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REVIEW

Sumatran tiger (*Panthera tigris sumatrae*): A review of conservation status

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Abstract

The majority of wild Sumatran tigers are believed to live in 12 Tiger Conservation Landscapes covering approximately 88 000 km². However, the actual distribution of tigers across Sumatra has never been accurately mapped. Over the past 20 years, conservation efforts focused on the Sumatran tigers have increased, but the population continues to decline as a result of several key threats. To identify the status of the Sumatran tiger distribution across the island, an island-wide questionnaire survey comprised of 35 respondents from various backgrounds was conducted between May and June 2010. The survey found that Sumatran tigers are positively present in 27 habitat patches larger than 250 km² and possibly present in another 2. In addition, a review on major published studies on the Sumatran tiger was conducted to identify the current conservation status of the Sumatran tiger. Collectively, these studies have identified several key factors that have contributed to the decline of Sumatran tiger populations, including: forest habitat fragmentation and loss, direct killing of tigers and their prey, and the retaliatory killing of tigers due to conflict with villagers. The present paper provides management authorities and the international community with a recent assessment and a base map of the actual distribution of Sumatran tigers as well as a general overview on the current status and possible future conservation challenges of Sumatran tiger management.

Key words: hunting tigers, Sumatra, Sumatran tiger distribution, Tiger Conservation Landscapes, tiger–human conflict.

INTRODUCTION

In Indonesia, tigers were once widely distributed on the islands of Sumatra, Java and Bali. Today, both the Bali (*Panthera tigris balica* Linnaeus, 1758) and Javan subspecies (*P. t. javanica*) are extinct. The only remaining subspecies, the Sumatran tiger (*P. t. sumatrae*), persists across Sumatra but in isolated populations. This subspecies faces many threats to future survival (Seidensticker 1986; Seidensticker *et al*. 1999). In 2009, the International Union for Conservation of Nature listed the Sumatran tigers as critically endangered and the Government of Indonesia has made it a priority species for protection (Indonesian Ministry of Forestry 2007). Today, the majority of wild Sumatran tigers persist in 12 Tiger Conservation Landscapes (TCL) covering approximately 88 000 km² (Sanderson *et al*. 2006). Despite these large areas of forest, an increase in the rate of habitat fragmentation and loss in recent years (FWI/GFW 2002) threatens the integrity of these tiger landscapes (Kinnaird *et al*. 2003; Linkie *et al*. 2003, 2004, 2006). In addition to the loss of habitat, continued demand for tiger body parts (Seidensticker

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1986; Nowell & Jackson 1996; Nowell 2000), non-selective ungulate snares, and authorized removal (Seidensticker 1986; Tilson *et al*. 1994; Seidensticker *et al*. 1999) and retaliatory killing of tigers as a result of conflict with humans are the main factors depleting populations of Sumatran tigers (Nyhus & Tilson 2004; Sheppart & Magnus 2004; Ministry of Forestry 2007).

Several major conservation initiatives dedicated to save the last remaining Sumatran tigers have been carried out over the past 15 years. However, none of these initiatives have provided detailed information about the actual spatial distribution of Sumatran tigers over the whole

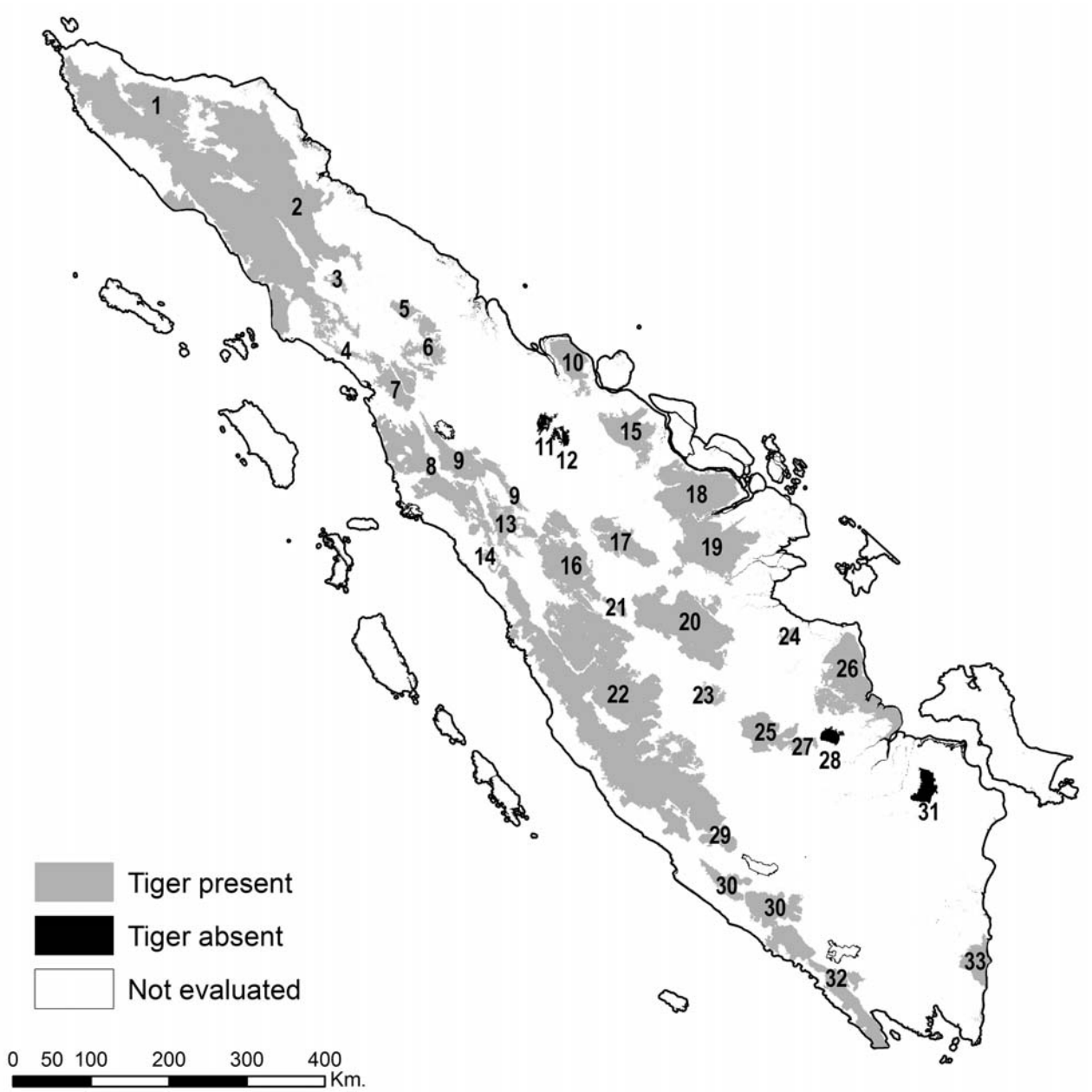

Figure 1 The distribution map of Sumatran tigers over the past 5 years. A total of 33 out of 38 forest patches were evaluated. The grey polygons are forest patches revealing evidence of tigers. The black polygons are forest patches with no evidence of tigers. Five forest patches were not evaluated due to lack of information.

of the island. In this paper, we provide an update of the current distribution of Sumatran tigers across the island of Sumatra over the past 5 years. The main objectives of the present paper are: (i) to provide the management authorities and tiger conservationists with the most recent actual distribution of Sumatran tigers across the island; (ii) to provide a finer base map of Sumatran tiger distribution to aid in future conservation management, especially for non-priority habitats and unprotected landscapes; and (iii) to provide international communities with a general review on the current status of Sumatran tiger landscapes. Later in this paper, we provide a general overview on the status and challenges of Sumatran tiger conservation, along with several management options.

MATERIALS AND METHODS

Basic presence/absence information for Sumatran tigers throughout the remaining forest patches on Sumatra has never been mapped despite the fact that this would provide a useful indication of their general distribution. To address this issue, an island-wide survey was conducted between May and June 2010 to identify the status of the Sumatran tiger distribution across the island. A literature review was conducted prior to the survey in order to identify the target respondents. A total of 35 respondents were identified, including tiger conservationists (12), field biologists and technicians (17), concessionaires (4) and government officers (2). A 2000 forest cover map (Gaveau *et al*. 2007) was used as the basis for identifying potential habitat patches. A potential patch was defined as an area equal to a minimum of 250 km^2, corresponding to the largest expected home range of a male Sumatran tiger (Griffith 1994). Under such criteria, some protected areas were excluded for further analysis because their forest covers are smaller than 250 km^2. These include Bukit Dua Belas National Park (ID 23) and Way Kambas National Park (ID 33) (Fig. 1). To overcome this limitation, the forest layer was superimposed with conservation area polygons and TCL boundaries (Sanderson *et al*. 2006), resulting in a total of 38 patches (144 160 km^2) ranged between 275 and 32 560 km^2. For non-technical reasons, we were not able to visit each patch to verify the actual size on the ground.

A standardized questionnaire that included a set of simple questions was distributed to the target respondents. The questions included: (i) the name and official status of patch they evaluate; (ii) the status of tiger occurrence in the patch (presence/absence) over the past 5 years; (iii) the evidence they had found of tiger presence; (iv) the source of information they used; and (v) the latest biological survey that has been conducted in the patch. Tiger presence was identified following 4 basic classifications (from the most to the least reliable): (i) direct sighting, which commonly came from tiger–human conflict; (ii) photograph, which commonly came from camera traps; (iii) pugmark, which commonly come from basic presence/absence and reconnaissance surveys, and incidental findings; and (iv) information from third parties, such as park officers, local informal and formal leaders, and local communities. We classified the first 3 types of evidence as "positively present" and last type as "possibly present."

Roads have been identified as having negative impact on several wildlife species (Bennett & Robinson 2000; Kerley *et al*. 2002; Linkie *et al*. 2006). Bennett and Robinson (2000) find higher mortality rates for large mammals, possibly because they have large home ranges that bring them in close proximity to roads more often than is the case for smaller mammals. A catalog of road data developed by the Committee on Data for Science and Technology (CODATA 2009) was used to identify the road network on Sumatra Island. A road layer published by Global Forest Watch (Nelson 2002) and protected area polygons were then used to calculate the total length of roads within Sumatra's protected areas. In addition, tiger–human conflict localities recorded between 2007 and 2010 in Northern Sumatra (WCS 2010) were used to define the total length of roads having potential risk of tiger mortality outside forested areas. In Northern Sumatra, conflicts between tigers and humans were recorded as far as 5.6 km away from forest boundaries (n = 24, 2.1 ± 1.3). Roads were then defined as vulnerable for tigers if they fell within an average distance of tiger–human conflict localities from forest boundaries. A dissolved buffer of the average distance from the forest boundaries was created using ArcGIS 9.1 Spatial Analyst (ESRI, Redlands, USA) to clip the total length of vulnerable roads. In addition, we reviewed major studies related to Sumatran tigers and their habitats conducted over the past 15 years to identify the main threats to the existence of the species and to formulate the future direction of conservation management of the Sumatran tiger.

RESULTS

Out of 38 patches; we successfully identified the status of tiger occurrence in 33 patches. We verified the data following the most recent and reliable information collected from the respondents. Over the past 5 years tigers were positively present in 27 patches and possibly present

Table 1 List of evaluated forest patches across Sumatra corresponding to tiger occurrence. The protection status refers to the type of protection present at a given patch, either entirely or partially. The area is defined as the entire patch size. The recent survey is defined as the most recent survey conducted in the past 5 years

Patch ID	Identity	TCL Name	TCL ID / Level	Protection Status	Area (km^2)	Tiger	Evidence	Source	Recent Survey
1	Ulu Masen Ecosystem		N/A	Protection Forest	8 977	Present	Photos and pugmarks	FFI (2009, unpublished)	FFI occupancy 2008 - 2009
2	Leuser Ecosystem	Leuser Ecosystem	14 / IV	National Park	32 560	Present	Pugmarks, photos, conflicts	WCS & LIF (2010, unpublished)	WCS cameratrap 2010
3	Tanah Karo		N/A	Protection Forest	318	Present	Pugmarks	WCS (2010, unpublished)	WCS conflict mitigation 2009
4	Parmonangan		N/A	Settlement	354	Present	Snared tiger	WCS (2010, unpublished)	WCS conflict mitigation 2009
5	Asahan		N/A	Production Forest	526	Present	Conflict incident	WCS (2010, unpublished)	WCS conflict mitigation 2009
6	Dolok Surungan		N/A	Settlement	1 950	Present	Pugmarks	WCS (2010, unpublished)	WCS conflict mitigation 2009
7	Batang Toru	Sibolga	13 / IV	Protection Forest	2 174	Present	Photos	YEL/SOCP (2009, unpublished)	SOCP cameratrap 2009 - 2010
8	Batang Gadis	Rimbo Panti - Batang Gadis East	11 /III	National Park	6 183	Present	Photos	Wibisono *et al*. (2009)	WCS & CII cameratrap 2006
9	Barumun	Rimbo Panti - Batang Gadis West	12 / III	Wildlife Reserve	3 095	Present	Information	Bangun *et al*. (2009, unpublished)	Univ. of North Sumatra 2009
10	Senepis - Buluhala		N/A	Production Forest	1 800	Present	Photos	STCP (2010)	STCP cameratrap 2010
11	Koto Tengah		N/A	Production Forest	346	Absent	-	WCS (2009, unpublished)	WCS occupancy 2009
12	Balai Raja		N/A	Wildlife Reserve	330	Absent	-	WCS (2009, unpublished)	WCS occupancy 2009
13	Pasaman		N/A	Protection Forest	1 940	Present	Pugmarks	Dinata Y (2010, pers. comm.)	Nepenthes Team survey 2005
14	Maninjau		N/A	Nature Reserve	275	Present	Conflict incident	Martyr D (2010, pers. comm.)	N/A
15	Giam Siak Kecil		N/A	Biosfere Reserve	2 722	Present	Information	UNESCO (2010, unpublished)	N/A
16	Rimbang Baling	Bukit Rimbang Baling	6 / III	Widlife Reserve	5 137	Present	Pugmarks, photos	Dinata *et al.* (2010), WWF (2010, unpublished)	FFI occupancy 2008
17	Tesso Nilo	Tesso Nilo Landscape	8 / III	National Park	2 458	Present	Photos	WWF (2010, unpublished)	WWF cameratrap 2005 - 2008
18	Kuala Kampar	Kuala Kampar Kerumutan	9 / II	Non protected	4 879	Present	Pugmarks	WWF (2007, unpublished)	WWF cameratrap 2007
19	Kerumutan	Kuala Kampar Kerumutan	9 / II	Widlife Reserve	5 784	Present	Photos	WWF (2010, unpublished)	WWF cameratrap 2007
20	Bukit Tiga Puluh	Bukit Tiga Puluh Landscape	7 / I	National Park	7 359	Present	Photos, pugmarks	STCP (2010)	STCP cameratrap 2010
21	Bukit Betabuh - Bukit Sosa		N/A	Protection Forest	305	Present	Pugmarks, photos, videos	Dinata *et al.* (2010)	WWF cameratrap 2009 - 2010
22	Kerinci Seblat	Kerinci Seblat	5 / I	National Park	31 754	Present	Photos, pugmarks	Linkie *et al.* (2006, 2008) Dinata (2008)	FFI occupancy 2008
23	Bukit Dua Belas	Bukit Dua Belas	N/A	National Park	677	Present	Pugmarks	ZSL (2007, unpublished)	ZSL occupancy 2007
24	Bramitam		N/A	Protection Forest	277	Present	Conflict incident	Nurazman (2010, unpublished)	N/A
25	Harapan Rainforest		N/A	Production Forest	2 271	Present	Photos, pugmarks, direct sighting	Irmansyah (2010)	HRF cameratrap 2009
26	Berbak - Sembilang	Berbak	10 / IV	National Park	5 817	Present	Photos, direct sighting	ZSL (2010, unpublished)	ZSL camera traps 2009 - 2010
27	Dangku		N/A	Wildlife Reserve	537	Present	Photos	Maddox *et al*. (2007)	ZSL occupancy 2009
28	Bentayan		N/A	Wildlife Reserve	417	Absent	-	Maddox *et al*. (2007)	ZSL cameratrap 2006
29	Bukit Kaba		N/A	Nature Reserve	808	Present	Dead tiger	FFI (2010)	N/A
30	Bukit Balai Rejang	Bukit Balai Rejang South	4 / II	Protection Forest	3 561	Present	Pugmarks	WCS (2009, unpublished)	WCS occupancy 2008
31	Padang Sugihan		N/A	Wildlife Reserve	870	Absent	-	ZSL (2010, unpublished)	N/A
32	Bukit Barisan Selatan	Bukit Barisan Selatan	3 / III	National Park	4 406	Present	Photos	Wibisono (2005)	WCS & RFI occupancy 2008
33	Way Kambas		N/A	National Park	1 321	Present	Photos	STCP (2010)	STCP cameratrap 2010

N/A, not applicable; TCL, Tiger Conservation Landscapes.

in 2 other patches covering a total of 140 226 km^2 (Table 1, Fig. 1). Only 29% of these habitat patches are protected. As indicated by their global distribution, tigers are capable of living in a wide range of environments as long as sufficient prey and water are available (Schaller 1967; Sunquist 1981; Seidensticker *et al*. 1999). Survey results confirm this. Sumatran tigers occupy a wide array of habitats, ranging from 0 m above sea level in the coastal lowland forest of Bukit Barisan Selatan National Park (BBSNP) on the southeastern tip of Lampung province (ID 32) to 3200 m above sea level in mountain forests of Gunung Leuser in Aceh province (ID 2) (Fig. 1). In Gunung Leuser National Park, tiger pugmarks were found as high as 3200 m above sea level. Recently, Sumatran tigers have also been repeatedly photographed at 2600 m above sea level (WCS & LIF 2010) in a rugged region of northern Sumatra. This survey also revealed that more than 430 km of public roads lay within the Sumatra protected areas and a total of 6494 km of roads close to tiger habitats across Sumatra are a possible danger for tigers.

Over the past 15 years, there have been various major studies on Sumatran tigers, including on the site-specific status of the Sumatran tiger population (Franklin 2002; O'Brien *et al*. 2003; Wibisono 2005; Linkie *et al*. 2006; Wibisono *et al*. 2009) and their habitats (Kinnaird *et al*. 2003; Linkie *et al*. 2006; Linkie *et al*. 2008; Wibisono *et al*. 2009), illegal trade in tiger parts (Sheppard & Magnus 2004; Ng & Nemora 2007) and tiger–human conflict (Nyhus & Tilson 2004; Ng & Nemora 2007; Rudijanta & Sugardjito 2009). Collectively, these studies have identified several key factors that contribute to the decline of Sumatran tiger populations, including: forest fragmentation and loss (Kinnaird *et al*. 2003; Wibisono 2005; Linkie *et al*. 2006; Wibisono *et al*. 2009), direct killing of tigers (Sheppard & Magnus 2004; Ng & Nemora 2007) and their main prey (Wibisono 2005), and the retaliatory killing of tigers as a result of conflict with villagers (Nyhus & Tilson 2004; Sheppard & Magnus 2004; Ng & Nemora 2007; Rudijanta & Sugardjito 2009).

DISCUSSION

The latest effort to map Sumatran tiger habitats was published by Sanderson *et al*. (2006) in the globally recognized report "Setting priorities for the conservation and recovery of wild tigers: 2005–2015: The technical assessment." This report provides a thorough spatial analysis on the current potential habitats of tigers throughout their global range and identifies a total of 76 priority landscapes, TCL. The report classified many small forest patches as non-habitats, leaving only 12 large habitat patches in Sumatra for further analysis. The present paper provides the most recent island-wide assessment of general tiger distribution covering all potential habitat patches across Sumatra. It is based on reliable evidence, including a recent signs survey, tiger–human conflict incidents and photographs.

Based on this study, the status of Leuser Ecosystem (ID 2) and Berbak - Sembilang (ID 26), which are now listed as class IV TCL (due to data deficiency, Sanderson *et al*. 2006) should be reassessed for at least 3 reasons: (i) there was a landscape-wide biological survey conducted by the Wildlife Conservation Society (WCS) and Leuser International Foundation (LIF) in the Leuser Ecosystem between 2007 and 2009; (ii) there is an ongoing camera trap study conducted by the Zoological Society of London (ZSL) in Berbak National Park (BNP); and (iii) BNP (1627 km^2) is well connected to the newly-established Sembilang National Park (2028 km^2). Approximately 5800 km^2 of contiguous forest lies within and around these parks. The status of the Ulu Masen Ecosystem (ID 1), which is connected with the Leuser Ecosystem in the north, should be assessed for at least 2 reasons: (i) there was a landscape-wide biological survey conducted by Fauna and Flora International (FFI) between 2007 and 2009; and (ii) as this paper shows, the Ulu Masen Ecosystem covers a vast, intact healthy tiger habitat of more than 8900 km^2. In addition, patrol units, long-term biological monitoring, tiger–human conflict mitigation and community engagement have improved the conservation measures in these 3 landscapes and, therefore, their respective statuses should be reassessed.

The status of the Batang Gadis (ID 8) (TCL name: Rimbo Panti Batang Gadis East) should also be reevaluated. Wibisono *et al*. 2009 conclude that it could hold as many as 117 tigers. Finally, Giam Siak Kecil (ID 15) (2772 km^2) could also be considered for TCL status. It along with Kuala Kampar (ID 18), Kerumutan (ID 19), and Berbak - Sembilang are the last remaining large peat swamp habitats in Sumatra. In addition, Giam Siak Kecil was recently named a UNESCO biosphere reserve.

Roads are responsible for forest fragmentation in many wild lands. The forest becomes more vulnerable the closer it is to public and logging roads (Linkie *et al*. 2004). In Russia, roads that cross optimal tiger habitat have caused the Russian tiger to go from a source population to a sink population (Kerley *et al*. 2002). In Sumatra, roads have been responsible for bringing a high level of human activity into wild habitats, and have, subsequently, resulted in large tiger habitats being carved up into smaller, less-

viable habitat patches (Ministry of Forestry 2007). The present study reveals that as much as 430 km of roads lie within the boundaries of Sumatra's protected areas and that nearly 16% of approximately 41 000 km of habitat boundaries lie near roads, posing a threat to Sumatran tigers. In addition to public roads, more than 49 000 km of logging roads were constructed inside forested areas between 1990 and 2000 (Gaveau *et al*. 2009). In the Kerinci Seblat ecosystem, Linkie *et al*. (2006) show that tiger occurrence decreased close to the public roads. They also identify 2 isolated core habitats that, as a consequence of the road network in the region, contain few tigers. Road networks have also increased tiger poaching, the hunting of tiger prey, and the probability of tiger–human conflict.

Laumonier *et al*. (2010) conclude that only 29% of 130 000 km^2 of the remaining forest cover in Sumatra is protected. Gaveau *et al*. (2009) demonstrate that the deforestation rate in Sumatra is much lower (0.5% per year) inside protected areas compared to adjacent non-protected areas (4.1% per year). These findings, along with the findings with regard to road discussed above, indicate that most of the remaining tiger habitat patches in Sumatra are highly vulnerable to encroachment and deforestation and this, in turn, poses a very real threat to the tigers themselves. In the following sections, we provide a general overview on the status and challenges of Sumatran tiger conservation.

Population assessment

Since the 1970s, there have been several studies that assess the status of Sumatran tigers. In 1978, the Sumatran tiger population was estimated at 1000 individuals, based on responses to a questionnaire survey (Borner 1978). In 1985, Santiapillai & Ramono (1987) identified a total of 26 protected areas across Sumatra containing approximately 800 tigers. In 1992, a Population and Habitat Viability Analysis of Sumatran tigers estimated that 400-500 tigers lived in 5 national parks and 2 protected areas (Tilson *et al*. 1994). In 2007, the authors of the "Strategy and action plan for the conservation of the Sumatran tiger (*Panthera tigris sumatrae*): 2007-2017" estimated that a minimum of 250 adult tigers were living in 8 of the 18 tiger habitats across Sumatra (Indonesian Ministry of Forestry 2007).

Since 1995, several tiger-specific projects have been carried out in various tiger habitats, including Way Kambas National Park in 1995 (Franklin 2002), BBSNP in 1998 (O'Brien *et al*. 2003), Kerinci Seblat Landscape in 1996 (Linkie *et al*. 2003), Tesso Nilo and Bukit Tiga Puluh Landscapes in 2004 (WWF 2004), Senepis-Buluhala in 2002 (Franklin 2002), Batang Gadis National Park in 2006 (Wibisono *et al*. 2009), Leuser Landscape in 2007 (WCS & LIF 2010), and the Ulu Masen Ecosystem in 1998 (FFI 2010). These studies cover a wide range of habitats with estimated densities between 0.3 tigers/100 km^2 in montane habitat (Linkie *et al*. 2006) and 4.3 tigers/100 km^2 (Franklin 2002) in lowland habitat. Despite all projects involving an assessment of local population status, they have not collectively assessed the status of the Sumatran tiger populations on an island-wide scale. To address this issue, a collaborative field survey of the major Sumatran tiger landscapes was carried out between 2007 and 2009 by the Indonesian Ministry of Forestry, WCS, FFI, LIF, World Wide Fund for Nature, ZSL, Sumatran Tiger Conservation Program, and the Rhino Foundation of Indonesia. Analyses of these data are ongoing.

Deforestation

The most recent comprehensive study found that the deforestation rate in Sumatra was fivefold faster compared to other humid tropical forests throughout the rest of the world (Achard *et al*. 2002). Tiger habitat on the island has shrunk and fragmented (Ministry of Forestry 2007). Holmes (2000) estimates that almost 67 000 hectares of covered forest was cleared in Sumatra between 1985 and 1997. Since the late 1970s, the main causes of deforestation in Sumatra have shifted from subsistence agriculture to large-scale production of oil palm and rubber, widespread logging by timber industries (Laumonier *et al*. 2010) and transmigration programs (Fearnside 1997; Laumonier *et al*. 2010). The allocation of ex-logging concessions to transmigration areas had become common practice in Sumatra between late 1970s and early 1980s (Laumonier *et al*. 2010). Between the national launch of the transmigration program in 1905 and 1989, nearly 4.9 million Javanese were moved and Sumatra was the primary destination (Fearnside 1997).

Hunting tigers

Illegal hunting is a significant threat to the survival of Sumatran tiger populations (Mills & Jackson 1994; Sheppard & Magnus 2004; Indonesian Ministry of Forestry 2007; Ng & Nemora 2007). Tiger bones are commonly exported to mainland Asia to supply the demand for Traditional Chinese Medicine. Over 3990 kg of Sumatran tiger bones were illegally exported from Indonesia to South Korea between 1970 and 1993 (Mills & Jackson 1994). Sheppard and Magnus (2004) estimate that at least 253 tigers were removed from their natural

habitat between 1998 and 2002, the majority for illegal trade. The price of tiger bones in international markets tends to increase overtime. In South Korean markets, tiger bone was sold at US$26/kg in 1973 and jumped to US$238/kg by 1992 (Mills & Jackson 1994). Meanwhile, the price of a good quality tiger skin in Sumatra reached US$1000 in the 1970s (Borner 1978) and more than doubled that amount by 2002 (Sheppard & Magnus 2004).

Hunting of tiger prey

Studies suggest that prey depletion is largely responsible for the current decline of tiger population in the wild (Karanth & Stith 1999). One of the main threats to the conservation of Sumatran tigers is crop depredation by large ungulates in agricultural lands near protected areas, which typically involves wild pigs (*Sus scrofa* Linnaeus, 1758) and several species of deer, the principal prey of Sumatran tigers (O'Brien *et al*. 2003; Wibisono 2005). A study conducted by Wibisono (2005) in BBSNP reveals that crop protection by farmers is negatively correlated with the relative abundance of Sambar deer (*Cervus unicolor* Kerr, 1792), but not with wild pig, mainly because of their high survival rate and adaptability to human presence. Techniques commonly used to protect crops are often non-selective, including snaring, poisoning and drive netting. Of these techniques, drive netting is the most effective but provides the greatest threat for large ungulates. However, there has not been a study undertaken in Sumatra that specifically addresses the direct impact of prey depletion on tiger populations.

Tiger–human conflict

The uncontrolled use of natural resources and deforestation has forced many species of wildlife to live in close proximity to human-dominated landscapes, which leads to prolific wildlife–human conflict (Nowell & Jackson 1996; Wibisono 2005; Inskip & Zimmermann 2009). Although it is a prominent threat, the only published paper to quantify the level of tiger–human conflict throughout Sumatra was written by Nyhus and Tilson (2004) and was based on a literature study. Between 1987 and 1997, they recorded as many as 146 people and at least 870 livestock killed by tigers. West Sumatra, Riau and Aceh were the 3 provinces with the highest level of conflict, with 48, 46 and 34 tiger–human incidents, respectively. They also found that 265 tigers were killed in response to conflict, for profit or accident, and that 97 tigers were captured. Subsequently, TRAFFIC (2002) found that at least 35 tigers were killed due to conflict between 1998 and 2002. In northern Sumatra alone, WCS recorded a total of 76 conflict incidents between 2007 and 2010, which caused the deaths of 9 humans and resulted in the death or removal of 25 tigers (WCS 2010).

FUTURE DIRECTIONS

Several major studies are dedicated to addressing questions about the conservation status of the Sumatran tiger. By reviewing this literature, we have identified several key factors that contribute to the decline of Sumatran tiger population: forest fragmentation and loss, direct killing of tigers and their main prey, and the retaliatory killing of tigers due to conflict with villagers. Despite such prominent threats, considerable potential remains for the conservation of tiger populations in Sumatra. There are at least 4 reasons for this: (i) there are still substantial large habitats with viable tiger populations that can assure the long-term survival of the species if effective conservation measures are taken; (ii) many of these remaining large habitats have legal protection status and management infrastructure; (iii) there has been a substantial improvement in scientific knowledge of Sumatran tiger ecology and the tiger's conservation status, as well as technical skills to improve management capacity; and (iv) there are an increasing number of Indonesian conservationists who have been dedicating their professional careers to saving the last remaining Sumatran tigers.

Although the current conservation effort to save Sumatran tigers has accelerated, most of the effort has been unfocused and geographically dispersed (Walston *et al*. 2010). Therefore, conservation investments should be focused on tiger source sites that provide sufficient refuge from anthropogenic threats so that the reproduction of tigers and their prey will be sufficient to allow population recovery in the larger ecosystems. The 3 most significant landscapes with viable populations of Sumatran tigers are Leuser in the north, Kerinci Seblat in the west and Bukit Tigapuluh in central Sumatra. These 3 landscapes occupy a vast area of more than 69 300 km^2 (Sanderson *et al*. 2006). In addition to their sheer size, their inaccessible rugged terrain might provide the best long-term prospects for population security. Under this strategy we expect tiger populations to persist in the long term.

Successful habitat protection also depends on the number of active well-trained forest guards. In India, where some good examples of successful tiger conservation practices have been implemented, a recent survey found that the average ratio between the number of forest guards and the size of the conservation area is 1 person/20 km^2

area (Government of India 2005). In comparison, the average ratio in Sumatra is 1 person/17 km^2 area (Indonesian Ministry of Forestry 2000). This implies that the number of forest guards is not an issue in Sumatra. However, some conservation areas in Aceh and Jambi Provinces seem to have insufficient numbers of forest guards, with a ratio closer to 1/34 km^2 and 1/50 km^2 area, respectively (Indonesian Ministry of Forestry 2000). Therefore, an attempt should be made to balance the number of forest guards. Insufficient protection capacity in Sumatra is also related to at least 3 other factors: (i) the lack of motivation of protection personnel to conduct routine patrols; (ii) the lack of an effective monitoring mechanism to evaluate patrol activities; and (iii) the lack of strong leadership. To overcome these problems, each conservation area should have specialized patrol units each consisting of well-trained personnel and managed by a dedicated and well-trained patrol leader.

Sumatra has long been recognized as a major source of tiger bones exported to mainland Asia. WCS and FFI have focused their respective strategies on tackling illegal killing and trafficking of tigers and tiger body parts by operating anti-trafficking units in southern and central Sumatra. The success of these units in tackling tiger trafficking in the regions has been independently confirmed in 2 reports released by TRAFFIC South East (Sheppard & Magnus 2004; Ng & Nemora 2007). However, they are insufficient for tackling the full magnitude of tiger trafficking over the whole of Sumatra. Therefore, a reasonable number of anti-trafficking units should be created to combat illegal trafficking of tigers across Sumatra. Both anti-trafficking units and the specialized patrol units described above should complement one another at the site and regional levels.

To conserve wildlife and their habitats, the involvement of local communities living in and around conservation areas is necessary (Saberwal 1997). However, investment of conservation resources in community-based conservation efforts should be carried out reasonably, with a balance between direct conservation approaches and community-based approaches. Improvement of community livelihoods should be the responsibility of other relevant authorities. Nevertheless, insufficient political commitment from the government of tiger range countries has been recognized by tiger conservation communities as a major obstacle to effective conservation (Saberwal 1997). Therefore, an attempt should be made to initiate an interministerial forum in order to gather sufficient political support and to place tiger conservation onto the rural and regional economic development agenda of specific jurisdictions near tiger conservation areas.

A common conflict between humans and wildlife in Sumatra is livestock hunting by tigers (Nyhus & Tilson 2004; WCS 2010), which often leads to both tiger and human casualties. In BBSNP, informal interviews with local people indicated a marked increase in livestock depredation by tigers (Wibisono 2005). This presents a challenging situation because the exclusion of humans and livestock from conservation areas is unlikely to generate local support for tiger conservation (Saberwal 1997). In South Aceh, tiger-proof enclosures introduced by WCS along with thematic awareness activities have proven to be successful in decreasing the level of livestock depredation and increasing local support. As a result, tiger removal due to conflict with villagers has decreased by 60% over the past 3 years, although conflict incidences still seem to be increasing (WCS 2010). To reduce retaliatory killing of tigers, the approach should be replicated in other tiger–human conflict hotspots throughout Sumatra.

In anticipating further damage to wildlife habitats, the Indonesian Ministry of Home Affairs launched "Sumatra Vision 2020" (Roosita *et al*. 2010), which aims to save the last remaining Sumatran ecosystems. The document was developed to provide guidance for the district and provincial governments to develop ecosystem-based spatial planning. Although promising, the implementation of such an approach will be quite challenging because most district and provincial governments still focus largely on economic development. A similar approach called the Integrated Conservation Development Program costing up to US$19 million was implemented in the Kerinci Seblat region between 1997 and 2002 with no significant benefit to its ecosystem (Linkie *et al*. 2008).

In 2010, the World Bank/Global Tiger Initiative launched a new approach of smart, green infrastructure specifically for tiger range countries. The World Bank has found that infrastructure, especially roads, have significantly contributed to the vast and growing deforestation and fragmentation of natural tiger habitats. The World Bank proposes a multi-level approach, which addresses policies of all types, to ensure that infrastructure development is smart, green and tiger-friendly (Quintero *et al*. 2009). As a new and promising approach for Indonesia, we strongly suggest that the government of Indonesia adopt this method by incorporating it into any road and infrastructure development planning. However, at the same time, we also argue that development of infrastructure should be the very last option and strictly prohibited inside tiger source population habitats.

Finally, the impact of tiger conservation intervention should be evaluated following standard scientific measures to evaluate the status and distribution of tiger populations over time. This should be done by defining and consistently implementing a standardized biological monitoring protocol. The conservation of wildlife species is fundamentally dependent on the availability of well-trained and dedicated conservationists. Prior to the late 1990s, tiger conservation in Indonesia had largely depended on international experts because dedicated and well-trained national tiger conservationists were few in number. Therefore, while maintaining a good relationship and exchange of knowledge with international experts, it is important to train as many young conservationists in tiger range countries as possible.

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