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## COMMUNICATION

### STATUS OF SUMATRAN TIGER IN THE BERBAK-SEMBILANG LANDSCAPE (2020)

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## INTRODUCTION

Among the six extant subspecies of tigers, the Sumatran Tiger *Panthera tigris sumatrae* survives in isolated populations across 27 forest patches in Sumatra (Figure 1, combined forest area ~140,226 km<sup>2</sup>) (Wibisono & Pusparini 2010). It is listed as Critically Endangered on the IUCN Red List (Linkie et al. 2008), threatened by: 1) habitat loss and fragmentation, largely the result of regular forest fires and land clearance for agricultural use; 2) poaching, encouraged by the illegal wildlife trade and international illegal wildlife trade; and 3) human-tiger interaction (Nyhus et al. 2004; Ng & Nemora 2007; Linkie et al. 2008; Kartika 2017). To conserve the subspecies, six of the existing 12 tiger conservation landscapes (TCLs) in Sumatra have been designated as priority tiger landscapes in the National Tiger Recovery Plan, including the Berbak-Sembilang TCL (GTI 2012), the focus of the current study (forest patch number 26 in Figure 1).

The Berbak-Sembilang TCL comprises Berbak-Sembilang National Park (BSNP, 3,442km<sup>2</sup>), Air Hitam Peatland Protected Forest (187km<sup>2</sup>), Orang Kayo Hitam Forest Park (181km<sup>2</sup>), timber concessions (622km<sup>2</sup>), acacia plantation concessions (517km<sup>2</sup>), and oil palm plantations (106km<sup>2</sup>) (KLHK 2020). With over 3,800km<sup>2</sup> of wetland forest (Wibisono & Pusparini 2010), the landscape is a combination of mixed peat swamp, freshwater forest (Giesen 2004; GTI 2012) and mangrove forest (Silvius et al. 2018a). It is also an important carbon sink (GTI 2012), but it is experiencing deforestation caused by logging and human-caused fires (Giesen 2004).

Since 2007, a tiger conservation programme has been operational in Berbak-Sembilang TCL to monitor and protect the tiger population and its habitat. The adaptive patrol management system, SMART (Spatial Monitoring and Reporting Tool, <https://smartconservationtools.org>), has been implemented by BSNP since 2014, led by the Tiger Patrol and Protection Units (TPPUs), to tackle tiger poaching and habitat destruction. A Wildlife Conflict Response Team (WCRT) has been operational since 2011 and a Wildlife Crime Investigation Unit (WCIU) since 2015, combating the illegal wildlife trade, mitigating human-wildlife conflict and combating the illegal wildlife trade. Establishing and conserving a viable tiger population requires long term monitoring of tigers, co-predators, prey and their habitats to evaluate a conservation programme's effectiveness and inform management decision-making (Jhala et al. 2009; Goodrich et al. 2013). The objective of

the study was to assess the status of the Sumatran Tiger in the Berbak-Sembilang TCL, as part of implementation of a tiger conservation strategy.

## MATERIALS AND METHODS

### Study area

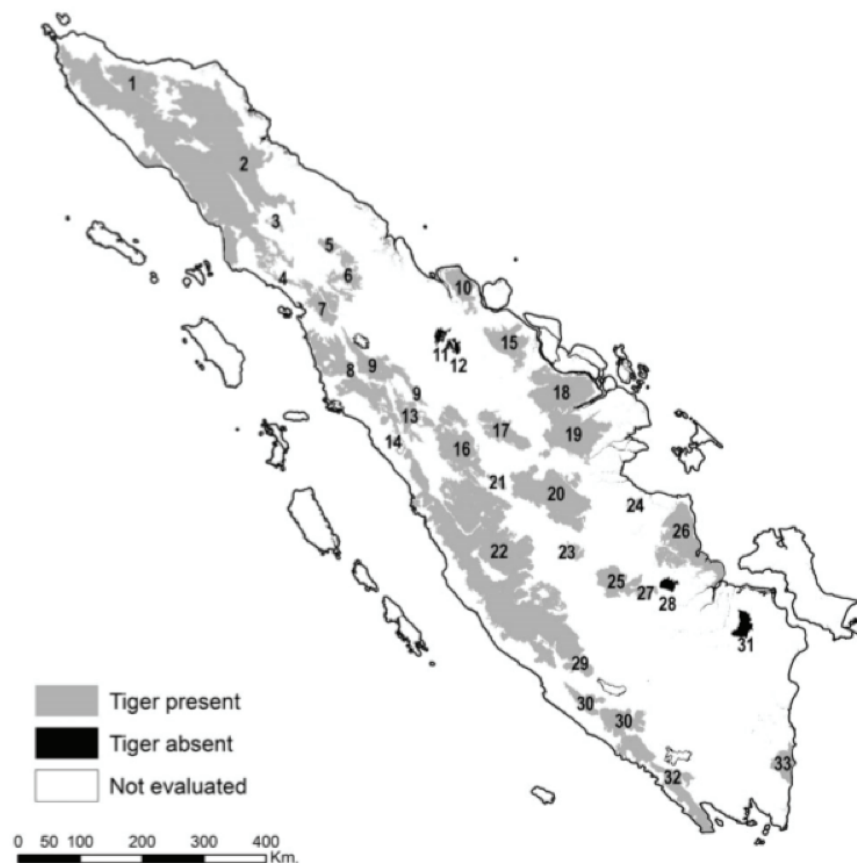
The study was conducted in Berbak Tiger Core Area (BTCA, area 657km<sup>2</sup>) and Sembilang Tiger Core Area (STCA, area 695km<sup>2</sup>) within BSNP, located on the east coast of Sumatra island, Indonesia (1.08°–2.45°S and 103.80°–104.90°E). Berbak Tiger Core Area mainly consists of freshwater swamp forest and peat swamp forest. The topography is flat with elevation less than 15m (Giesen 2004). Sembilang Tiger Core Area contains the largest area of mangrove forest in the Indo-Malayan region (Silvius et al. 2018a). It is made up of peatland and mangrove forest in the east and peat swamp forest in the west. Both core areas come together in the small blackwater Benuh River\*, and in a large peat dome in the west that forms the upper catchment of the Benuh River. Annual rainfall is c. 2,466mm with lowest and highest records of 933mm and 3,972mm, respectively (Silvius et al. 2018a).

Tiger prey species in Berbak-Sembilang TCL include Wild Boar *Sus scrofa*, Bearded Pig *Sus barbatus*, Southern Red Muntjac *Muntiacus muntjak*, Sambar Deer *Rusa unicolor* and two sympatric species of chevrotain: Greater Oriental Chevrotain *Tragulus napu* and Lesser Oriental Chevrotain *Tragulus kanchil*. The other felid species in the study area include Sunda Clouded Leopard *Neofelis diardi*, Marbled Cat *Pardofelis marmorata*, Leopard Cat *Prionailurus bengalensis*, and Flat-headed Cat *Prionailurus planiceps* (BSNP & ZSL 2018).

### Field methods

Tiger population densities were estimated using standardized camera trapping procedures based on capture-recapture method (Karanth & Nichols 2002). Surveys were conducted in BTCA between 31 January 2018–22 August 2018, 14 February 2015–8 April 2016, and 23 June 2010–2 February 2011; and in STCA between 1 January–1 July 2019 and 5 September 2018–21 December 2018. A nine km<sup>2</sup> grid system was used, and paired camera traps (1 pair of camera traps= 1 camera trap station) were deployed in accessible tiger

\* A blackwater river is a river with a slow-moving channel flowing through forested swamps or wetlands, whose water is tannin-stained, in this case from the peat.



**Figure 1.** Distribution of the Sumatran Tiger: 33 of 38 forest patches have been assessed (figure from Wibisono & Pusparini 2010). Berbak-Sembilang TCL the focus in the current study is in forest patch 26.

habitat (Figure 2). Average Sumatran Tiger home range is estimated at 50–70 km<sup>2</sup> for adult female and 110km<sup>2</sup> for adult male (Franklin et al. 1999). Camera traps were placed along animal trails to maximise tiger detection (Sunarto et al. 2013). Camera traps were attached to trees and positioned approximately 40cm above ground with each of the paired camera traps about 7m apart and pointing towards each other, in order to capture both flanks of a tiger to facilitate individual identification. In total, 125 camera trap stations were placed in BTCA and 146 camera trap stations in STCA over the five surveys (Table 1). DLC Covert II, Panthera V4, and Reconyx Hyperfire HC500 digital cameras were used, programmed to take three photographs per trigger with no delay. All camera traps used white flash to obtain colour images at night to aid in individual tiger identification.

#### Data analysis

The metadata (i.e., image name, date and time) associated with all images were extracted with Exiv2 software (Huggel 2012) and compiled in an Excel spreadsheet (Microsoft Office Professional Plus 2010). Information on identified species was then added for all images obtained. Individual tigers were identified based

on their unique stripe patterns and gender determined by secondary sexual traits.

Tiger population densities were estimated using the Bayesian Spatial Capture Recapture (SCR) method. A 90-day data subset for each survey was used for the analysis to avoid violation of the population closure assumption. Three data input files were created: a camera trap station activity file specifying camera trap station location and operation by 24-hour day; a tiger capture history file specifying capture events as a single detection of an individual tiger at a camera trap station in each 24-hour period; and a binary habitat mask file. The analysis was carried out in the program JAGS (Just Another Gibbs Sampler) accessed through the program R, version 3.6.0 (R Development Core Team 2019) using the package RJAGS (<http://mcmc-jags.sourceforge.net>). In data augmentation, M was set to 80 – larger than the largest possible population size (i.e., the number of activity centres). The centroid of capture locations of individual animals caught were used as the starting values for activity centres. Three MCMC (Markov Chain Monte Carlo) chains with 60,000 iterations, a burn-in of 1000, and a thinning rate of 10 were implemented. This combination of values ensured an adequate number of



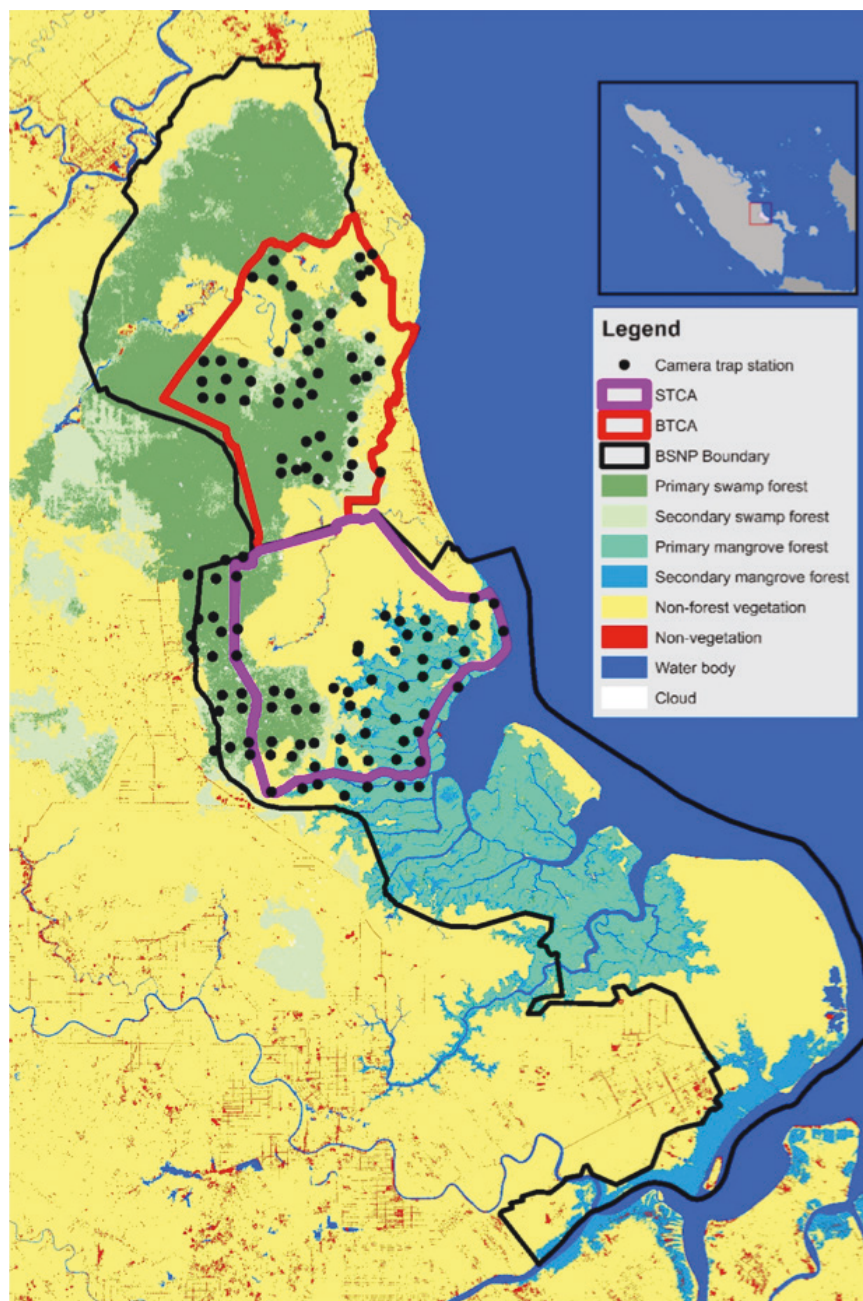


Figure 2. Location of camera trap stations in Berbak-Sembilang National Park (2018–2019), Sumatra. Berbak and Sembilang Tiger Core Areas are in red and purple outlines respectively.

Table 1. Camera trap sampling effort, number of tiger detections and number of individual adult tigers captured (sub-period of 90 days was used for the analysis - see methods).

Area	Survey year	Trap-nights (number of camera trap stations)	Number of tiger independent photo-captures	Number of adult tigers captured	Number of adult female tigers captured	Number of adult male tigers captured
Berbak Tiger Core Area	2018	2,885 (50)	63	10	5	5
	2015	3,731 (48)	31	6	4	2
	2010	1,152 (27)	16	6	2	4
Sembilang Tiger Core Area	2019	6,570 (73)	11	4	2	2
	2018	5,934 (73)	13	4	1	3

iterations to characterise the posterior distributions. Chain convergence was checked using the Gelman-Rubin statistic (Gelman et al. 2004),  $R$ -hat, which compares between and within chain variation.  $R$ -hat values below 1.1 indicate convergence (Gelman & Hill 2006). The approach of Royle et al. (2014) was used for the model goodness-of-fit test, calculating three statistics, all using Freeman-Tukey discrepancies: individual animal by camera trap station capture frequencies, aggregating the binary daily capture data by animals and camera trap stations; individual animal capture frequencies, aggregating for each animal; camera trap station animal capture frequencies, aggregating for each camera trap station.

For tiger prey species, trap rate for each species was calculated as the mean number of independent photographic 'events' per trap day  $\times 100$ . An 'event' was defined as any sequence for a given species occurring after an interval of  $>60$  min from the previous three-image sequence of that species (Amin et al. 2015).

## RESULTS

Survey effort ranged from 1,152 trap nights (BTCA 2010 survey with 27 camera trap stations) to 6,570 trap nights (STCA 2019 survey with 73 camera trap stations; Table 1). The number of adult tigers captured at a study site ranged from 4 to 10 individuals (Table 1). One individual was captured in both BTCA and STCA in different years.

Given the small sample size, it was not possible to model differences in space use and movement range between the sexes. The STCA 2018 survey had only one individual tiger captured at more than one location and therefore it was not analysed. The Bayesian  $p0 \sim 1$ ,  $\sigma^2 \sim 1$  model  $R$ -hat values for all estimated parameters were below 1.01 and fitted well to the data ( $P=0.3$ – $0.5$  for all three statistics). Berbak Tiger Core Area had a higher density of tigers (1.33 individuals/100km<sup>2</sup>, 95% CI 0.82–1.91 in 2018) than STCA (0.56 individuals/100km<sup>2</sup>, 95% CI 0.45–0.89 in 2019). The BTCA tiger population also showed a stable trend between the study years (Table 2, 2.78% per year, SE 1.18).

The most recent BTCA (2018) and STCA (2019) tiger population density maps, derived from the model, are not presented due to data sensitivity<sup>2</sup>. Several tigers were caught in 1–2 locations close to the northern periphery of BTCA, and the western and southeastern edge of the STCA, so there was greater uncertainty in their activity centres (Figure 3).

Our study provided evidence of breeding, with two adult females each with two cubs photographed in STCA (2018–2019), and one adult female with her two cubs in BTCA (2018) (Image 1). The surveys also indicated relatively good population of medium-to-large-bodied prey species, including Lesser Oriental Chevrotain, Wild Pig, and Bearded Pig in BTCA and STCA (Table 3).

## DISCUSSION

Our study has shown that the tiger population within BSNP is small, and has remained stable over the past ten years despite facing significant threats (Giesen 2004). The estimated tiger density for BTCA was similar to those recorded in the mangrove habitat of the Sundarban landscape (1.08–4.79 tigers/100km<sup>2</sup>, Jhala et al. 2016), while the estimated density of tigers in STCA was lower. Although we were unable to measure the scale of hunting or poaching in BSNP, patrol data between 2015–2019 show that snares were reported at a rate of 0.89 traps/100 km (BSNP 2020). A recent study on the spatio-temporal distribution of human-tiger interaction in Sumatra classified the relative distribution of conflict cases in the Berbak-Sembilang TCL as low to moderate (Kartika 2017). Furthermore, within the last five years, there has only been a single record of human-caused tiger mortality in the landscape (Zoological Society of London 2020). Evidence of tiger breeding also suggests a relatively healthy prey population to support lactating tigress.

### Enhancing tiger recovery in the Berbak-Sembilang landscape

Within the forests and peatlands of Berbak Sembilang TCL, habitat loss, mainly by human-caused forest fires, is the current main threat (Abood et al. 2015). In just eight years between 2000 and 2018, there were 12,084 fire hotspots in BSNP (80% confidence level) occurring in both dry and wet seasons (Mora et al. 2019). Across the landscape, forest fires are changing the structure of the peat swamp forest (Wetland International-Indonesia Programme 2002), with large areas of closed canopy-tall trees with undergrowth being replaced by a mosaic of open patches of grasses and shrubs (Giesen 2004). The average rate of annual forest loss for the period 2010–2040 has been predicted to be 1.1–1.6 % (Elz et al. 2015).

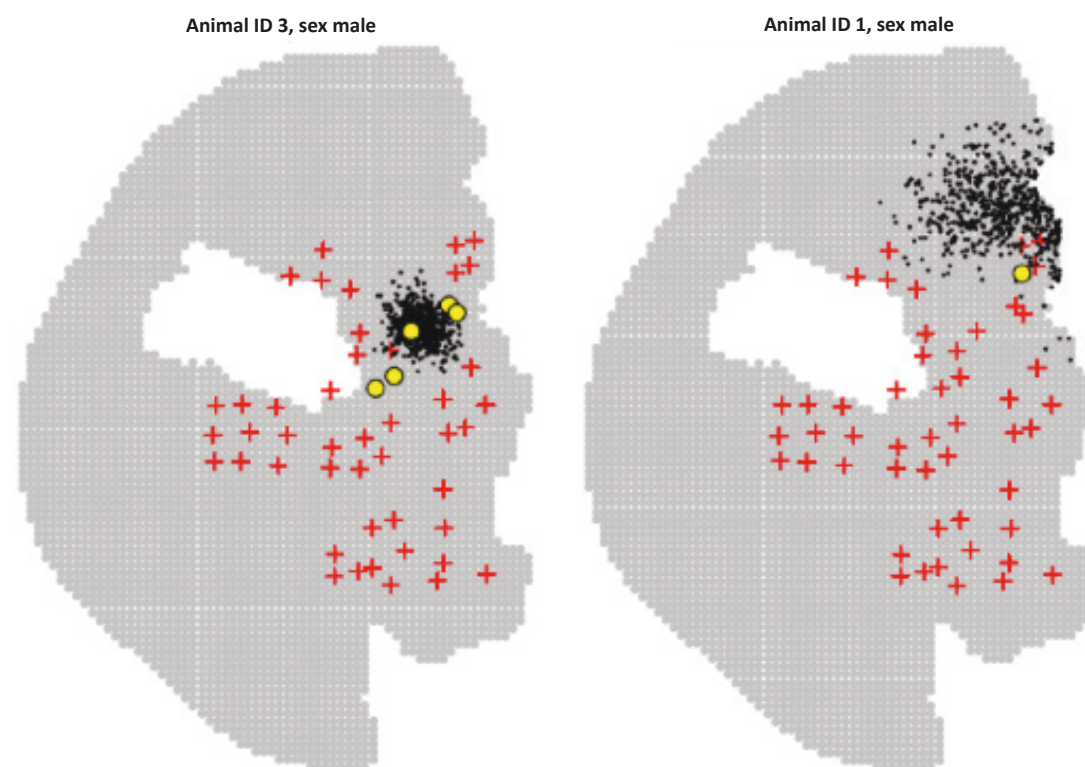
Maintaining forest integrity is critical for the survival of tigers (Wibisono et al. 2011), and this requires increased protection from illegal logging and forest clearance. A comprehensive fire management plan

**Table 2.** Estimates of Bayesian spatial capture recapture model outputs. Sigma is the ranging scale parameter.

Area	Survey year	Tiger density (95% CI) per 100km <sup>2</sup>	Tiger adult female density (95% CI) per 100km <sup>2</sup>	Tiger adult male density (95% CI) per 100km <sup>2</sup>	Sigma (95% CI) (km)	Population size (95% CI)
Berbak Tiger Core Area	2018	1.33 (0.82–1.91)	0.66 (0.34–1.02)	0.66 (0.34–1.02)	4.16 (3.27–5.14)	19 (11–27)
	2015	1.09 (0.48–1.78)	0.70 (0.27–1.23)	0.39 (0.14–0.82)	3.02 (2.22–3.97)	16 (7–26)
	2010	1.36 (0.54–2.35)	0.49 (0.18–0.99)	0.87 (0.36–1.63)	3.82 (2.24–5.82)	15 (6–26)
Sembilang Tiger Core Area	2019	0.56 (0.45–0.89)	0.28 (0.22–0.45)	0.28 (0.22–0.45)	4.59 (2.67–6.97)	5 (4–8)

**Table 3.** Tiger prey species trap rates for Berbak Tiger Conservation Area and Sembilang Tiger Conservation Area. The trap rate was calculated as the number of independent photographic events per 100 trap days. We defined a camera trap ‘independent photographic event’ as any sequence of photographs of the species occurring after an interval of >60 minutes from the previous photograph of the species (Amin et al. 2015).

Species	BTCA 2010	BTCA 2015	BTCA 2018	STCA 2018	STCA 2019
Wild Boar <i>Sus scrofa</i>	0.66	0.79	1.81	6.07	5.80
Bearded Pig <i>Sus barbatus</i>	0.03	0.20	15.71	6.89	10.59
Sambar Deer <i>Rusa unicolor</i>	-	-	0.10	0.67	0.49
Muntjac Deer <i>Muntiacus muntjak</i>	-	-	-	0.16	0.01
Greater Oriental Chevrotain <i>Tragulus napu</i>	4.33	0.35	9.81	0.74	0.35
Lesser Oriental Chevrotain <i>Tragulus kanchil</i>	-	0.19	13.62	5.56	4.17
Long-tailed Macaque <i>Macaca fascicularis</i>	0.46	0.06	0.76	2.23	2.06
Pig-tailed Macaque <i>Macaca nemestrina</i>	2.14	0.83	4.19	3.37	2.36



**Figure 3.** Activity centre posterior distributions (black dots); capture locations (yellow circles); and camera trap station locations (red cross) for an adult tiger caught in multiple locations (left) and an adult tiger caught in a single location close to the edge of the camera trap grid (right), Berbak Tiger Core Area (2018).





**Image 1. Top: Tigress and her two cubs captured on camera trap in Sembilang Tiger Conservation Area in October 2018. Bottom: Another tigress and her two cubs captured in February 2019. Images of another tigress with two cubs in Berbak Tiger Conservation Area were also captured.**

should also be created and implemented, based on suitable technologies such as remote sensing and appropriate levels of SMART patrolling in this physically challenging environment. A reforestation programme with replanting of indigenous trees needs to be urgently undertaken in the affected areas. The BTCA should be extended to include the primary swamp forest north of the area, following camera trap surveys. The delineation of the existing tiger core area was based on tiger occurrence detected by camera trap and sign surveys (Wibisono et al. 2011; Goodrich et al. 2013). A massive forest fire in 2015, however, has significantly altered forest cover in the core area, and our study revealed activity centres of several tigers lying north of the core area (Fig. 3).

Suitable habitat for tigers also needs to be expanded, increasing the chances for establishing a long-term viable tiger population. A landscape-based approach to the management of the area is being implemented by the Indonesia Government, combining the previously separate Berbak National Park and Sembilang National

Park into a single national park (BSNP) under the management of a single authority (via MoEF decree No. P.07/2016). The peatlands of Sembilang remain contiguous with those of Berbak, and together they provide habitat for tigers in this unique ecosystem (Silvius et al. 2018a). As a next step, it should be a priority that government owned lands adjacent to the national park are protected, and incompatible land-uses prohibited (Silvius et al. 2018b). Ultimately, concession areas will need to be integrated into tiger managed habitats and habitat connectivity re-established if tigers and other threatened wildlife are to have a future in this unique landscape.

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**Bahasa Indonesia:** Harimau Sumatera telah mengalami menurun populasi sekitar 16,6% antara tahun 2000 dan 2012 yang sebagian besar disebabkan oleh hilangnya hutan dan degradasi habitat. Saat ini mereka sangat terancam punah dan pemantauan yang efektif terhadap populasi tersisa dalam lanskap prioritas sangat penting untuk menginformasikan rencana pengelolaan dan konservasi guna mengamankan masa depan spesies karismatik ini. Survei dengan kamera penjemput di bentang alam prioritas konservasi harimau Berbak-Sembilang di Sumatera timur, mencakup Area Inti Harimau Berbak dan Sembilang (BTCA, STCA) selama 10 tahun. Perkiraan kepadatan populasi 2018-2019 terbaru, yaitu di BTCA 1,33 individu dewasa / 100 km<sup>2</sup> (95% CI 0,82 - 1,91) dan STCA 0,56 dewasa / 100 km<sup>2</sup> (95% CI 0,45 - 0,89) dengan perkiraan kelimpahan, BTCA 19 individu dewasa (95% CI 11 - 27) dan di STCA 5 individu dewasa (95% CI 4 - 8), hasil ini telah mengkonfirmasi bahwa populasi kecil tapi stabil. Kepadatan populasi harimau Berbak-Sembilang lebih tinggi daripada lanskap Kerinci-Seblat di Sumatera Barat dan lanskap Lueser-Ulu Masen di Sumatera Utara, dan lebih rendah dari lanskap Bukit Barisan Selatan di Sumatera Selatan. Populasi harimau Berbak-Sembilang, seperti di lanskap konservasi harimau Sumatera lainnya, terancam oleh deforestasi, yang sebagian besar diakibatkan oleh kebakaran hutan secara rutin dan pembukaan lahan untuk pertanian, dan perburuan ilegal yang berkelanjutan, yang didorong oleh perdagangan satwa liar ilegal nasional dan internasional. Sejak tahun 2007, program konservasi harimau Berbak-Sembilang telah dilaksanakan melalui kerangka kerja sama antar lembaga. Pemantauan status populasi harimau merupakan komponen kunci untuk mengukur efektivitas intervensi konservasi di lanskap dan menginformasikan perencanaan strategis. Populasi harimau kecil lebih rentan terhadap fluktuasi demografis dan genetik, yang dapat memengaruhi kelangsungan hidup jangka panjang mereka. Oleh karena itu, pendekatan pengelolaan tingkat lanskap yang efektif menjadi prioritas, membangun koridor harimau yang berfungsi dengan lanskap harimau lainnya dan melindungi zona penyangga taman nasional. Sama pentingnya untuk meningkatkan kapasitas pemantauan, analisis data dan pelaporan di antara para pemangku kepentingan dan membangun basis data harimau tingkat nasional yang tersentralisasi untuk pemantauan status dan pengambilan keputusan.

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