam start conservation actions to tackle the high-priority threats. The Forest Department are now implementing a 5-year programme to improve protection of the Sundarbans Reserve Forest, and WildTeam are preparing social marketing campaigns to address killing of stray tigers and poaching of deer, and carrying out research to fill in the information gaps identified through the assessment of threats.

The findings of this case study may also be applicable to the Sundarbans in India because of the similarity of the ecological settings. The conservation framework could also be useful to improve strategies for tiger conservation in all Tiger Conservation Landscapes and could be adapted and applied to improve conservation of other species and ecosystems.

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