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Tigers and Their Prey in Bukit Rimbang Bukit Baling: Abundance Baseline for Effective Wildlife Reserve Management

Harimau dan Mangsanya di Bukit Rimbang Bukit Baling: Basis Informasi Kelimpahan untuk Pengelolaan Suaka Margasatwa yang Efektif

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ABSTRACT

Managing the critically endangered Sumatran tiger (Panthera tigris sumatrae) needs accurate information on its abundance and availability of prey at the landscape level. Bukit Rimbang Bukit Baling Wildlife Reserve in central Sumatra represents an important area for tigers at local, regional and global levels. The area has been recognized as a long-term priority Tiger Conservation Landscape. Solid baseline information on tigers and prey is fundamentally needed for the management. The objective of this study was to produce robust estimate of tiger density and prey a vailability in the reserve. We used camera traps to systematically collecting photographic samples of tigers and prey using Spatial Capture Recapture (SCR) framework. We estimated density for tigers and calculated trap success rate (TSR; independent pictures/100 trap nights) for main prey species. Three blocks in the reserve were sampled from 2012 to 2015 accumulating a total of 8,125 effective trap nights. We captured 14 tiger individuals including three cubs. We documented the highest density of tigers (individuals/100 km²) in southern sampling block (based on traditional capture recapture (TCR) : 1.52 ± SE 0.55; based on Maximum Likelihood (ML) SCR:0.51 ± SE 0.22) and the lowest in northeastern sampling block (TCR: 0.77 ±SE 0.39; ML SCR: 0.19 ± SE 0.16). The highest TSR of main prey (large ungulates and primates) was in northeastern block (35.01 ± SD 8.67) and the lowest was in southern block (12.42 ± SD 2.91). The highest level of disturbance, as indicated by TSR of people, was in northeastern sampling block (5.45 ± SD 5.64) and the lowest in southern (1.26 ± SD 2.41). The results suggested that human disturbance strongly determine the density of tigers in the area, more than prey availability. To recover tigers, suggested strategies include controlling human disturbance and poaching to the lowest possible level in addition to maintaining main prey availability.

KATA KUNCI
Capture-Mark-Recapture
populasi tertutup
pengelolaan habitat
kesintasan populasi
pemulihan harimau

INTISARI

Mengelola spesies kunci seperti harimau Sumatera (*Panthera tigris sumatrae*) yang dalam kondisi kritis, memerlukan informasi terkait populasi satwa tersebut dan ketersediaan satwa mangsanya pada tingkat lanskap. Suaka Margasatwa Bukit Rimbang Bukit Baling di Sumatera bagian tengah merupakan sebuah kawasan penting untuk harimau baik pada tingkat lokal, regional, maupun global. Kawasan ini telah diakui sebagai sebuah kawasan prioritas jangka panjang *Tiger Conservation Landascapes* (TCL). Informasi dasar yang sahih mengenai populasi harimau dan mangsanya sangat dibutuhkan untuk pengelolaan efektif satwa tersebut dan kawasan habitatnya. Tujuan dari studi ini adalah untuk menghasilkan perkiraan kepadatan populasi harimau dan ketersediaan mangsanya di kawasan suaka margasatwa tersebut. Kami menggunakan perangkap kamera untuk mengumpulkan sampel gambar harimau dan mangsanya secara sistematis menggunakan kerangka kerja *Spatial Capture Recapture* (SCR). Kami memperkirakan kepadatan harimau dan menghitung angka keberhasilan perangkap atau *trap success rate* (TSR: gambar independen/100 hari aktif kamera) untuk satwa mangsa utama. Tiga blok di dalam suaka margasatwa telah disurvei dari tahun 2012 hingga 2015 mengakumulasikan keseluruhan 8,125 hari kamera aktif. Kami merekam 14 individu harimau termasuk tiga anak. Kami mendokumentasikan kepadatan tertinggi harimau (individu/100 km^2) di blok sampling selatan (berdasarkan pendekatan analisa *capture recapture* tradisional (TCR) 1.52 ± SE 0.55; berdasarkan *Maximum Likelihood* (ML) SCR 0.51 ± SE 0.22) dan terendah di utara-timur (TCR: 0.77 ±SE 0.39; ML SCR: 0.19 ± SE 0.16). TSR tertinggi dari mangsa utama (ungulate besar dan primata) adalah di blok sampling utara-timur (35.01 ± SD 8.67) dan terendah adalah di blok sampling selatan (12.42 ± SD 2.91). Tingkat gangguan tertinggi, sebagaimana diindikasikan oleh TSR manusia, adalah di blok sampling utara-timur (5.45 ± SD 5.64) dan terendahnya di blok sampling selatan (1.26 ± SD 2.41). Hasil studi ini mengindikasikan bahwa gangguan manusia yang sangat tinggi sangat menentukan kepadatan harimau di kawasan ini, melebihi pengaruh dari ketersediaan satwa mangsa. Untuk memulihkan populasi harimau, disarankan beberapa strategi termasuk mengendalikan gangguan manusia dan perburuan hingga ke tingkat terendah, selain tetap memastikan ketersediaan satwa mangsa utama yang memadai.

Introduction

Managing the critically endangered Sumatran tiger (*Panthera tigris sumatrae*) requires solid baseline and up to date information on the population at a landscape or forest management unit level (Linkie et al. 2006). Around 10% of the 3890 global tiger population lives on the island of Sumatra (Goodrich et al. 2015; WWF - Tigers Alive Initiative 2016). The population of this only remaining island tigers is still believed to be decreasing, mainly due to hunting pressure (poaching for domestic and international markets as well as prey depletion due to hunting and trapping) and habitat loss because of small to large-scale logging (both legal and illegal), development of commercial crops (primarily rubber, oil palm and pulpwood plantations), conversion to agriculture, and forest fires (Linkie et al. 2003; Kinnaird et al. 2003; Indonesian Ministry of Forestry 2007; Uryu et al. 2010; Wilting et al. 2015).

Tiger experts have classified global tiger habitats into several categories of Tiger Conservation Landscapes (TCL). Sumatra has 12 TCLs with total area of around 88,000 km^2 that falls into several categories based on priority scales related to tiger viability and action needed to conserve (Dinerstein et al. 2006). While some TCLs are already widely recognized and relatively more intensively managed such as Kerinci Seblat and Bukit Barisan Selatan, there are some that have only received minor attention despite their high potential for global tiger conservation such as Rimbang Baling, Batanghari, and Bukit Balai Rejang Selatan. Among the TCLs that have been overlooked from the management perspective include the long-term priority Rimbang Baling Tiger Landscape. The core of this tiger landscape is the Bukit Rimbang Bukit Baling Wildlife Reserve (BRBBWR). Due to its potentially strategic role for tiger recovery and relatively low level of hitherto management attention, WWF Tigers Alive Initiative has appointed this area as one of their Tx2 (where the network plan to recover tiger population by implementing strategic conservation interventions) sites (WWF - Tigers Alive Initiative 2012). The premise is that conservation resources invested in such a site can potentially make higher return in terms of tiger recovery, compared to same amount of investments allocated to areas that are already relatively well managed.

Managing and recovering tigers in BRBBWR needs accurate knowledge of species' ecological and geographic requirements, that is fundamental for conservation planning and effective management (Elith et al. 2006). Monitoring tigers and promoting the effectiveness of conservation management involve the establishment of robust baseline information and closely monitoring subsequent trends. Human as a key factor to influence and affect tiger presence, needed to be considered, understood, and managed to ensure effectiveness of the conservation of tigers and forest as their main habitat (Linkie et al. 2008; Wibisono & Pusparini 2010; Imron et al. 2011). The objective of this study was to provide robust estimation of tiger density and prey availability including human disturbance level in Bukit Rimbang Bukit Baling Wildlife Reserve as a baseline for effective wildlife reserve management especially for its contribution to national species conservation target and global tiger recovery program.

Materials and Methods

Study Area

This study was conducted in Bukit Rimbang Bukit Baling Wildlife Reserve (BRBBWR), central Sumatra. Established in 1984, the reserve measured around 136.000 ha and is managed by BBKSDA Riau (Nature Resource Conservation Agency of Riau), Indonesia Ministry of Environment and Forestry (MoEF). Based on Forestry Minister Decree No. SK.3977/Menhut-VII/KUH/2014 year 2014, the reserve is now measured 141,226.25 ha. The area plays important role for tiger conservation as a breeding site, and as a connectivity among the otherwise isolated neighboring tiger landscapes such as Batanghari, Kerinci Seblat, Bukit Tigapuluh, and Rimbo Panti landscapes. Previous tiger study in the reserve was conducted in 2006 where only 2 individuals of tigers were identified from 1,574 total effective trap nights of camera traps deployed in 20 camera stations, covering a relatively small portion of the reserve (Sunarto et al. 2013).

The reserve borders with acacia plantations, palm oil plantations, coal mining, and community lands. Bukit Rimbang Bukit Baling is dominated by hills with slopes mainly ranging from 25% to 100%. The highest elevation measured ±1070 masl. The area serves as a major water catchment area in central Sumatra. To ensure the ecosystem function and better management of the area, in 2016, the Ministry of Environment and Forestry has recently inaugurated Bukit Rimbang Bukit Baling as a Conservation Forest Management Unit (CFMU, based on Environment and Forestry Minister Decision Letter No. SK.468/Menlhk/

Setjen/PLA.0/6/2016). The Forest Management Unit, measured ± 142,156 ha, is located in two districts of Riau Province: Kampar and Kuantan Singingi. The designation as an FMU indicates an improvement in the management of the conservation area, allowing the area to be managed by a special management body with specially allocated budget and facilities from the government.

Methods

This study applied capture-mark-recapture (CMR) approach that was developed to tackle the difficulties associated with the estimation of population size in highly mobile animals (Petit & Valiere 2006). Noninvasive CMR in this study was implemented using remotely-triggered camera traps that allow researchers to collect reliable evidence of animal presence and associated data such as time, location, and other relevant variables (Sunarto et al. 2013).

We superimposed the study area with 2x2-km grid system, and divided it into three sampling blocks. To ensure that every tiger in the study area has a non-zero probability of being captured, we installed camera station in every other 2x2-km grid cell. With this and assuming that smallest tiger homerange in Sumatra is 49 km2 (Franklin et al. 1999), we believe that every tiger homerange would have around 3 camera stations (Sunarto et al. 2013). We set the camera to take both of videos and photos which is useful for individual description and identification. We followed closed-population CMR framework. During the sampling period in every block, we can assume that there is no migration (outward and inward), mortality or birth. We used 3 months in each sampling period to meet closure assumption, as tigers' gestation period take around the same period (Sunarto et al. 2013). We used stripe patterns to distinguish the uniqueness between tiger individuals. The differences in stripe patterns were sufficiently distinct allowing unambiguous identification of individual tigers (Karanth et al. 2006).

Population and Density Estimation

We used two different methods to estimate tiger density: traditional capture-recapture (TCR) and spatial capture recapture (SCR). The first allows comparison of results to previous studies conducted in other places; while the second allows application of the latest advanced technique that presumably more likely produce results with better accuracy.

We implement the TCR framework in Program CAPTURE (Rexstad & Burnham 1992). Detection history used in this approach was developed by collapsing every 10-day period into one sampling occasion. So, for the three-month sampling, we have approximately 9 to 10 sampling occasions in the detection history. We selected models based on Akaike Information Criteria (AIC; Akaike 1973). However, when the only competing model is Mo (model assuming equal capture probability for all animals) we used the heterogeneity model (Mh) with Jackknife estimator, which allows each individual to have different and unique detection probabilities (Otis et al. 1978; Sunarto et al. 2013). To produce tiger density estimates, we calculated tiger density using TCR and by using ½ Mean Maximum Distance Moved (MMDM). Also, ½ MMDM plus a buffer (to calculate 'the minimum convex polygon'of the effective camera trapping site) were used to calculate effective trapping area (ETA) based on tiger individual movements (Karanth & Nichols 1998; Sunarto et al. 2013). Mean Maximum Distance Moved (MMDM) was calculated based on the movement of all the tigers that were trapped more than once; it is used to compute boundaries of buffer strips within capture – recapture framework to estimate the density when home range information is not available in the area sampled (Soisalo & Cavalcanti 2006). Spatial Capture Recapture (SCR) to estimate population size and density was implemented using Maximum Likelihood approach and run in Program DENSITY (Otis et al. 1978; Efford 2004; Petit & Valiere 2006; Efford et al. 2016). Detection history for this approach was developed based on an occasion that represents a 24-hour period of camera trapping. For every occasion we marked each camera station as either active (1) when at least one camera was operational, or inactive (0) when no camera was working. This enabled us to use incomplete trap layout in the input option in Program DENSITY. We selected the best model based on the Akaike Information Criteria (AIC; Akaike 1973), or that corrected version adjusted for small sample sizes, and their Akaike weights (wi) (Linkie et al.2008; Sunarto et al. 2013). However, we followed Efford (2004) and used half normal model for the best density model with probability of capture (P) as a function of distance (d) from home range centre to trap, in the absence of competition that is suitable to tiger density study. For better accuracy of possible areas available for tigers, we used forest cover map 2011 available from WWF-Indonesia (Setiabudi 2015); published at) as habitat mask in program DENSITY.

Trap Success Rate

We used the trap success rate (TSR) or commonly known as Relative Abundance Index (RAI) to indicate abundance of prey species which mostly are difficult to identify individually for capture-recapture analysis. TSR represents the number of independent pictures for each species per 100 trap nights. We followed the definition of independent pictures as (1) consecutive photographs of different individuals of the same or different species, (2) consecutive photographs of individuals of the same species taken more than 0.5 hours apart, (3) nonconsecutive photos of individuals of the same species (O'Brien et al. 2003). While we recognize some of the drawbacks, the use of photographic rate (photographs per sampling time) as an index of abundance potentially applies to the majority of terrestrial mammals where individual recognition, and hence capture–recapture analysis, are unfeasible (Rovero & Marshall 2009).

We compared trap success rates of tigers, main prey species, and people. In this topic we use large ungulates because tigers are the largest of the fields and prey almost exclusively on large ungulates (Karanth et al. 2004). We defined main prey species to include barking deer (*Muntia cusmuntjac*), bearded pig (*Susbar batus*), sambar deer (*Rusa unicolor*), serow (*Capricornis sumatraensis*), and wild pig (*Sus scrofa*); and primate sincluding pig-tailed macaque (*Macacane mestrina*) (Table 2). We did not include Malayan sun bear (*Helarcto smalayanus*) and Malayan tapir (*Tapirus indicus*) as main prey species because they are unlikely become main tiger prey species (Sriyanto 2003).

We also assessed the level of human activity in each sampling block using the photographic rate of humans, excluding the monitoring team, and level of vandalism to the cameras by camera lost numbers (Sunarto et al. 2013). The trap success rate of people was used to indicate the level of human disturbance in the study area.

Results and Discussion

The total 8,125 effective trap nights in 83 camera station resulting in 227 tiger photographs from 30 locations (Table 1). Tiger images were identified into 14 unique individuals including three cubs. The three sampling blocks, measured 498 km^2, covers secondary and primary forest areas in the reserve (Fig. 1). Elevation of the camera trap station range between 102 and 1,247 m.asl (Table 1).

We used minimum convex polygon (MCP) of camera trap stations with buffer of ½ mean maximum distance moved (MMDM) to calculate effective trapping area (ETA) for each sampling block. The largest ETA was in northwestern sampling block (645 km^2) and the lowest ETA was in northeastern sampling block (267 km^2) (Table 1).

Table 1. Summary of the survey efforts and tiger density estimates in three different sampling blocks of Bukit Rimbang Bukit Baling Wildlife Reserve
Tabel 1. Ringkasan usaha survei dan perkiraan kepadatan harimau di tiga blok sampling berbeda di Suaka Margasatwa Bukit Rimbang Bukit Baling

	Northeastern	**Northwestern**	**Southern**
Survey period	16 November 2011 - 25 February 2012	12 February - 10 June 2014	28 August - 19 December 2015
ETA (km^2)[a]	267	654	525
Trap polygon size (km^2)[b]	95	195	208
Station altitude range (m)	102-830	378-1,247	291-886
Number of stations[c]	20	31	32
No. of camera lost	0	4	0
No. of trap nights[d]	1,688	3,169	3,268
Detection probability (P)	0.3889	0.3704	0.4074
Unique individual (Mt+1)	2	3	6[b]
Population estimate ($\widehat{N}$)[e]	2 (SE 0.04)	3 (SE 0.23)	6 (SE 0.73)
½ MMDM (km^2)	3.520	6.187	4.573
$\widehat{D}$ with ½ MMDM (km^2)[f]	0.77 (SE 0.39)	0.46 (SE 0.17)	1.52 (SE 0.55)
$\widehat{D}$ MLSCR[g]	0.19 (SE 0.16)	0.23 (SE 0.14)	0.51 (SE 0.22)

Remark : [a]Effective Trapping Area (ETA) with buffer ½ MMDM with total size was 1,446 km^2, [b]Trap polygon size by using Minimum Convex Polygon (MCP) of camera stations with total size was 498 km^2, [c]Cameras were placed in stations (each station has a pair of cameras) and in every other 2x2 km grid cell/2 km, cameras were placed for ± 3 months, [d]Total effective trap nights were 8,125, [e](N^) The best fit model was Mh, [f]Density estimate based on ETA with ½ MMDM, [g]Density with MLSCR (Maximum Likelihood Spatially Explicit Capture Recapture) of the best model, [h]We only analyzed 6 adult tigers, but in total 9 tiger individuals captured including 3 cubs; cubs were not included in the density analysis. Totally, we captured 14 individuals in all sampling block.
Keterangan : [a]Ukuran sampling efektif/*Effective Trapping Area*(ETA) dengan penyangga ½ MMDM dengan ukuran total adalah 1,446 km^2, [b]Ukuran poligon dengan menggunakan Poligon Terhubung Terkecil/*Minimum Convex Polygon* (MCP) dari stasiun – stasiun kamera penjebak dengan ukuran total adalah 498 km^2, [c]Kamera ditempatkan di stasiun – stasiun (setiap stasiun terpasang kamera secara berpasangan) dan berseling di setiap grid sel 2x2km/± 2 km, kamera dipasang selama ± 3 bulan, [d]Jumlah keseluruhan hari aktif kamera adalah 8,125, [e](N^) model terbaik adalah Mh, [f]Perkiraan kepadatan berdasarkan pada ETA dengan ½ MMDM, [g]Kepadatan dengan MLSCR (*Maximum Likelihood Spatially Explicit Capture Recapture*) dari model terbaik, [h]Kami hanya menganalisis 6 harimau dewasa, tetapi secara keseluruhan tertangkap 9 harimau termasuk 3 anakan; anakan tidak dimasukkan ke dalam analisis kepadatan. Secara keseluruhan, kami mendapatkan 14 individu harimau di seluruh blok sampling.

Tiger Density

Two approaches of tiger density estimation produced different results. Traditional Capture Recapture (TCR) approach generally resulted in higher estimate than the newer technique of Maximum Likelihood Spatial Capture Recapture (MLSCR). This apparently consistent with previous and other studies implementing the two approaches (Sunarto et al. 2013).

We documented the highest tiger density in southern sampling block (1.52 ± SE 0.55 individuals/100 km^2 based on TCR), followed by 0.77± SE 0.39 individuals/100 km^2 in northeastern sampling block, and 0.46± SE 0.17 individuals/100 km^2 in northwestern sampling block (Table 1). Compared to result from previous study by Sunarto et al. (2013) in northeastern sampling block (with density estimation was 0.86 ± SE 0.50 individuals/100 km^2), the density estimate from this study in the same sampling block was lower. But, compared to the other sampling blocks, especially in southern, the estimated density from this study was higher.

Compared to other studies in Sumatra using the same approach namely in Way Kambas National Park 4.3 individuals/100 km^2 (Franklin et al. 1999), Bukit Barisan Selatan National Park 1.6 individuals/100 km^2 (O'Brien et al. 2003) and Bungo and Ipuh at Kerinci Seblat National Park (2.95 ± 0.56 adult individuals/100 km^2 and 1.55 ± SE 0.34 adult individuals/100 km^2) (Linkie et al. 2008), generally the estimated density from this study was lower.

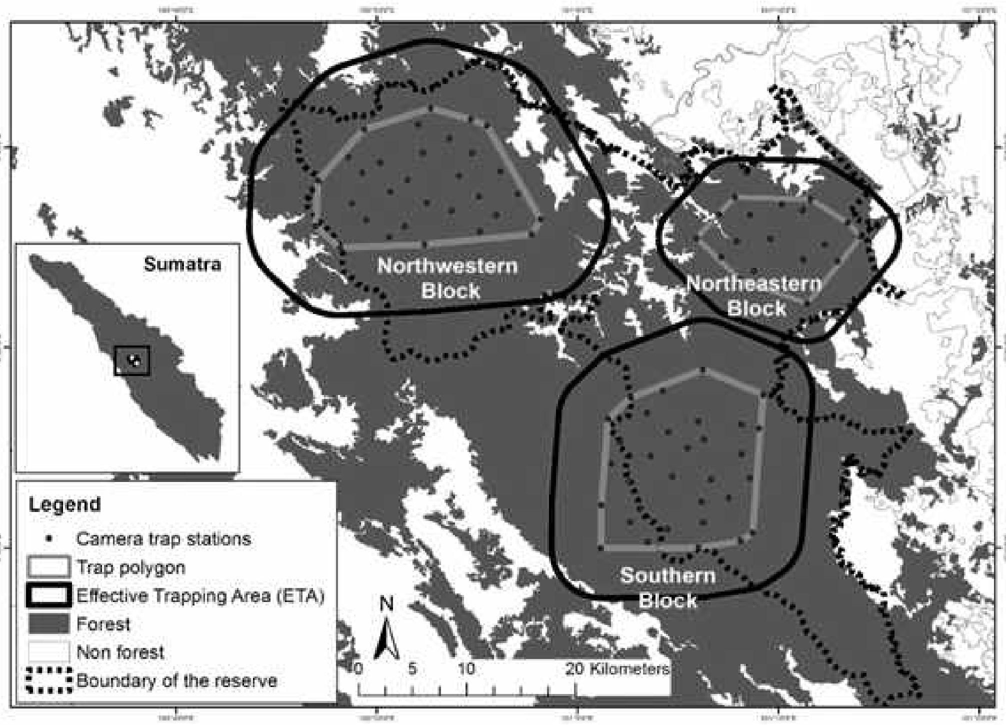

Figure 1. Three sampling blocks in the study areas of Bukit Rimbang Bukit Baling Wildlife Reserve with trap polygon and effective trapping area (ETA)
Gambar 1. Tiga blok sampling di kawasan studi Suaka Margasatwa Bukit Rimbang Bukit Baling dengan ukuran poligon sampling and ukuran sampling efektif (*effective trapping area*/ETA)

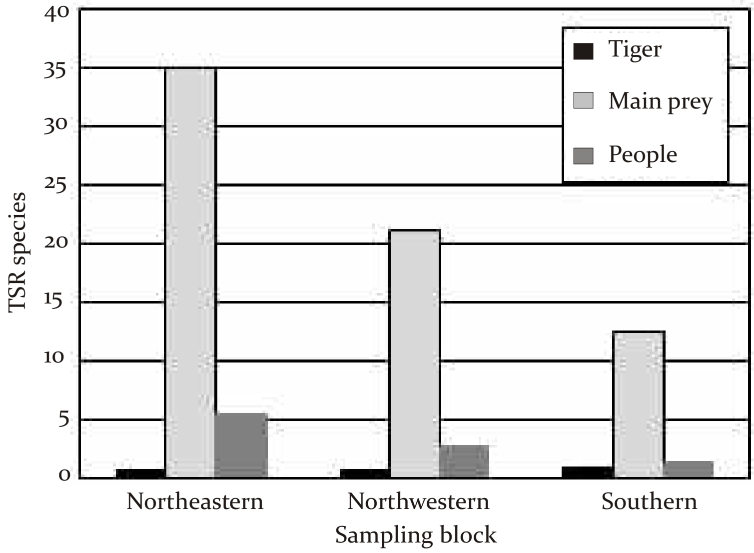

Figure 2. Trap success rates (TSR) of tigers, main prey species and human in three different sampling blocks of Bukit Rimbang Bukit Baling Wildlife Reserve
Gambar 2. Angka keberhasilan perangkap (TSR) dari harimau, jenis mangsa utama, dan manusia di tiga blok sampling berbeda di Suaka Margasatwa Bukit Rimbang Bukit Baling.

Compared to other studies outside of Sumatra such as in Malaysia namely Merapoh 1.98 ± SE 0.54 individual/100 km^2, Kuala Terengan 1.10 ± SE 0.52 individuals/100 km^2, and Kuala Koh 1.89 ± SE 0.77 individuals/100 km^2 (Kawanishi & Sunquist 2004) and Gunung Basor Forest Reserve, Peninsular Malaysia 2.59 ± SE 0.71 individuals/100 km^2 (Rayan & Mohamad 2009), in India (Bhadra 3.42 ± SE 0.84 individuals/100 km^2, Kanha 11.70 ± SE 1.93 individuals/100 km^2, Nagarahole 11.92 ± SE 1.71 individuals/100 km^2 and

Kaziranga 16.76 ± SE 2.96 individuals/100 km²), the estimated density of tigers from this study was generally lower. However, the estimated density from this study was higher than the estimated density in Terengan, Malaysia.

We believe that the lower density of tiger in this study area compared to other places was attributed to human disturbance, poaching, and prey availability as the highest influence to tigers. We found that tiger density was highest in southern block where the lowest human activities were documented (Fig. 2).

TSR of prey and people

We use TSR to get insight into prey availability and human disturbance for each sampling block. The highest TSR of main prey was documented in northeastern sampling block, followed by north-western sampling block and southern sampling block. The highest TSR of people was documented in northeastern sampling block, followed by north-western sampling block and southern sampling block (Table 2, 3, and Fig. 2).

Sambar deer as the largest potential prey species of tigers, were only documented in two sampling blocks: northeastern with TSR was 0.14 ± SD 0.44 and northwestern with TSR was 0.09 ± SD 0.37. However, TSRs of sambar deer were the lowest compared to other main prey species. Wild pig's TSR was the highest among other main prey species in north-eastern sampling block (22.28 ± SD 26.82). Bearded pig, another species of pigs, was only captured in northwestern and had higher TSR (13.80 ± SD 12.76) than wild pig (0.49 ± SD 1.61) and other main prey species in the same sampling block. TSRs of barking deer, as the main target of hunting by local people, were almost similar in all sampling block (north-eastern 4.36 ± SD 5.00, northwestern 3.56 ± SD 5.68 and southern 5.53 ± SD 6.31).

Some studies have suggested that prey availability is the most if not the single most important determinant for tiger density (Karanth & Stith 1999; Karanth et al. 2004; Wibisono & Pusparini 2010; Sunarto et al. 2013). However, this study showed that, tiger densities do not seem to directly correspond to the abundance of main prey as indicated by TSR. Sampling block where the highest tiger density was documented (the southern block) had the lowest TSR of main prey, but also the lowest human activity as indicated by their TSR. On the contrary, sampling block with the highest TSR of main prey (northeastern) but also had the highest TSR of human, had the lowest density of tigers. Tiger Protection Units of WWF and BBKSDA Riau

Table 2. Trap success rates of tigers, each main prey and people in three sampling blocks of Bukit Rimbang Bukit Baling Wildlife Reserve
Tabel 2. Angka keberhasilan perangkap (TSR) dari harimau, jenis mangsa utama dan manusia di tiga blok sampling di Suaka Margasatwa Bukit Rimbang Bukit Baling

Object	Trap Success Rate (TSR) ± SD*		
	Northeastern	Northwestern	Southern
Barking deer	4.36 ± SD 5.00	3.56 ± SD 5.68	5.53 ± SD 6.31
Bearded pig	0.00	13.80 ± SD 12.76	0.00
Sambar deer	0.14 ± SD 0.44	0.09 ± SD 0.37	0.00
Sumatran serow	0.17 ± SD 0.78	0.49 ± SD 1.07	0.06 ± SD 0.40
Wild pig	22.28 ± SD 26,82	0.49 ± SD 1.61	0.73 ± SD 1.19
Pig-tailed macaque	8.06 ± SD 9.56	2.70 ± SD 1.61	6.08 ± SD 6.90
People	5.45 ± SD 5.64	2.70 ± SD 3.27	1.26 ± SD 2.41
Sumatran tiger	0.57 ± SD 0.87	2.59 ± SD 3.39	0.89 ± SD 1.85

Remark : Total trap success rates of main prey species in each sampling block: northeastern sampling block was 35.01 ± SD 8.67, northwestern sampling block was 21.14 ± SD 5.22 and southern sampling block was 12.42 ± SD 2.91, *Standard Deviation
Keterangan : Jumlah keseluruhan angka keberhasilan perangkap dari mangsa utama di setiap blok sampling: blok sampling utara – timur 35,01 ± SD 8,67, blok sampling utara – barat 21,14 ± SD 5,22, dan blok sampling selatan 12,42 ± SD 2,91, *Standar Deviasi

Table 3. Tiger density (individual/100 km^2) model selection with AIC (from the lowest AIC to the highest AIC) of spatial capture–recapture with conditional maximum likelihood estimators in Program DENSITY. We have chosen half normal model following Effort (2004) half-normal model for probability of capture (P) as a function of distance (d) from home range centre to trap, in the absence of competition that is suitable to tiger density study.

Tabel 3. Model seleksi kepadatan harimau (individu/100 km^2) dengan AIC (dari AIC terendah ke AIC tertinggi) *spatial capture – recapture* dengan estimator kemungkinan maksimal kondisional di Program DENSITY. Kami memilih model *half normal* mengikuti Effort (2004) model *half normal* untuk kemungkinan tangkapan (P) sebagai sebuah fungsi jarak (d) dari pusat wilayah jelajah ke jebakan pada kehadiran – ketidakhadiran yang cocok untuk studi kepadatan harimau.

Detection function	K	AIC	AICc	ΔAICc	D ± SE	g0 ± SE	σ ± SE
Northeastern, 2012 (N capture = 9, N animal = 2, N recapture = 7)							
Half normal	2	131.50	NA	0	0.19 ± 0.16	0.00409 ± 0.00824	14623.60 ± 473803.60
Negative exponential	2	131.53	NA	0.03	0.19 ± 0.16	0.00305 ± 0.00867	101746.33 ± NA
Hazard rate	3	131.86	NA	0.33	0.21 ± 0.17	0.00406 ± 0.00168	14597.74 ± NA
Northwestern, 2014 (N capture = 17, N animal = 3, N recapture = 14)							
Negative exponential	2	253.26	NA	0	0.23 ± 0.14	0.00387 ± 0.00507	18762.14 ± 106648.16
Hazard rate	3	254.95	NA	1.69	0.23 ± 0.14	0.00218 ± 0.00099	21154.09 ± 11381.42
Half normal	2	256.79	NA	1.84	0.23 ± 0.14	0.00281 ± 0.00194	16737.05 ± 17379.77
Southtern, 2015 (N capture = 32, N animal = 6, N recapture = 26)							
Hazard rate	3	436.13	476.13	0	0.55 ± 0.25	0.07635 ± 0.08053	781.73 ± 890.72
Negative exponential	2	445.75	457.75	9.62	0.59 ± 0.27	0.02173 ± 0.00895	3613.29 ± 788.86
Half normal	2	454.43	466.43	8.68	0.51 ± 0.22	0.00853 ± 0.00345	7027.30 ± 1156.70

documented high level of hunting in some areas of the reserve, especially near human settlements. In 2015, for example, the team collected more than 100 tiger snares from the reserve. Meanwhile, Wildlife Crime Team of WWF Indonesia and Ministry of the Environment and Forestry have identified many poachers and traders tigers operating around the reserve.

We believe that prey availability in all areas is already above the threshold needed to sustain the highest recorded density of tigers (such as in southern sampling block) that overall living under high poaching pressure. Considering the prey availability, the density of tigers in northeastern sampling block, we believe, could be higher that what we documented, but the human disturbance and poaching should be minimized. The role of human disturbance in suppressing large mammal population has been documented, especially in Sumatra (Griffiths & Schaik 1993; Kinnaird et al. 2003; Wibisono & Pusparini 2010).

While TSR has been relatively commonly used as an indicator of animal activity or abundance, we recognize that there are drawbacks potentially involved in the used of TSR for such a purpose. For example, trap shyness or trap happiness might affect the result of TSR calculation (Wegge et al. 2004). In this study, however, we deem that using TSR to indicate availability of main prey and level of human activity in each sampling block is still appropriate. Possible existence of trap shyness or trap happiness of one species can likely be compensated by other species as we calculated the TSR not just for single but for an assemblage of species as the potential main tiger prey. Interestingly, for tigers where absolute density and TSR were also calculated in this study, we found consistency of both results. In this case, for example, southern sampling block with the highest tiger density was also the highest TSR of tigers.

Conclusions

This study captured 14 tigers including three cubs in three sampling blocks of Bukit Rimbang Bukit Baling Wildlife Reserve. The result proofed that BRBBWR provides habitat allowing tigers to breed. The study also showed that tiger densities in three different sampling blocks vary. Different approaches used to estimate tiger density resulting in different estimates. The highest tiger density were documented in southern sampling block that has the longest distance to villages, the lowest level of human disturbance, albeit also the lowest TCR of main tiger prey species. The result showed that tiger density does not correspond directly to the indication of prey availability which suggests that prey might still be adequate to sustain higher density of tigers if human disturbance and poaching can be controlled. For tiger recovery, therefore, some strategies need to be implemented in BRBBWR especially to control human disturbance and poaching to the lowest possible level, while maintaining prey availability to sustain the tiger population at an increased number. To ensure long-term viability of tigers, continuing monitoring of tigers and habitat, active management, and stronger protection of the key wildlife are fundamentally needed. Furthermore, as a follow up from this, we suggest to conduct tiger's population viability to assess the best options for management interventions to recover tigers and increase their long-term viability (Moßbrucker et al. 2016).

Southern forest block of BRBBWR currently has the highest density of tigers and likely can be maintained as the core area of the tiger landscape. This area should be more strictly protected to prevent poaching. Other forest block should be managed by accommodating sustainable use in some areas without compromising the security of key wildlife from poaching. An integrated protection that focus not only on law enforcement but also other approaches, and intensive management through multi-stakeholder partnerships can help reduce the level of human disturbance and facilitate the recovery of the habitat and prey, and thus tigers. Also, maintaining a primary forest refuge for tigers is important (Linkie et al. 2008). As additional to support a primary forest refuge for tigers, forest production, and plantation areas in surrounding of the reserve should also be well managed (Maddox et al. 2011). Suggested approach to reduce threats and control human disturbance include a combination of protection/law enforcement, awareness and alternative livelihood. Through the newly inaugurated Rimbang Baling Conservation Forest Management Unit, the management of the area can be improved through an integrated approach of wildlife conservation and sustainable livelihood through full engagement of local communities and other key stakeholders.

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